Springer Series on Cultural Computing

Rae Earnshaw · Susan Liggett ·
Peter Excell · Daniel Thalmann *Editors*

Technology, Design and the Arts—Opportunities and Challenges

Springer Open

Springer Series on Cultural Computing

More information about this series at http://www.springer.com/series/10481

Rae Earnshaw · Susan Liggett · Peter Excell ·
Daniel Thalmann
Editors

Technology, Design and the Arts—Opportunities and Challenges

Springer Open

Editors
Rae Earnshaw
Department of Computer Science, Faculty of Engineering and Informatics
University of Bradford
Bradford, UK

St John's College
Durham University
Durham, UK

Faculty of Art, Science and Technology
Wrexham Glyndŵr University
Wrexham, UK

Peter Excell
Emeritus Professors, Executive Office
Wrexham Glyndŵr University
Wrexham, UK

Faculty of Engineering and Informatics
University of Bradford
Bradford, UK

Susan Liggett
Faculty of Art, Science and Technology
Wrexham Glyndŵr University
Wrexham, UK

Daniel Thalmann
MIRALab Sarl
Geneva, Switzerland

ISSN 2195-9056 ISSN 2195-9064 (electronic)
Springer Series on Cultural Computing
ISBN 978-3-030-42096-3 ISBN 978-3-030-42097-0 (eBook)
https://doi.org/10.1007/978-3-030-42097-0

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

The editors dedicate this book to their partners and parents

Foreword by Jill Journeaux

Charcoal, the interaction of fire and carbon, and naturally occurring pigments such as red clay were the first materials used by homo sapiens to record their presence in the world. Throughout time, artists have been curious about tools and technologies that have emerged from adjacent or alternative domains and have been open to reapplying those tools and technologies into new areas in innovative ways. In recent times, it is computers and interactive systems that have driven this curiosity, but we should also remember the great variety of forms of technology that have expanded and accelerated art practice throughout history. These include photography, the use of hot metals such as bronze and steel to create form, the unique qualities of plastics, the simple processes of fire in raku ceramics and in making charcoal, and the creation of synthetic pigments in 1704. The application of these inventions and innovations to artmaking has involved highly skilled technologists who have worked in the spaces between art and science to manifest new possibilities of form and expression.

In order to make sense of the world and our place within it, we attempt to construct conceptual models. Artists are often attracted to the apparent certainties of science but bring to it expressions of doubt and uncertainties about a rationalist approach. They utilize dialogues between interiority and exteriority in order to confirm the nature of being in the world as known or understood through inner emotional and spiritual worlds, and use artmaking as a process that searches for established and new truths based on knowledge and science but felt and intuited through visual recognition by others. They place value on the unknown as well as the known.

In this book, Rae Earnshaw, Susan Liggett, Peter Excell and Daniel Thalmann, explore the spaces between technology, design and the arts and ask questions of the challenges and opportunities that are presented by interdisciplinary research across these fields. The inclusion of a series of case studies allows for consideration of the value of interdisciplinary research which incorporates practitioners, practice and practice research and enables explorations of the manner in which technological innovations shape cultural manifestations and extend the capacity for artists to articulate experiences of being, thinking and questioning.

Rae Earnshaw and Susan Liggett first collaborated in 2015 when Liggett curated the exhibition *Carbon Meets Silicon*, in Oriel Sycharth. This exhibition included works by artists who collaborate with scientists, or technologists and was accompanied by a symposium as part of the 6th International Conference on Internet Technologies and Applications. The conference brought together researchers and developers from academia and industry across engineering, computing and art and design, and was inspired by Alan Turing's explorations of artificial intelligence as opposed to cognitive psychology. Artwork in the exhibition explored a range of media practices including film and video installation, painting, printmaking, jewellery and sound-based works.

As part of the 7th International Conference on Internet Technologies held in 2017, Earnshaw and Liggett organized the exhibition *Carbon Meets Silicon II* which brought together fifteen diverse artists using science and technology to better understand the world we live in. The thematic exhibition used carbon and silicon as metaphors for the evolving nature of art practice in a digital era. Carbon was used to refer the materiality of art objects and silicon to refer to how an artworks' physical presence may be questioned by new media and technologies, thus bringing artist and scientist closer together.

The editors of this book are concerned to reframe perceptions of dualism and difference between artists and scientists to ensure that they are not set apart but can instead find ways of working together to solve problems. However, if we consider the processes and ambitions associated with creativity supposed differences between artists and scientists may become less distinct. Creativity theorist Mihaly Csikszentmihalyi reminds us that: *creativity does not happen inside people's heads, but in the interaction between a person's thoughts and a sociocultural context. It is systemic rather than an individual phenomena* (1997: 23). In his book, *Creativity* Csikszentmihalyi argues that levels of creativity do not just depend upon creative individuals but are also affected by the willingness of domains and fields to recognize novel ideas and artefacts (1996: 31).

Writing about successful collaborative partnerships in both science and the arts Vera John-Steiner emphasizes the value of complementarity stating: *Each individual realizes only a subset of the human potential that can be achieved at a particular historical period* (2000: 40). She argues that the *modes of thought involved in generating explanatory principles are not necessarily the ones used in communicating scientific discoveries* and refers to Reuben Hersh's idea of the 'backstage' of discovery, which may consist of fragments, the conversational, informal and intuitive propositions, and tentative notions. As with artists some scientists only share their complete and finished products, but others reveal their thought processes through notebooks, drawings, journals and other preparatory thinking processes and formats [3]. Technologists, artists and scientists visualize the as yet unmade and the possible as well as the actual and the clearly thought and understood.

In an interview with Alfred Appel Jr., in 1966, Vladimir Nabokov reacted to C. P. Snow's assertion that the gap between the two supposedly separate cultures of science and the arts was unbridgeable. He argued that science has an artistic and creative side and that the arts require scientific truths, saying: *I certainly welcome the free exchange of terminology between any branch of science and any raceme of art. There is no science without fancy, and no art without facts* (1973: 78–79).

Jill Journeaux
Professor of Fine Art
Centre for Arts, Memory and Communities
Coventry University, UK

References

1. Csikszentmihalyi, M.: Creativity: Flow and the Psychology of Discovery and Invention, p. 31. Harper, New York (1996)
2. Earnshaw, R.A., Liggett, S., Excell, P.S., Thalmann, D. (eds.): Technology, Design and the Arts—Challenges and Opportunities. Springer, Cham, Switzerland (2020). ISBN 978-3-030-42096-3
3. Nabakov, V.: Strong Opinions, pp. 78–79. McGraw-Hill Book Company, New York (1973)
4. John-Steiner, V.: Creative Collaboration, pp. 40–46. Oxford University Press, New York (2000)

Foreword by Jon Peddie

Technology, Design and the Arts—Opportunities and Challenges is a book for the times. Never before has there been such a confluence between technology and art as today. Amazing new developments in computer graphics, not the least of which is the democratization of the tools, has empowered and emboldened designers, and want-to-be artists all over the world. Art, from fine art to set backdrops, video games and graphics novels, has permeated our lives, imaginations and culture at all levels—and we are richer for it all.

It all begins with the software tools, which as the book beautifully illustrates, have been used from the earliest times to create and modify artistic works. And the concept is not limited to just graphics art, but various types of tools for creating image and musical instruments—computer technology has been used to create digital images and audio.

The authors are to be congratulated for being brave enough to examine and discuss the symbiotic relationship between artistic works and the cultural context in which they are produced.

Computers have been used to mimic the way classical artists did things, their attempts were not always successful. The technology can provide continuity by taking traditional methods and techniques and making them more efficient and effective. However, it can also provide divergent results and open up new perspectives and paradigms—sometimes intentionally, and sometimes accidentally. The authors argue that it can produce a greater understanding of artistic processes and how they are implemented in practice. The reader will be the judge.

The authors believe a tighter coupling of the interplay between the goal of the creator, the selection and use of appropriate tools, and the materials and representations chosen has been created. They cite Gombrich who argued that, *There really is no such thing as Art. There are only Artists*. Thus, although creative works may generate a variety of interpretations in the minds of observers, say the authors, the focus also remains on the creator, and the vision and insight that causes them to create. Thus, what has been created provides insight into the cultural context and social environment at the time of creation. Powerful ideas are very effectively argued and demonstrated in the book.

The book proposes to define and detail the relationship between the artist and their works by the types of tools they use, and the environments that have facilitated and extended these processes. Such tools for graphics say the authors have encompassed computer technology, computer environments, and interactive devices for a range of information sources and application domains. They have also provided new kinds of created works which are able to be viewed, explored, and interacted with, either as an installation or via a virtual environment such as the Internet.

I agree, and think this introduces new dimensions of understanding and experience for both artist and the public's contact with, and hopefully understanding of the works that are produced. But it doesn't come for free. A variety of interdisciplinary opportunities and issue are raised, and the authors bravely examined them in detail. Spanning from the classics such as Leonardo da Vinci to contemporaries like David Hockney the opportunities for artistic and creative expression have transformed the worlds of which they are an integral part.

The contributions and themes in this book are rich in information in various forms. The interaction of technology and computer generation of information with artefact creation and dissemination is discussed and the reader is left with a sense of wonder, questions and hopefully a few answers. The topic is, and may always be, a work in process. That is reflected in that this book is a continuation of, and development from, the research and development detailed in the earlier book—Earnshaw R. A. (2017): *Art, Design and Technology: Collaboration and Implementation*.

Dr. Jon Peddie
Jon Peddie Research
Tiburon, CA, USA

Preface

This volume explores emerging aspects of the relationship between artists (and other creatives) and their created works, and also how a variety of tools and environments have facilitated and extended these processes. Such tools encompass computer technology, computer environments, and interactive devices, for a range of information sources and application domains. They also provide new kinds of created works which are able to be viewed, explored and interacted with, either as an installation or via a virtual environment such as the Internet. This introduces new dimensions of understanding and experience for both artist and the public's relationships with the works that are produced. This has raised a variety of interdisciplinary opportunities and issues. From Leonardo da Vinci to David Hockney the opportunities for artistic and creative expression have transformed the worlds of information of which they are an integral part.

Tools have been used from the earliest times to create and modify art works and sculptures. Naturally occurring pigments have been used for cave paintings, but these were more than pictorial representations: they were inextricably linked to narrative (of hunting) and this form of linkage is now returning to the forefront, due to the facilities of digital media. What has been created provides insight into the cultural context and social environment at the time of creation. There is an interplay between the goal of the creator, the selection and use of appropriate tools, and the materials and representations chosen. Gombrich argues that, *There really is no such thing as Art. There are only Artists* [1]. Thus, although creative works may generate a variety of interpretations in the minds of observers, the focus also remains on the creator, and the vision and insight that causes them to create.

The symbiotic relationship between art works and the cultural context in which they are produced is examined. Technology can provide continuity by making traditional methods and techniques more efficient and effective. It can also provide discontinuity by opening up new perspectives, paradigms and dimensions of interaction with the viewer. This can produce a greater understanding and expansion of artistic processes and how they are implemented in practice.

This book includes the arts in general, so is not limited to the visual arts. The arts may be defined as the theory and physical expression of creativity found in human cultures and societies. A key component of this is communication and narrative.

This book brings together a variety of national and international authors who present current research and development at the interface between technology and the arts and humanities. The chapters are grouped into themed parts as follows:

Part I: A Panoramic View of the Field
Part II: Facilitating Communication Between the Arts, Technology, and Audiences
Part III: Interactions Between the Arts and Data
Part IV: Audio Visual Installations to Generate Collective Human Responses
Part V: The Convergence of Digital Design, the Arts, Computing, and the Environment
Part VI: The Use of Virtual Reality and Augmented Reality to Extend Creativity, Reach, and Engagement in the Arts
Part VII: The Future of Interdisciplinary Research

These parts present an increasing reach across the interface using the following modalities—communication, interaction, installation, convergence, and the utilization of VR and AR technologies. The book concludes with an assessment of the extent to which the current opportunities and challenges are being addressed and realized.

The convergence of IT, telecommunications, and media is bringing about an explosion of data and also a revolution in the way information is collected, stored and accessed, plus the major scope of enhancement into time-based media. There are three principal reasons why this is happening—reducing cost, increasing quality and increasing bandwidth. This is likely to result in a closer relationship between technology and the arts and humanities.

Where the references are to online papers and documents, the authors have endeavoured to provide those that are open source and in the public domain rather than behind a paywall. The current move to a requirement for open source publication in Europe will assist this situation in the future (on the basis that the taxpayer has already contributed to the funding of research and development and therefore should be entitled to read the publications without further charge). Where publications are currently behind a paywall, readers can normally read the abstract and see the list of references before deciding whether to purchase the paper.

There are many references to online sources on the Internet. Readers of the e-book can access these directly as they are embedded in the text as hot links. Some URLs of web pages change over time due to site names being changed by their owners, or the position of the web site in the site hierarchy being altered. Where the link does not access the required page, the correct page can often be located by putting the URL into Google. If this doesn't work due to Google's cached copy of the original website having been over-written, then the title of the reference can be typed into Google.

This volume is published as a Springer Open Access book in order to make the e-book freely available to everyone for study and further research, particularly students who may be least able to afford the normal cost of a book. Although the e-book contains colour figures, these are rendered in monochrome in the printed version, as this is current Springer policy. Therefore, because many of the colour figures have been produced by artists, these are best viewed in the e-book. There is a nominal charge for the printed book to cover the cost of printing.

It is hoped that this book makes a useful contribution to an important area of significant ongoing research, development and application.

Leeds, UK The Editors
Wrexham, UK
Bradford, UK
Lausanne, Switzerland
December 2019

Acknowledgements Thanks and appreciation are due to all those who read draft versions of the chapters and provided comments to improve technical content and readability. However, responsibility for the final text rests with the authors.

Thanks are expressed to Prof. Jill Journeaux and Dr. Jon Peddie for providing the Forewords to the book.

Thanks and appreciation are also due to Springer for assistance and support with the editing and production of this book.

Reference

1. Gombrich, E.H.: The Story of Art, p. 15. Phaidon Press Ltd., London (1995)

Contents

Editors and Contributors

About the Editors

Prof. Rae Earnshaw is Professor of Electronic Imaging at the University of Bradford, UK since 1995 (now Emeritus), Honorary Visiting Professor in Creative Industries at Glyndwr University and Visiting Fellow at St John's College, University of Durham. He gained his Ph.D. at the University of Leeds and is a chartered engineer and chartered information technology professional. He was Dean of the School of Informatics (1999–2007) and Pro-Vice-Chancellor (Strategic Systems Development) (2004–2009). He has been a Visiting Professor at Illinois Institute of Technology, George Washington University, USA and Northwestern Polytechnical University, China. He is a member of ACM, IEEE, CGS and a Fellow of the British Computer Society and the Institute of Physics. He has authored and edited 42 books on computer graphics, visualization, multimedia, design, and virtual reality, and published over 200 papers in these areas. Book publishers include: Academic Press, Cambridge University Press, Addison Wesley, Springer (UK), Springer (USA), John Wiley & Sons Inc and IEEE Computer Society Press. Although playing a significant role in academic leadership and management over the past 20 years, he has maintained his research and publication record. He is a member of the Centre for

Visual Computing at the University of Bradford which performs world-class research and development in the area of visual image data processing.

https://sites.google.com/site/raearnshaw/home.

https://www.bradford.ac.uk/ei/media-design-technology/research/centre-for-visual-computing/.

Dr. Susan Liggett is Reader in Fine Art and Associate Dean for Research in the Faculty of Art, Science and Technology at Wrexham Glyndŵr University. She has a Ph.D. from the University of Wales, a Post Graduate Diploma in Painting (MA) from the Royal Academy Schools, London and a BA (Hons) Fine Art from Nottingham Trent University. Her work as a practicing artist includes paintings, fine art films and arts in health collaborative research projects resulting in her artwork being exhibited in different and varied contexts including galleries, public spaces conferences and festivals. As a curator, she has organized exhibitions, chaired conferences and published work on the interface of art/science. She is a member of the Royal Cambrian Academy and SUITE Studio Group, Salford.

https://www.susanliggett.com/.

Prof. Peter Excell is Emeritus Professor of Communications and former Deputy Vice-Chancellor at Glyndwr University. His interests cover computing, electronics and creative industries, with a strong spirit of interdisciplinarity that is needed for the digital knowledge economy. He gained his B.Sc. in Engineering Science at the University of Reading and Ph.D. in Electronic Engineering at the University of Bradford. His principal research has been in the area of future mobile communications technologies and services and this has been carried out in conjunction with colleagues from wider discipline areas, analysing human communications in a holistic way and developing new ways of using mobile multimedia devices. He has published over 500 papers. He is a Fellow of the British Computer Society, the Institution of Engineering & Technology and of the Higher Education Academy, a Chartered IT Professional and Chartered Engineer.

Prof. Daniel Thalmann is a Swiss and Canadian Computer Scientist. He is currently Honorary Professor at EPFL and Director of Research development at MIRALab Sarl. Pioneer in research on Virtual Humans, his current research interests include social robots, crowd simulation and Virtual Reality. Daniel Thalmann has been the Founder of The Virtual Reality Lab (VRlab) at EPFL, Switzerland, Professor at The University of Montreal and Visiting Professor/Researcher at CERN, University of Nebraska, University of Tokyo, and National University of Singapore. From 2009 to 2017, he was Visiting Professor at the Nanyang Technological University, Singapore. Until October 2010, he was the President of the Swiss Association of Research in Information Technology and one Director of the European Research Consortium in Informatics and Mathematics (ERCIM). He is coeditor-in-chief of the *Journal of Computer Animation and Virtual Worlds*, and member of the editorial board of 12 other journals. Daniel Thalmann was a member of numerous Program Committees, Program Chair and CoChair of several conferences including IEEE VR, ACM VRST and ACM VRCAI. Daniel Thalmann has published more than 600 papers in Graphics, Animation and Virtual Reality. He is coeditor of 30 books, and coauthor of several books including Crowd Simulation (second edition 2012) and Stepping Into Virtual Reality (2007), published by Springer. He received his Ph.D. in Computer Science in 1977 from the University of Geneva and an Honorary Doctorate (Honoris Causa) from University Paul-Sabatier in Toulouse, France, in 2003. He also received the Eurographics Distinguished Career Award in 2010, the 2012 Canadian Human Computer Communications Society Achievement Award and the CGI 2015 Career Achievement.

Wikipedia: http://en.wikipedia.org/wiki/Daniel_Thalmann.

CV: https://www.dropbox.com/s/wfh7fxi1bagv65r/CV%20%28engl.%29.pdf?dl=0.

Contributors

Daniel Buzzo University of the West of England, Creative Technology Lab, Bristol, UK

Chris Meigh-Andrews University of Central Lancashire, Preston, UK

Mike Corcoran Wrexham, Wales

Stuart Cunningham Centre for Advanced Computational Science (CfACS), Manchester Metropolitan University, Manchester, UK

Naira Danielyan Philosophy, Sociology and Political Science Department, National Research University of Electronic Technology, Moscow, Russian Federation

A. Darby Lancaster Institute for Contemporary Arts, Lancaster University, Lancaster, UK

Rachel Davies Kingston University, Kingston, UK

C. Dean Edge Hill University, Ormskirk, UK

Rae Earnshaw Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, UK; St John's College, Durham University, Durham, UK; Faculty of Art, Science and Technology, Wrexham Glyndŵr University, Wrexham, UK

L. Edwards School of Computing and Communication, Lancaster University, Lancaster, UK

Peter Excell Centre for Ultra-Realistic Imaging, Wrexham Glyndwr University, Wrexham, UK

Peter S. Excell Wrexham Glyndŵr University, Wrexham, UK;
University of Bradford, Bradford, UK

Carlo Ferigato European Commission, Joint Research Centre (JRC), Ispra, Italy

John Henry Centre for Advanced Computational Science (CfACS), Manchester Metropolitan University, Manchester, UK

Susan Liggett Faculty of Art, Science and Technology, Wrexham Glyndŵr University, Wrexham (Wales), UK

Manoli Moriaty University of Salford, Salford, UK

Rinat R. Nasyrov Department of Power Electrical Systems, Institute of EPE, National Research University for Power Engineering "MPEI", Moscow, Russia

Marlena Novak Department of Film Video, New Media and Animation, The School of the Art Institute of Chicago (SAIC), Chicago, USA

Ardeshir Osanlou Centre for Ultra-Realistic Imaging, Wrexham Glyndwr University, Wrexham, UK

I. Pioaru Wrexham Glyndwr University, Wrexham, UK

Tracy Piper-Wright University of Chester, Chester, UK

Daniel Saul Royal College of Art, London, UK

Alan Summers University of Chester, Chester, UK

Jill Townsley University of Huddersfield, Huddersfield, UK

Anastasia Tyurina Queensland University of Technology (Brisbane), Brisbane, QLD, Australia;
National Research University MIET (Moscow), Moscow, Russia

Shuo Wang Beijing Institute of Graphic Communication, Beijing, China

Jonathan Weinel London South Bank University, London, UK

Jay Alan Yim Composition and Music Technology, Bienen School of Music, Northwestern University, Evanston, USA

Part I
A Panoramic View of the Field

Chapter 1
Introduction and Background to Technology and the Arts

Rae Earnshaw

Abstract Interactions between disciplines are reviewed. The long history of the relationship between the arts and sciences is summarized, and the challenges at the interface are outlined. The historical developments between technology and the arts are summarized, including computer arts, computer animation, digital media, and digital humanities. The current enablers for progressing interdisciplinary collaborations are presented. The possibility for a new Renaissance between technology and the arts is discussed.

Keywords Forms of knowledge · Scientific revolution · Cultural context · Computer arts · Story-telling · Reciprocal relationships · Renaissance teams

1.1 Interactions Between Disciplines

Interactions between disciplines have always had the potential to be exciting and ground-breaking. It can take the participants on all sides into new areas, often uncovering new understandings and new forms of knowledge. However, cutting across the boundaries of disciplines can take researchers out of their traditional comfort zones, and can be uncomfortable and challenging for all parties. It has been assumed in the past that it is a priority for a particular discipline to protect its legacy, its areas of interest, and the particular body of knowledge that it has established and would claim as its heritage. This is the foundation upon which new knowledge is expected to be built. This been mirrored to some extent by the structures set up in the academy to study and disseminate knowledge and research in the disciplines. This foundation built over many years can result in inertia and a wish to maintain the status quo.

R. Earnshaw (✉)
Department of Computer Science, Faculty of Engineering and Informatics,
University of Bradford, Bradford, UK
e-mail: r.a.earnshaw@bradford.ac.uk

St John's College, Durham University, Durham, UK

Faculty of Art, Science and Technology,
Wrexham Glyndŵr University, Wrexham, UK

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*,
Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_1

However, new disciplines can arise at the boundaries between existing disciplines. Examples are oceanography, cognitive science, genetic engineering, tribology, and digital media. Developments and advances such as these have focused attention on the interface areas between disciplines, and they are increasingly being recognized as important for support and investment.

1.2 Relationships Between the Arts and the Sciences

There has been a long history of antipathy between the arts and the sciences due to different modes of discourse, different forms of language, and different ways of working. This appears to have been caused principally by the early forms of education from the foundation of the academy until the scientific revolution from the sixteenth to the eighteenth centuries. Prior to this revolution, many understandings of the natural world were often misguided and erroneous because they were not based on a systematic and rigorous methodology. It is understandable therefore that attention in the academy should concentrate on what was regarded as the development and disciplining of the mind by means of subjects such as grammar, rhetoric, and logic. Later on, physics, metaphysics, and moral philosophy based on an Aristotelian framework were also included. Mind took the pre-eminence over matter. The natural world was regarded as an environment for the use of tools and the work of tool-smiths, and therefore not suitable for academic study. It was not until the key discoveries of the scientific revolution that a systematic enlargement of the curriculum in the academy took place, to produce the arts and the sciences as we have them today.

1.3 Historical Developments in the Relationship Between Technology and the Arts

1.3.1 Computer Arts

The Computer Arts Society [1] in the UK was founded in 1968. Its objective is to promote the creative uses of computers in the arts and culture. It acts as a forum to bring together those with interests in the cultural impact of information technology, and the various ways this impact can occur. This can involve those who create cultural artefacts by information technology or manage collections or those who are seeking to interpret and understand the cultural implications of the artefacts. An archive of the collections of the Computer Arts Society is hosted by the Victoria and Albert Museum in London, UK, and is part of their Computer Art Collections. Mason [2] and Brown et al. [3] detail the early history of computers and the arts up to 1980.

Franco [4] detailed the work of Edmonds on generative systems art from the 1960s to the present day. This explored the relationship between art and computer technologists in terms of concepts, tools, and forms of art. Candy et al. [5] reviewed the history of art and technology collaborations highlighting the contributions of practitioners and researchers at the interfaces between technology and the arts.

In the UK in the 1980s, Lansdown and Earnshaw brought together the output from the joint work of the Computer Arts Society and the Displays Group of the British Computer Society. This work consisted of contributions to visualization, computer art, design, and animation [6]. It was recognized that the boundaries between these various disciplines were blurring due to the increasing power and capability of the computer and the facilities of software packages, with interfaces that were more accessible and user-friendly for arts users.

Computer Art and Technocultures was a 3-year project supported by the Arts and Humanities Research Council (AHRC) in the UK to study the history of computer-generated art. The project was based jointly at Birkbeck College and the Victoria and Albert (V&A) and was completed in August 2010. A display at the V&A on Digital Pioneers was exhibited from December 2009 until April 2010. An associated symposium, Ideas before their Time [7], was held at the British Computer Society, and a two-day conference, Decoding the Digital [8], at the V&A on 4–5 February 2010. Dodds [9] and Beddard and Dodds [10] provide an account of the V&A's collections and their relationship to art history, and their social and technological context and implications. It also examines the outputs of the AHRC project. These are also summarized as part of the project [11].

1.3.2 Computer Animation

Making images move has been a preoccupation of computer technologists from the earliest days of computers [12]. Prior to this, successive frames of an animated sequence had to be composed on print media and then filmed, which was a time-consuming process. With the advent of computer displays and software, image sequences could be created and displayed directly. This facilitated ease of editing and re-display, which was more time consuming with print-based media.

Today there is a wide variety of desktop software packages that enable home users to create animations with audio tracks. Vince [13] discusses animation techniques, animation hardware, and animation software such as Softimage, Maya, 3d Studio Max, and Lightwave. Post-production techniques are presented, and animation applications are reviewed. Such Computer-Generated Imagery (CGI) has found widespread use in the applications such as special effects in films, computer games, advertising, computer-aided design, and simulation. However, computer technology of itself does not provide an automatic or easy solution. The imagination and creativity of the person formulating the animation need to be the fundamental driving force. The hardware and software technology are just tools and need to be used appropriately [14]. Animated films such as Pixar's Toy Story [15], which won awards, illustrate this point. It is the story which draws in, and captivates, the viewer. Therefore, in order to be effective artistically, animation sequences are designed and chosen to best represent the story. Story-telling is itself an art and has a long history [16], whether in oral form or using various forms of media that were available at the time in earlier centuries.

1.4 Digital Media

Collaboration in the production of digital media may involve a variety of discipline specialists. This is because of the diversity of its constituent parts such as hardware, software, digital images, digital, audio, sensors, games, interaction devices, and social media. This in turn may involve different constituencies such as industry, the academy, research and development organizations, and Small and Medium Enterprises (SMEs) with all their different cultures and working practices [17, 18]. The challenges are therefore significant. However, for those with a good collaboration methodology geared to generating successful outcomes, the rewards can be substantial.

1.5 Digital Humanities

On the wider front, the humanities disciplines such as history, literature, and philosophy are increasingly using computational tools and facilities to advance their research. Digitized texts can be searched, word frequencies can be calculated, and indexes and concordances can be produced [19]. In addition, image processing and 3D recording can be useful for pictorial data and 3D spaces such as museums and heritage sites [20]. Two broad areas of digital humanities research may be identified: firstly, the use of digital tools to perform and extend research in the humanities and, secondly, the use of humanities applications to perform research in computer science in the development of new interfaces and more advanced tools. Thus, there is a mutual reciprocity between technology and the humanities, even if this is not initially recognized [21]. The cultural context of computing also needs to be taken into account when evaluating its contributions. Such interdependencies are of increasing importance when seeking to understand current interdisciplinary activity and define potential ways forward for the future.

1.6 A New Renaissance?

The Renaissance in the fourteenth century onward marked a transition from the medieval era to modernity, and it opened up the possibilities of new horizons and new ways of thinking and working. Similarly, Renaissance Teams [22] in the twenty-first century offer the opportunity to utilize the expertise now available and work together toward a common objective which can transcend the traditional boundaries of the past.

This point is illustrated and exemplified by the contributions to this book.

This book brings together a variety of national and international authors who present current research and development at the interface between technology and the arts and humanities. The chapters are grouped into themed sections as follows:

Section 1: A Panoramic View of the Field.
Section 2: Facilitating Communication between the Arts, Technology, and Audiences.
Section 3: Interactions Between the Arts and Data.
Section 4: Audio Visual Installations to generate Collective Human Responses.
Section 5: The Convergence of Digital Design, the Arts, Computing, and the Environment.
Section 6: The Use of VR and AR to extend Creativity, Reach, and Engagement in the Arts.

These sections present an increasing reach across the interface using the following modalities—communication, interaction, installation, convergence, and the utilization of VR and AR technologies. The book concludes with an assessment of the extent to which the current opportunities and challenges are being addressed and realized.

The convergence of IT, telecommunications, and media is bringing about an explosion of data and also a revolution in the way information is collected, stored, and accessed. There are three principal reasons why this is happening—reducing cost, increasing quality, and increasing bandwidth. This is likely to result in a closer relationship between technology and the arts and humanities.

References

1. Computer Arts Society. https://computer-arts-society.com/
2. Mason, C.: A Computer in the Art Room: The Origins of British Computer Arts 1950–1980. Quiller Press, Shrewsbury, UK (2008). https://www.amazon.co.uk/s?k=Mason%2C+C.+A+Computer+in+the+Art+Room%3A+The+Origins+of+British+Computer+Arts+1950-1980&i=stripbooks&ref=nb_sb_noss
3. Brown, P., Gere, C., Lambert, N., Mason, C. (eds.): White Heat Cold Logic: British Computer Art 1960–1980. MIT Press, Cambridge, MA (2009). https://mitpress.mit.edu/books/white-heat-cold-logic
4. Franco, F.: Generative Systems Art: The Work of Ernest Edmonds. Routledge, Abingdon, UK (2018). https://www.routledge.com/Generative-Systems-Art-The-Work-of-Ernest-Edmonds-1st-Edition/Franco/p/book/9781472436009
5. Candy, L., Edmonds, E., Poltronieri, F.A.: Explorations in Art and Technology. Springer, London (2018)
6. Lansdown, J., Earnshaw, R.A. (eds.): Computers in Art, Design, and Animation. Springer, New York (1989, 2012). https://link.springer.com/book/10.1007/978-1-4612-4538-4

7. Ideas before their Time. Symposium summary. http://www.technocultures.org.uk/Symposiumoutline.html
8. Decoding the Digital. Symposium outline. http://www.technocultures.org.uk/decodingthedigital.pdf
9. Dodds, D.: Computer Art and Technocultures: Evaluating the V&A's Collections in the Digital Age. In: Proceedings of the Conference on Electronic Visualisation and the Arts (EVA) (2008). https://www.bcs.org/upload/pdf/ewic_eva08_paper10.pdf
10. Beddard, H., Dodds, D.: Digital Pioneers. Roli Books, New Delhi, India (2012)
11. Outcomes of the Computer & Technocultures project. http://www.technocultures.org.uk/outcomes.html
12. Badler, N.I., Barsky, B.A., Zeltzer, D. (eds.): Making them Move: Mechanics, Control and Animation of Articulated Figures. Morgan Kaufmann, San Mateo, CA (1991)
13. Vince, J.A.: Essential Computer Animation fast: How To Understand The Techniques And Potential Of Computer Animation. Springer, London (2013)
14. Catmull, E.: Creativity. Bantam Press, Inc., London (2014)
15. https://en.wikipedia.org/wiki/Toy_Story
16. https://en.wikipedia.org/wiki/Storytelling, https://www.thehistorypress.co.uk/local-history/storytelling/
17. Earnshaw, R.A.: Research and Development in Art, Design and Creativity, Springer, Lodnon, Sections 3.1 (pp 32–33), 5.2.5 (pp 74–75) (2016). ISBN 978-3-319-33005-1. http://dx.doi.org/10.1007/978-3-319-33005-1, http://www.springer.com/gb/book/9783319330044
18. Earnshaw, R.A.: State of the Art in Digital Media and Applications, Chapter 3 Collaboration on Digital Media. Springer, London (2017). https://doi.org/10.1007/978-3-319-61409-0. https://www.springer.com/gb/book/9783319614083
19. https://en.wikipedia.org/wiki/Digital_humanities
20. Warwick, C., Terras, M., Nyhan, J. (eds.): Digital Humanities in Practice. Facet Press, London (2012)
21. Berry, D.M., Fagerjord, A.: Digital Humanities: Knowledge and Critique in a Digital Age. Polity Press, Cambridge, UK (2017)
22. Cox, D.J: Collaborations in art/science: Renaissance teams. J. Biocommun. **18**(2):15–24 (1991). https://www.ncbi.nlm.nih.gov/pubmed/1874707

Chapter 2
Positioning the Arts in the Research Process: Perspectives from Higher Education

Susan Liggett

Abstract Research in the visual arts has contributed to the creation of environments that involve cross-disciplinary, multidisciplinary and interdisciplinary or transdisciplinary projects in departments within and across universities. An overview is provided of the historical context of doctoral awards in the arts with a definition of the terms practice-based, practice-led, and practice as research discussed. It articulates the challenges when acquiring explicit and exact knowledge alongside more subjective approaches that utilize tacit knowledge from artistic practice in research projects. Drawing on examples from art practice and doctoral students work, it analyzes objective, subjective, empirical, and hermeneutic paradigms, as described by Pierre Bourdieu, which can combine empirical approaches and individual understandings to re-enforce our understandings of the world.

Keywords Practice-based research · Practice-led research · Practice as research (PaR) creative arts Ph.D. · Collaboration · New technologies · Cross-disciplinary · Interdisciplinary

2.1 Introduction

Most researchers are aware of the need to position themselves in relation to other fields or disciplines in order to reveal the particular characteristics of their research findings. At the start of the research process, usually in writing the proposal, it can be challenging for artists when "oneself" often plays a significant role in the object of an enquiry. Research in the arts can be largely hermeneutic; that is the understanding and interpreting of it exposes the subjective limits of the artists' ways of doing and seeing. It is this epistemological method of socially constructing meaning that gives the arts authority within a process of enquiry. However, it is all too easy for knowledge gained tacitly to be "overlooked because it is subsumed into the rational logic of discursive accounts of artistic production" [1]. The articulation of possibilities of artists for shaping consciousness and providing cultural capital can be difficult even

S. Liggett (✉)
Faculty of Art, Science and Technology, Wrexham Glyndŵr University, Wrexham, UK
e-mail: s.liggett@glyndwr.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_2

for the more experienced academic. How can, as Barrett [1] says, "*the interplay of disparate areas of knowledge create new analogies, metaphors and models for understanding objects of enquiry*"?

Cross-disciplinary research involves viewing one discipline from the perspective of another. Interdisciplinary research involves integrating knowledge and methods from different disciplines that use a synthesis of approaches and multidisciplinary research that involves people from different disciplines working together, each drawing on their disciplinary knowledge. Transdisciplinary is close to multidisciplinary but it moves beyond a discipline taking more of a holistic approach creating a union of intellectual knowledge that goes beyond the disciplinary perspectives.

From experience of supervising doctoral students in the creative arts, I have noticed that an artist's identity can be lost when research methods are combined from different disciplines, such as those from the social sciences where is it easier to articulate the possible new knowledge that may emerge from interviews or surveys, for example, than those resulting from the art practice. This is particularly evident when the student begins to scrutinize artwork in unfamiliar ways to seek validation from research communities in different disciplines. For example, at Wrexham Glyndŵr University all research students are required to present their work to the whole research community in an event called "Open House for Researchers". Art students need support when combining different methodological paradigms in their research to bring fresh perspectives and new possibilities to problems. Artists in academia need to convince practitioners from other fields of enquiry within and beyond the university that they can reflect new objective realities that may be of benefit to society.

2.2 Artistic Research and the Academy

It is useful to decode some of the terminology surrounding the arts in academia to facilitate analysis of what artists do in a meaningful way. The word "practice" is used in the arts as it is in other professions to recognize knowledge production through action and doing. We can only fully understand what happens when we make artwork through the process of doing it, as opposed to purely thinking about it and the way artists create work goes beyond the physical activity to include influences, ideas, and critical reflections. The term practice refers to all artists work, but not all art practice can be termed research in an academic context. Despite the fact that most practice involves some form of research as part of the process, for example taking photographs in preparation for a painting, is not considered research in an academic context if the resulting work is not shared and its contributions to knowledge challenged. The theory/practice nexus helps define research in the arts by the linking of theory and practice through a method of intentionally investigating the process and outcomes informed by practice. The term "praxis" is often used to describe the making of artwork in a research context. Practice without the theory remains "practice" which can get very confusing for those involved in the arts, and also for those from the outside looking in. However, the adoption of the term practice is clear and implies that the production of artworks is part of society and connected to lived experience rather than existing in an ethereal world empty of everyday concerns and therefore unimportant and insignificant. Integrating the arts in society forces us to articulate how the purpose and meaning of art is constructed, challenged and its investments accounted for.

Bringing the arts into academia gives it status and legitimizes it as a profession. In the UK the first training in the arts was available in 1768 when The Royal Academy of Arts opened; art schools were further developed in the nineteenth century and re-designed in post-war Britain under the influence of the Bauhaus [2]. In 1974 in the UK the National Council for Diplomas in Art and Design was merged into the Council for National Academic Awards (CNA) allowing Polytechnics with art departments to issue honors degrees for the first time. Further academization of the arts happened in 1992 with former polytechnics becoming Universities [3]. This put the arts on an equal footing with other subject areas historically considered more academic. With the home of the Art School now residing within Universities, artists have the opportunity to study for research degrees and there has been an exponential growth in uptake of doctorates in the arts over the last decade. Between 1986 and 1995, 181 students received research degrees in the arts subjects in the UK [4] and in 2016/17 alone, 880 students were awarded research degrees in art and design (HESA) [5].

The Ph.D. is now a standard requirement for teaching in an art department in a UK University and with this, it brings pressure on academics to compete for research funding in ways comparable to other academic subjects. With the arts being newcomers to universities system, ontological truth claims between the Realist[1] worldview and the Constructivist[2] world view are challenged with artists claiming that often regulatory frameworks within Universities consist of a strong Realist components with the use of the terms "question" and "answer" rather than the terms "issue" and "response".

> If the arts do indeed operate within a new paradigm they should be able to say: our ontological position is this, our epistemological position is this, our methodological position is this and all of these are coherent and this is why we warrant special different conditions to the ones that have formally been recognized [6].

Art departments have had to fight hard to ensure that systems were set up to support their students in practice-based research. Between 2000 and 2006 debate surrounding the doctorate in the arts was highlighted at the University of Hertfordshire's annual conferences on the foundations of practice-based research which published Working Papers on Art and Design [7]. Particular concern regarding academic standards being imposed on art practices and artistic research were further addressed internationally [8] with European League for the Institute of the Arts (ELIA), with the creation of an

[1]Realist view here refers to the idea that reality exists independently of observers and their thoughts, feelings, intuitions, and opinions.

[2]Constructivism her is recognition that reality human construct that interacts with our experience in the real world.

advocacy network to address issues facing the arts in higher education. Its aim is to collaborate to create networks that strengthen, support, promote, and encourage arts institutions across Europe. A specific working group to enhance doctoral research in the arts known as the SHARE[3] network holds annual events to raise the platform for research in the arts.

2.3 Knowledge Production and Practice-Based/Practice-Led Research

Practice-based, practice-led, practice as research (PaR), artistic research, and arts-based research are all widespread terms in creative arts research which are not interchangeable and exhibit qualities that need to be understood regarding the nature of the art practice and the resulting production of knowledge. Different perspectives on these can be explored through the writings of Candy and Desmond [9, 10], Barratt and Bolt [11], Grey and Malins [12], Macleod and Holdridge [13], Briggs and Karlsson [14], Nelson [15].

In summary, "*Practice-based Research is an original investigation undertaken in order to gain new knowledge partly by means of practice and the outcomes of that practice*". By contrast "*Practice-led Research is concerned with the nature of practice and leads to new knowledge that has operational significance for that practice*" [16]. Practice as research (PaR) distinguishes artist-scholars in a university context from professional practice. Nelson [15] describes PaR as a research project in which practice is a key method of enquiry where the practice is submitted as evidence of a research enquiry. An important difference between the personal or professional artist and artwork in the doctoral research is the form the knowledge produced takes. For example, "*understandings about audience experience, taxonomies, models of collaboration and the artwork themselves*" [17]. This is not to be confused with arts-based research which is another term used principally in the fields of education where it is used to understand education through arts-based concepts, techniques, and practice [18]. A practice-based Ph.D. includes creative works that arise from the research process as part of the submission.

Despite the literature available on different perspectives on practice-based research, there is still not an "an integrated discourse on the place of practice-based research in Ph.D. programmes" [17]. The definition of research within the university is clear and Wrexham Glyndwr University had articulated it as a "*process of investigation leading to new insights collectively shared*" [19]. Two expectations of new knowledge resulting from by research are firstly, that it has to be open to being

[3]SHARE stands for Step-change for Higher Arts Research and Education and was an international networking project, comprising 39 partners working together on enhancing the "3rd cycle" of arts research and education. It created a Europe-wide exchange framework for the widely different experiences, practices and ideas that make up the lively domain of artistic and cultural research. [https://www.elia-artschools.org/activities/artistic-research/share].

challenged and, secondly, that it has to be verified. Creative arts research outcomes and methodologies are sometimes difficult to understand and quantify in terms of traditional scholarship, which can lead to a devaluing of studio-based enquiry [20].

It is only when artist researchers, with their practice, firmly root themselves in their discipline, and position themselves in relation to other disciplines, that they can then truly reveal the characteristics particular to their research. Students enrolled on Ph.D. programmes are frequently expected to present their research to the wider community of students from other disciplines. This can have a "de-centering" effect on the newly enrolled student. On writing the research proposal it can, initially, be confusing if "oneself" plays a significant role in the object of an enquiry. This has also presented challenges to supervisors at Wrexham Glyndwr University guiding students in cross-disciplinary teams.

2.4 Cross-Disciplinary, Interdisciplinary, and Multidisciplinary Collaborative Research in Doctoral Studies

Bourdieu notes that on-going privileges of positivistic and instrumentalist approaches to research persist [20, p. 4]. The researchers in the case studies described have experienced a de-stabilizing effect on their confidence when writing proposals. A lack of experience sometimes leads to an over reliance on scientific or social science paradigms to justify "fuzzy" concepts.

The following examples demonstrate a research project conducted by Liggett and two that she has supervized to illustrate how these challenges have been overcome by researchers having a clear understanding of themselves and their motivations for the research. They all adopt a mixed-method approach and involve interdisciplinary or cross-disciplinary collaborations through the research design of the supervisory teams comprising academics from different subject areas. Supervisors recognized the importance of openness and a willingness to seek the advice of other academics to ensure the support was provided for cross-disciplinary dialogues in the following projects.

Firstly, Heald and Liggett undertook a multidisciplinary research project in collaboration with a Consultant psychiatrist and Professor of social psychiatry both from Bangor University titled In-between-ness: using art to capture a sense of self during anti-depressant treatment [21]. The rationale for the research was to try and understand how reality is constructed and whether this process can be manipulated with medication and also, to determine the implications for the authenticity of "self" for someone undergoing treatment for depression. The artists worked one-to-one with four participants over 6 weeks. Service users were issued with a video camera and asked to film on a weekly basis with visual prompts introduced as a stimulus. The process allowed participants to explore how views of themselves changed as they recovered from depression. Interviews and psychometric tests were carried out before, during and after their treatment, in collaboration with the trial psychiatrist. The findings revealed that the interview transcripts recorded positive benefits to participants in terms of increased responsiveness to sensations, their surrounding environment, the quality of their feelings and their sense of "self" when engaged in this creative process. The psychometric tests, by contrast, evidenced no change in data.

The artists' practice acted as a personal rationale in the approach to the research and initial research questions stemmed from the issues arising from their work.

These questions were recognized by the medical professionals and validated by the psychiatrists in the collaboration. This external rationale then drove the art practice as the artists made new artworks in response to the situations and experiences they encountered on their research journey. Figure 2.1 shows Liggett and Heald's film work made in response to feeling "in-between" working as artists at a psychiatric unit. The artwork cannot be detached from the research project, and the artwork produced by participants was seen as integral to the project and exhibited alongside the artists' work in the final exhibition concluding the project.

Secondly, Braisby's Ph.D. project, which was practice-led and interdisciplinary [22], identified how galvanic processes can enhance the work of the artist printmakers and act to reverse the current decline in the teaching of intaglio etching. His work involved making artworks to gain a deeper understanding of the chemical and electrochemical processes involved. Scientific advice was sought from academics in the chemistry department and workshops were designed for artists to learn about

Fig. 2.1 Paper Interior, film duration 9′ 20″, Heald and Liggett (2013). Photo credit Karen Heald. Copyright © K. Heald, 2019

the processes. The learning generated from the workshops was analyzed using Soft Systems Methodology (SSM) developed by Checkland [23]. It involved drawing a rich picture; a process that uses images and words drawn out on a large sheet of paper to describe the problem situation. Exposing the richness of the data helped in the framing and re-framing of the situation and generated new ideas and insights into the problem situation.

This rich picture process identified two aspects to the research question. The first relates to the research into the galvanic techniques and the second to their application as an artistic medium. The first is a well-defined problem that can be addressed through a scientific problem-solving experimental approach under the rubric of the "hard systems" [23]. The second part of the question needed to engage with messy, real-world issues. This world was engaged through: workshops (electro-etching), presentations (using the rich picture), collaborative work (other artists), and interviews.

The research strategy developed was based on a hybrid model of both the practice-based and practice-led methods [16]. The quantitative (practice-led) research collected data by experimentation and developed a new process to produce the artwork. The qualitative data (practice based) developed new understandings of the process. Figure 2.2 shows experiments in enameling or plating etching plates with a different metal in its impact on the practice of etching was evident in the creation of the

Fig. 2.2 Don Braisby, Experimenting with Enamelling (2019) 23 × 29 cm Copyright © D. Braisby 2019, reproduced by permission

artwork produced. The research required the researcher to move out of his artistic environment and engage with chemists, scientists, and physicists.

Finally, Wyatt's Ph.D. cross-disciplinary project [24] investigated how people living with dementia engage with, and experience, painting whilst working alongside an artist-researcher. Arts-based inquiry[4] was adopted as a method creating a body of paintings to provide insights into different experiences and forms of engagement when painting. Figure 2.3 is an example of a painting Wyatt made in response to the memory of a beach in Wales. These were used to inform a qualitative study that used social science methods of interviews observations and video recordings. The use of both arts and social science research methods presented a challenge initially but the research demonstrated how an artists' perspectives can contribute to the field of health by promoting new approaches to research.

In all three projects, the subjective strength of their work has grown out of the positioning of the researchers in their studies by a self-scrutinizing process that is, perhaps, unfamiliar in other disciplines. This process is necessary to prevent the artist becoming a "pseudo-scientist", having a "split personality" or being over narcissistic.

The in-between-ness project involved a collaborative multi-method pluralistic approach to the research questions and monthly dialogues within the research team. Initially, the challenge for the artists was to emphasize their individual practice in the research design. Ostensibly their role could be seen to be purely one of facilitator

Fig. 2.3 Megan Wyatt, Whistling Sands (my Favourite Beach), 2017 Copyright © M. Wyatt 2019, reproduced by permission

[4]Arts-based inquiry uses artistic expression as data for inquiry.

for the participants. In reality, it was much more than this. The collaborative process offered the artists a new method of challenging ideas that grew out of their practice. It wasn't until each researcher's motivations and position within the research process was established that a meaningful collaboration existed where all academics equally owned the research.

In the "In-between-ness" project with mental health participants and Wyatt's project involving people living with dementia the relationship between the researcher and the participants is an intrinsic aspect of the research. When viewing and making artwork, it is not merely the deciphering of reality which occurs, because new understandings emerge, and connections and explanations are exposed to both viewer and artist. Viewing and creating artwork can transform understanding to inform and generate new and valid knowledge [25]. Practice-based research is used in these projects as it allows for new outcomes which do not oppose a verbal explanation [26].

In Braisby's research involving galvanic etching, the known data from multiple points of view is gathered together and made visible. This data enabled the researcher to identify hidden links and make new connections and insights with their personal practice to facilitate the refinement of the research. This process exposed the richness of the data that emerged from the research and helped in re-framing the situation. This firmly positioned the researcher in this research field, and this practice generated new ideas and insights into the problem of why electro-etching has never become mainstream in institutes of art.

2.5 Art, Collaboration, and Technology

The use of art as tool for social change is gaining traction with advocates such as Alistair Hudson, the director of the Whitworth and Manchester Art Gallery since 2017, which promotes projects that have a real impact on people's lives. People need to value art so that they no longer say that they need a hospital rather than a gallery. The mission is to get people to understand that the two are not mutually exclusive and that people need both hospitals and art galleries [27].

According to the World Economic Forum, creativity is a key skill needed for future employment [28]. The Fourth Industrial Revolution [29] brings advances in technology that are challenging traditional jobs in the shift from the human to the digital. Robots and artificial intelligence (AI) are more efficient in certain areas than humans in the workplace. In the future, 47% of work may be lost to automation processes [30]. Mobile Internet and cloud technologies are impacting society. However, robots do not yet possess innate creativity (though software may soon be able to emulate some of its characteristics) so business leaders, educators, and governments still recognize the importance of human creativity.

Artists are increasingly collaborating with scientists and technologists in a multitude of ways that extend the boundaries of knowledge. For example, The Foundation for Art and Creative Technology (FACT) a leading UK visual arts organization has developed a number of projects promoting creative media and creative technology.

In 2019, it worked with the NHS, BBC, charities, and businesses in a project called "The Future World of Work" to provide an arts-led critique of innovation and technology, reimagining work in relation to gender, the gig economy and careers advice for uncertain times [30]. It worked with a number of artists who undertook workplace artist residencies who make artwork in response to their experiences culminating in an exhibition at FACT's gallery [31].

Artists can provide useful critiques of society and can raise awareness of societal issues in various ways. The German artist and filmmaker Hito Steyerl has an interest in how the media, technology, and the global circulation of images impact society.

> We live in a world that is already deeply edited and PhotoShopped. It is cut and pasted, and the people who know these practices because they work with them everyday – let's call them artists – they understand the importance of these practices, not only understanding the world but also making it as it is [32].

Steyerl's video installation *Factory of the Sun* examines the desires and threats of image circulation and the possibilities of shared resistance when surveillance is everywhere in our increasingly virtual world. *Factory of the Sun* tells the surreal story of workers whose forced moves in a motion capture studio are turned into artificial sunshine [33, 34].

2.6 Conclusions

The artists' subjective and hermeneutic approaches offer new perspectives to research but there are challenges in articulating the unique qualities their work offers. Cross-disciplinary supervisory teams at Wrexham Glyndwr University have enabled critical dialogues for the students and supervisors to set out clearly and test the concise methodological approaches to their work. The unpredictability of artistic research has brought challenges, particularly when adopting a less prescriptive approach to outputs in the research proposal. The researchers here often found it easier to talk about the results of their interviews, or scientific experiments, than articulating the impact of their practice within their projects when applying a multi-method approach to research questions. In the In-between-ness project, for example, the therapeutic effect of the project was not the primary measuring stick for assessing the success of their work.

According to Polanyi (1962), aesthetic insights "*motivates the early stages of much scientific research*" [35]. Mixed disciplinary supervisory teams at Wrexham Glyndwr University have forced us to challenge perceptions of ourselves as artists and consequently enriched our projects. We often cannot predict what others will learn from our work, but it is the process of learning and identifying one's individual position in the research process that will allow for new avenues of knowledge to emerge. The arts can be a powerful tool for social change, for wellbeing and for connecting people. As Candy states in the summary of her new book, there is a considerable amount we can learn from paying close attention to the world and it takes a creative mind to do this with insight [36].

References

1. Barrett, E., Bolt, B.: Practice as Research, Approaches to Creative Arts Enquiry, pp. 4–6. Bloomsbury Publishing Plc, London (2007)
2. Elkins, J.: Why Art Cannot Be Taught, pp. 37–39. University of Illinois Press, USA (2001)
3. Davis, M.C.: The Council for National Academic Awards 1964–74: A Study of A Validating Agency. Loughborough University, UK (1979). Available online: https://en.m.wikipedia.org/wiki/Council_for_National_Academic_Awards. Accessed April 2019
4. Elkins, J., Motram, J.: cited in Artists with PhD's, p. 13. New Academia Publishing, Washington, DC, USA (2009)
5. HESA. Available online: https://www.hesa.ac.uk/news/11-01-2018/sfr247-higher-education-student-statistics/qualifications
6. Biggs, M., Buchler, D., Nelson, S.: Social Dynamics of Knowledge Communication Within Higher Education: The Case of An Art-Science Collaboration (2011). Available online: https://uhra.herts.ac.uk/bitstream/handle/2299/7582/905511.pdf?sequence=1. Accessed March 2019
7. Biggs, M., et al.: Editorial: the foundations of practice-based research, vol. 1. Working Papers in Art & Design (2000). Available online: https://uhra.herts.ac.uk/bitstream/handle/2299/7325/101063.pdf?sequence=1. Accessed April 2019
8. Wilson, M., Van Ruiten, S.: ELIA SHARE (2013). Available at: https://www.elia-artschools.org/activities/artistic-research/share. Accessed May 2019
9. Candy, L.: Research and creative practice. In: Candy, L., Edmonds, E.A. (eds.) Interacting: Art Research and the Creative Practitioner, Chap. 2, pp. 24–59. Libri Publishing Ltd, Farringdon, UK (2011)
10. Candy, L., Edmonds, E.: Practice Based Research in the Creative Arts: Foundations and Futures from the Front Line. Leonardo **51**(1), 63–69 (2016)
11. Barrett, E., Bolt, B.: Practice as Research, Approaches to Creative Arts Enquiry. Bloomsbury Publishing Plc, London, UK (2007)
12. Grey, C., Malins, J.: Visualising Research: A Guide to the Research Process in Art and Design. Ashgate Publishing Ltd, Farnham, UK (2004)
13. Macleod, K., Holdridge, L.: Thinking Through Art: Reflections on Art as Research. Routledge, Abingdon, UK (2006)
14. Biggs, M., Karlsson, H. (eds.): The Routledge Companion to Research in the Arts. Routledge, Abingdon, UK (2011)
15. Nelson, R.: Practice as Research in the Arts. Palgrave MacMillan, London, UK (2013)
16. Candy, L.: Practice Based Research: A guide (2006). Available: http://www.creativityandcognition.com/resources/PBR%20Guide-1.1-2006.pdf. Accessed April 2019
17. Candy, L., Edmonds, E.: Practice Based Research in the Creative Arts: Foundations and Futures from the Front Line. Leonardo, vol. 51, Issue 1, February, pp 63–69 (2016)
18. Smithbell, P.: Arts-Based Research in Education: A Review. The Qualitative Report, **15**(6), 1597–1601 (2010). Available online: http://nsuworks.nova.edu/tqr/vol15/iss6/14. Accessed May 2019
19. Wrexham Glyndŵr University Vision & Strategy to 2025: Inspiring, Transforming, Enabling and Sustaining. Definition of Research taken from Vision and Strategy to 2025 (2018). Available online: https://www.glyndwr.ac.uk/en/media/156309%20Strategy%20English.pdf. Accessed April 2019
20. Barrett, E., Bolt, B.: Practice as Research, Approaches to Creative Arts Enquiry, pp. 1–13. Bloomsbury Publishing Plc, London, UK (2007)

21. Liggett, S., Heald, K.: In-between-ness: Using art to capture changes to the self during antidepressant treatment (2013). Available online: http://in-between-ness.co.uk/about/synopsis-of-research-project/. Accessed May 2019
22. Braisby, D.: How Can the Development and Use of Galvanic Etching Techniques Enhance the Work of the Artist Printmaker? Ph.D. Thesis, University of Wales (2017)
23. Checkland, P.: Systems Thinking, Systems Practice. Wiley, London (1981)
24. Wyatt, M.: A cross-disciplinary study into how people living with dementia engage with and experience painting alongside an artist researcher. Ph.D. Thesis, University of Wales (2019)
25. Sullivan, G.: Arts Practice as Research: Inquiry in the Visual Arts. Sage Publications, Newbury Park, CA, USA (2005)
26. Niedderer, K., Roworth-Stokes, S.: The Role and Use of Creative Practice in Research and its Contributions to Knowledge (2007). Available online: http://niedderer.org/IASDR07SRS.pdf. Accessed May 2019
27. The Guardian 21 Oct (2019). Available online: https://www.theguardian.com/culture-professionals-network/culture-professionals-blog/2014/oct/21/alistair-hudson-mima-modern-art). Accessed May 2019
28. World Economic forum. Available online: [https://www.weforum.org/agenda/2018/12/why-the-fourth-industrial-revolution-needs-more-arts-graduates/. Accessed May 2019
29. Schwab, K.: The Fourth Industrial Revolution (2015). Available online: https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution. Accessed May 2019
30. Benedikt Frey, C., Osborne, M.: The Future of Employment, Published by the Oxford Martin Programme on Technology and Employment (2013). Available at https://www.oxfordmartin.ox.ac.uk/downloads/academic/future-of-employment.pdf. (Benedikt Frey, C & Osborne). Accessed May 2019
31. FACT Future World of Work Project (2019). Available online: https://www.fact.co.uk/future-world-of-work. Accessed May 2019
32. Steyerl, H.: 12th ELIA Biennial Conference ART, SCIENCE AND SOCIETY: Art Questions, Art Knows, Art Matters Hosted by the University of Applied Arts Vienna at the Museums Quartier Wien, 8–10 November 20 (2012)
33. Steyerl, H.: Factory of the Sun, February 21–September 12, 2016 courtesy of The Museum of Contemporary Art, Los Angeles. Available online: https://www.moca.org/exhibition/hito-steyerl-factory-of-the-sun
34. Tattersall, L.: Curator MOCA LA. Available online: https://www.moca.org/exhibition/hito-steyerl-factory-of-the-sun. Accessed May 2019
35. Polanyi, M.: Personal knowledge: towards a post critical philosophy. Routledge, London (1962) cited in Rust, C. Unstated contributions: how artistic inquiry can inform inter-disciplinary research. Int. J. Des. **1**(3), (2007). Online at: http://www.ijdesign.org/index.php/IJDesign/article/view/201/80
36. Candy, L.: The Creative Reflective Practitioner: Research Through Making and Practice. Taylor Francis, Abingdon, UK (2019)

Part II
Facilitating Communication Between the Arts, Technology, and Audiences

Chapter 3
Framing the Conversation: The Role of the Exhibition in Overcoming Interdisciplinary Communication Challenges

Susan Liggett and Mike Corcoran

Abstract The role of the exhibition in overcoming interdisciplinary communication challenges is explored. The meaning of interdisciplinary communication is established, alongside the challenges it brings, where their route causes lie and the extent to which the exhibition is equipped to address them. It concludes that exhibitions of a particular nature are uniquely equipped to facilitate better quality interdisciplinary communication in certain contexts, but that further work is needed to develop mature curatorial models to facilitate this. A structure for such models is proposed, alongside the steps that now need to be followed if exhibitions are to fulfil this untapped potential at the interface of art and technology.

Keywords Curatorial model · Communication · Exhibition · Interdisciplinary · Art · Technology

3.1 Introduction

Interdisciplinary solutions are becoming the lingua franca in the discussion of the global challenges we face in the twenty-first century. Whether it's the education of our young people, the care of our elderly, the fight against disease or the protection of our environment, the answers will not be found in any one place. Rather, progress relies on the coming together of diverse expertise and perspectives, and the shared commitment of a vast number of individuals, unified by a common goal.

At the meeting point of art and technology, this is felt more sharply than perhaps anywhere else. The 'fourth industrial revolution' has blurred the boundaries between man and machine, with the designer's role fundamental in managing the interface between the two. Furthermore, artists have ever-increasing responsibility for bringing the challenges of our times to the masses in ways which are tactile, accessible

S. Liggett (✉) · M. Corcoran
Wrexham, Wales
e-mail: s.liggett@glyndwr.ac.uk

M. Corcoran
e-mail: mike@macorcoran.com

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_3

and engaging to all: driving political and social agendas. Conversely, technology is opening up endless new ways to create, display and interact with art, spawning new branches of artistic practice, and changing our perceptions of what art is and what it can achieve.

Communication is central to the success of any group, working towards any objective. When groups are interdisciplinary, subject matter is technical, stakeholders are global and success is critical, this presents unique challenges. However, in spite of this, the nuance of communication in such contexts is still poorly understood. Exhibitions are a unique communication tool. Their potential as a means to support better quality communication amongst interdisciplinary teams is apparent; yet this potential is under-investigated. The processes by which it could best be realized are ill-defined, and the models and tools required to facilitate the execution of such processes are absent.

Here, a forensic examination of communication amongst interdisciplinary art-technology teams is undertaken to establish the root causes behind the challenges which arise and the extent to which exhibitions are equipped to provide solutions to them. Assumptions are tested against the experiences of the principal actors in such communications and the way forward is posited, with proposals set out for the further work required if exhibitions are to fulfil their potential in improving interdisciplinary communication: for more people, more of the time.

3.2 Defining *Interdisciplinary Communication*

3.2.1 Defining Interdisciplinary

Before we identify interdisciplinary communication challenges, we must first establish what is meant by *interdisciplinary* and *communication*.

The terms *interdisciplinary*, *multidisciplinary* and *transdisciplinary* and applied inconsistently, and used interchangeably by many [1]. However, the National Academies provide the following working definition of *interdisciplinary research*: "*a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice*" [2].

It is in this sense that *interdisciplinary* will be referred to herein: referring to the coming together of teams or individuals from two or more bodies of specialized knowledge in research, or otherwise.

3.2.2 Defining Communication

In order to precisely identify communication challenges, it is helpful to adopt a simple conceptual model of human communication which clearly delineates each of its component parts. The Shannon–Weaver Model [3] was developed by Bell Laboratories engineers Elwood Shannon and Warren Weaver in the 1940's. It is widely regarded as the forerunner of modern communication studies and provides such components. Shannon and Weaver extrapolated a general theory of communication from the process by which radio technologies function and identified five components of all communications, as represented in Fig. 3.1.

An *Information Source* produces the message which is to be communicated. A *Transmitter* encodes that message into appropriate signals for transmission. A *Channel* provides the medium through which signals are transmitted (and as signals propagate through this Channel, they are vulnerable to '*Noise*' which can block, interrupt or distort signals). A *Receiver* decodes the signal to reconstruct the original message, and a *Destination* is an individual, group or entity for whom the message is intended.

Consider saying hello to a friend as you walk down the street. You, or perhaps we should say, the appropriate regions of your brain, are the Information Source, taking the decision to transmit the message, 'Hello!'. Your lungs, vocal folds, tongue and mouth are the Transmitter, working together to produce the appropriate sound waves and air is the Channel which carries these sound waves between you and your friend. Passing buses, sudden gusts of wind and much else can provide noise to distort the message at this stage, before your friend's ear receives the sound waves transmitted, and their brain converts and translates them to reveal their intended meaning. The message has now reached its intended destination and your friend

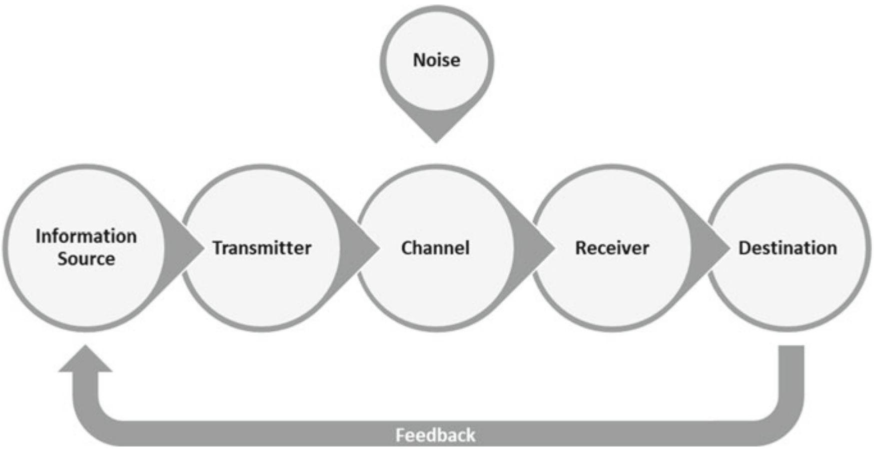

Fig. 3.1 Shannon and weaver's five component parts from which all communications are comprised. Copyright © M. Corcoran 2019

responds appropriately, perhaps with a wave in your direction. Through this new transmission (and feedback), the iterative process begins again.

3.2.3 Defining the Principal Actors in Interdisciplinary Communication

Alongside a conceptual model of communication, it is also crucial that we have an understanding of who the principal actors (in Shannon and Weaver's language, the Informational Sources and Destinations) in interdisciplinary communications typically are. We propose the following groups, as shown in Table 3.1.

With working definitions of *interdisciplinary* and *communication* established, alongside an understanding of who such interdisciplinary communication occurs between, we can now consider the challenges of interdisciplinary communication and their direct relationship to activities involving artists and technologists.

3.3 Interdisciplinary Communication Challenges

Shannon and Weaver proposed that, considering the five parts from which all communication is comprised, three fundamental types of communication challenge can arise:

Table 3.1 The principal actors interdisciplinary communication

Principal actor	Definition
Specialists	The individuals and teams who carry out the work. They possess knowledge of one or more technical discipline and are unified by a common set of objectives
Benefactors	Those who sponsor the work. This includes philanthropic funders, public bodies and private investors
Beneficiaries	Those who reap the rewards of the work, including governments, private companies and proportions of the general public
Publics	A meta-group that include all those within a given population who are stakeholders in an interdisciplinary activity, either as specialists (contributing their insights with respect to a particular problem), Benefactors (through the public funding of interdisciplinary work through taxation or others) and Beneficiaries (in virtue of an activity's impacts). Often Publics will hold multiple roles simultaneously
Translators	Facilitating communication between two or more of the aforementioned groups in any combination. For example, they may assist specialists in engaging with Publics, Benefactors in evaluating Beneficiaries, or Publics in lobbying Benefactors

1. *Technical Challenges*: relating to how accurately messages can be issued.
2. *Semantic Challenges*: relating to how precisely meanings can be conveyed.
3. *Effectiveness Challenges*: relating to how successful received messages are in bringing about their desired effects.

3.3.1 Communicating Accurately

Technical challenges arise due to the many different means artists and technologists have to adopt to get their messages across.

The typical interdisciplinary communication involves multiple information sources, and multiple Destinations. Diverse information is shared in all directions: both *within* specialist interdisciplinary teams, and *between* those teams and their Benefactors, Beneficiaries, Publics and Translators. Every group (and every actor within every group) has their own preference with respect to transmitting and receiving information (some like to write or talk, others like to draw or experience and so on), and information tends to go through many iterations of transmission and reception on its journey between actors, highly subject to noise and interference.

This is especially true when artists and technologists work together. Consider what it takes for the latest research in machine learning to reach the desk of the fine art professor or for the biomedical scientist to encounter theories in the teaching of painting. Consequently, before the insights of one actor enter the consciousness of another, they may be transmitted through many cycles of performance, discussion, publication or otherwise, with each increasing the probability of degradation, mistranslation and dilution of the overall message [4]. Even before interdisciplinary teams have been constructed, the basis for their very construction can run the risk of being underpinned by inaccurate information.

3.3.2 Communicating Precisely

Semantic challenges arise due to the difficulty of explaining things in a simple way which artists, technologists and everyone they engage with can understand.

There is no universally understood language amongst the principle actors in interdisciplinary activities. As Derrick et al. observe, "*Scientific disciplines have different cultures, languages, and standards*" [5] and the same can be said of non-scientific disciplines. The vocabulary and reference points of specialists are highly technical, and a deep understanding of issues is often contingent upon a contextual understanding of the wider subject, not always available to every specialist within an interdisciplinary team. This is particularly true when artists and technologists come together. Their respective disciplines having long been siloed into what CP Snow famously characterized as 'The Two Cultures' [6].

This problem is only compounded as specialists (of any discipline) look to communicate to their Benefactors, Beneficiaries and Publics. Translators can assist, but ultimately, communication is often heavily reliant on metaphor and simplification, inevitably impacting on the precision with which information can be shared, and preventing much information from being shared at all.

3.3.3 Communicating Impactfully

Effectiveness challenges arise due to the many different things artists and technologists have to simultaneously achieve when they communicate.

Often, a single communication will have multiple Destinations and multiple diverse objectives. As communication takes place amongst specialists within an interdisciplinary team, the outcomes and impacts of such work are simultaneously subject to the scrutiny of Benefactors, Beneficiaries and Publics, each with diverse needs and expectations. To achieve such objectives can be 'complex, nuanced and highly resource intensive' [4]. When it is simply not possible to tailor the perfect transmission for each target Destination, a 'one size fits all' approach can be considered as an alternative, but in striving to please all, there is an inherent risk of not pleasing any.

Taking into consideration the main components of communication, the fundamental types of communication challenge posited by Shannon and Weaver, and reflecting on each in the context of the principal actors in interdisciplinary communication, especially artists and technologists, we can conclude that such communication is a challenge because:

1. Technical challenges lead to the *accuracy* of information shared being impeded by the many different ways and means required to communicate.
2. Semantic challenges lead to the *precision* of information shared being impeded by the lack of common vocabulary and reference points amongst the principle actors who are communicating.
3. Effectiveness challenges led to the *impact* of communication being impeded by the multiple objectives it is required to serve.

In transitioning from an understanding of the challenges which lie at the heart of interdisciplinary communication to an understanding of the ways in which these challenges can be overcome and the role of the exhibition in facilitating this, it is essential to gain a deeper appreciation of the validity of our conclusions above. This includes the extent of their generalisability, and the contexts in which they most strongly apply. This starts through dialogue with those with lived experience of interdisciplinary collaboration from a variety of different perspectives.

3.4 Interviews with Interdisciplinary Practitioners

The following perspectives are derived from interviews conducted with various experts and specialists in the domain of this research. That is, those who are primarily responsible for the management and administration of interdisciplinary projects and activities, and the communication that comes with it. Their thoughts and experiences are summarized below.

3.4.1 The Specialist Technologist's Perspective

The specialist technologist's perspective was offered by a software engineer working predominantly in the rendering of digital holograms.

This involves communicating primarily with:

- Artists (Benefactor/Beneficiaries): including both independent artists and commercial customers looking for holographic solutions within their work and
- Optical engineers (Specialists): in order to understand and provide feedback on the strengths and restrictions of working in the medium.

Communication with fellow technical specialists (i.e., software and optical engineers) tends to be the most straightforward. This is in part thanks to the common vocabulary and reference points these specialists share, and the readily quantifiable nature of the information they typically share (for example, the technical parameters of the hologram printing equipment). For communication of this nature, communication tools such as email are very effective, allowing for precise information to be shared back and forth asynchronously.

Conversely, communication between artists and engineers is more challenging, because there is no common vocabulary and the information being shared is typically subjective and qualitative. Engineers and artists are often exploring the 'art of the possible', and the broad objective which the creative work is attempting to realize. In these circumstances, live and iterative communication, supported by visual aids, can prove effective.

With regards to exhibitions, they can play a valuable role in setting the context for discussions between any actors, alongside demonstrating the nature and potential of the technology, especially when bringing such state-of-the-art technology to general public audiences.

3.4.2 The Specialist Artist's Perspective

Jessica Lloyd Jones, an artist who exhibits internationally combining elements of art, science and technology provided the specialist artist's perspective. Lloyd Jones' work

Fig. 3.2 Jessica Lloyd Jones 'Forest Fuel' 2018, permanent projection onto a biomass plant, Gothenburg, Sweden. (Copyright © J. Lloyd Jones 2018) included by permission

explores concepts of energy, matter and natural phenomena through the interaction of materials and light through installations, projection and sculpture created from a variety of materials and processes. An example of this work is shown in Fig. 3.2, where a digital image is projected on to a biomass plant in Sweden.

Producing works of this nature requires effective liaison with a wide group of people. These include project managers, funders and commissioners (Benefactors), technologists, engineers, architects, fabricators and design teams (Specialists) and curators (Translators).

Internal communication between these people is, in part, influenced by the time sequence in which the various actors signed-up to the project. For example, commissioners and project managers will often be in place before the artist becomes involved, whereas others (for example, fabricators) can only be selected by the artist once a project has commenced. The structure, roles and responsibilities of a team will often be assigned in line with the common goals identified between the artists, technologists/scientists and the other stakeholders involved, with ultimate management responsibility depending on who instigated the project. Maquettes and visualizations provide useful aids here, illustrating ideas and concepts to stakeholders and potential stakeholders.

External communication to an artwork's intended audiences must simultaneously speak to many diverse individuals. Those with an active interest in the arts are the easiest to reach as they tend to be more open-minded and curious. This is especially true when the information to be communicated is broad-based and thematic, for example, communicating ideas about energy, beauty, innovation or creativity. When audiences have little knowledge, understanding or exposure of the arts, this can directly impact upon enthusiasm, open-mindedness and curiosity, and subsequently on the success of the communication which follows.

No one tool is the secret to successful communication, with the most effective means of communication depending on the context, though when engaging in a crowded market-place, novelty can be key. Audiences are more likely to be engaged if the artwork presents something they haven't seen before.

3.4.3 The Benefactor's Perspective

The benefactor's perspective was offered by a senior manager in a UK-based public services innovation foundation, often delivering projects bringing together artists, technologists and public bodies.

Audiences in communication in this environment are diverse. This is not only a diversity of organisations, but a diversity of individuals within each organisation, which communication must be sensitive to. However, across all audiences, the communication of 'facts and figures' tends to be easier than the communication of 'concepts and ideas,' thanks to:

- The clear and unambiguous nature of the information: usually concerning who, what, when, where and how;
- The clearly delineated audiences for the communication: with eligibility criteria defining the types of organisation for whom the information is relevant;
- The simple and well-established channels through which communication is shared: for example, application forms to access funding and;
- The simple feedback loops associated with these channels: for example, via workshops, emails and phone calls.

Conversely, communicating concepts and ideas, especially the learning arising from projects, is generally more challenging. Points can be nuanced and subtle; the learning potentially applicable to any audience and the channels through which such learning is shared are less well-established resulting in feedback loops which can be vague or non-existent.

Additional challenges can arise due to the differing organisational cultures in place between partners in a given project (especially those bringing academic, public and private sector partners together). Each may have different reasons for being involved in the project, and these need to be taken into account. At the same time, this diversity can be a strength of the project because it can lead to innovation and new ways of viewing the project and its outcomes, which can add value to the original concept.

Exhibition is a tool used regularly to communicate concepts and ideas, present the outcomes achieved and learning gained through collaborative projects and to foster multiple conversations simultaneously between many partners. It is often easier to show someone something than tell them about it. The innovation foundation often use ‘pitching exhibitions’ to invited audiences of key stakeholders at targeted events, which they find to be a highly effective method.

3.4.4 The Translator’s Perspective

The translator’s perspective was offered by a public engagement manager at a leading biomedical research facility. A permanent gallery at the facility, along with an accompanying public engagement outreach programme, aims to generate excitement and interest in discovery of science, human health and wellbeing: through artistic means and otherwise.

Exhibitions have to cater to many audiences, marrying rich content for high science capital peers (including those researchers based at the facility) simultaneously with that for a low science capital lay-public. Often, they also need to cater to visitors from different countries (with different cultural backgrounds), politicians, distinguished guests, as well as the accompanying press: simultaneously and seamlessly.

To bring these exhibitions together requires close communication with and between:

- Public engagement and education teams (Translators)
- Press and marketing teams (Translators)
- The organisation’s scientists (Specialists): including those directly involved in each exhibition, and the wider community of those working in the organisation.
- Exhibition funders (Benefactors).
- Contractors (Specialists) of diverse backgrounds and specialisms.
- Focus groups (Publics and Beneficiaries) contributing to each exhibition’s relevance and accessibility.
- Peers (Specialists and Translators): working in museums, galleries, and other science-communication environments, sharing best practice, knowledge and experience.

In practice, the planning of each exhibition can require communication with a diverse group of 30–40 people.

Internal communications are managed with a high degree of structure. An Internal Advisory Panel of senior managers and key stakeholders communicate the exhibition’s broad themes and messages. It also translates these into the wider strategic direction and brand identity that the organisation is seeking to achieve. This helps to build trust—so that the senior managers and key stakeholders feel confident in the processes being followed and the expected outcomes. An exhibition steering committee comprised of colleagues with a variety of roles across the organisation can provide feedback on various aspects of the exhibition plans. A project group is normally required to discuss the practicalities of bringing each exhibition together and meeting the needs of all stakeholders within the constraints of the space available. It is also important to maintain communication with any external teams of contractors and keep track of timelines, deliverables and issues as they arise. Communication within these structures is aided by video conferencing, formal presentations, document sharing and Gannt charts, but the most effective method is often to communicate face-to-face (or via video conference for more remote collaborators).

Communication is most effective when it is between individuals who all work in the same context, with the same strategy, and the same audience. The greatest challenge is when the time is limited, audiences are disparate, and a contextual understanding is absent, communication is far more complex.

With regard to the content of the exhibitions, to achieve their intended impact of making a tangible impact to the feelings and perceptions of their audiences, consideration needs to be given to the diverse ways in which they may be interpreted by different kinds of audiences, particularly where advanced or specialist subjects are involved. There is also a distinction between the explicit information the exhibition communicates directly and the implicit communication of its values, character and context. The latter can be assisted, amongst other things, by the atmosphere created by the exhibition and the personnel who bring it to life. Both are needed if the exhibition is to be successful.

3.4.5 The Combined Perspective

In many cases, one individual may take on multiple communication roles in their work.

Such a combined perspective was offered by Jamie Harris, founder of Elder3D, a company specialising in making artworks affordable to the masses through utilization of cutting-edge 3D design and manufacturing technologies (Fig. 3.3). Harris is a

Fig. 3.3 A metallic 3D Print (Left) and its supporting digital 3D Model (right). (Copyright © J. Harris 2019) included by permission

Specialist in both artistic and technological practices, a *Benefactor* commissioning work from his international network of associate artists and technologists and a *Translator*, ensuring the wants and needs of his customers are always catered to.

In this context, understanding and trust are the basis for successful communication. Artists and 3D print specialists have to understand that the quality of the final product is dependent on the quality of information provided initially. The print specialists have to understand every detail in the brief and customers have to understand what is and what is not possible within the limitations of the technology.

Communication is easiest when the information shared is quantitative and unambiguous (for example, specifying the material and dimensions for a 3D print run) and when it is between actors who speak a common language, sharing common skills and experiences. Conversely, when the information to be shared is nuanced and qualitative (for example, when a family wishes to convey the 'spirit' of a person in a portrait) and when commonality of language is missing, communication is a challenge. Commonality lies in the shared experience of actors, but also on the number of individuals comprising each 'Information Source'. When a customer artist or printer is in practice, and when decisions are made by committee, information can quickly become confused, unclear or contradictory.

Trust is a prerequisite to understanding allowing honest and open communication to take place customers must trust that their vision can translate into a high-quality product, and artists must trust that a printer can bring their designs to life, print specialists must trust that the designs will be suitable for 3D printing in the specified materials and so on. Therefore, establishing a strong rapport and a personal relationship with everyone is essential to the business.

With regards to exhibition, showing the actual work is often the best way to communicate because people can touch and handle the work. This creates excitement, promotes questions and produces a better understanding.

3.4.6 An Interdisciplinary Communication Tool Wish List

In Sect. 3.3 we proposed that the challenge of interdisciplinary communication was rooted in the many different ways and means required to communicate (impairing accuracy), the lack of common vocabulary and reference points amongst the principal actors communication is between (impairing precision), and the multiple, simultaneous objectives such communication is often required to serve (impairing impact).

The views of those with direct experience of working in these environments certainly do not contradict these conclusions. Rather, we observe many instances of these challenges in action. We also gain a deeper insight into how these challenges arise, the other challenges they are closely related to and how such challenges might be addressed.

Table 3.2 An interdisciplinary communication tool 'wish list'

An interdisciplinary communication 'wish list'	
More accurate communication (to overcome technical challenges)	
1	Reduce the total number of channels needed to communicate messages
2	Reduce the quantity and improve the quality of Transmitters/Receivers
3	Reduce the risk of noise within multiple communication-feedback cycles
More precise communication (to overcome semantic challenges)	
4	Bring clarity to open ended, subjective and qualitative messages
5	Bring shared language, reference points and context to messages between diverse actors
6	Bring clarity to single messages compiled by multiple actors
More impactful communication (to overcome effectiveness challenges)	
7	Provide simultaneous communication of multiple (implicit and explicit) messages
8	Build trust and rapport amongst the principle actors in communication

Taking all of this into consideration, we propose a simple 'wish list' (see Table 3.2) of outcomes for any tool which could make interdisciplinary communication involving artists and technologists easier to facilitate.

With a wish list for an interdisciplinary communication tool established, we can assess the extent to which the exhibition has the potential to be such a tool. This can be done by considering what exhibitions are and how well aligned (and potentially impactful) they are with respect to each of our desired outcomes.

3.5 The Exhibition as an Interdisciplinary Communication Tool

3.5.1 Defining Exhibition

Exhibition is a broad and all-encompassing term. It may refer to any "*event at which objects are shown to the public, a situation in which someone shows a particular skill or quality to the public, or the act of showing these things*" [7], and it is this general sense that exhibitions are discussed here. This definition excludes private and informal day-to-day interactions. Furthermore, when we discuss exhibitions herein, we refer primarily refer to them in their most common temporary and ephemeral form, as opposed to permanent installations and collections.

Our wish list (Table 2.2) is composed in the language of the Shannon–Weaver Model and so before we can assess exhibitions against each of its desired outcomes, we must first ensure we can describe exhibitions in a consistent way. For virtually any exhibition, in any form:

- The ideas of the exhibiting artist and/or the curator serve as the *Information Source*.

- The artworks, in their particular arrangement, are the *Transmitters* of these ideas.
- The exhibition environment is the *Channel* through which these ideas pass.
- The senses of the exhibition's audiences are the *Receivers* of these ideas, and
- A given subset of the exhibition's total audience is the intended *Destination* for these ideas.

Furthermore, as done so throughout Sect. 3.4, the principal stakeholders in exhibitions can be simply mapped to the principal actors in interdisciplinary communication which we have defined as follows:

- *Specialists*: the exhibitors and/or the exhibition's curator.
- *Benefactors*: the sponsors, institutions or others who fund the exhibition.
- *Beneficiaries*: the audiences who are the intended 'Destination' for the exhibition's messages.
- *Publics*: formed from some combination of the above.
- *Translators*: curators and exhibition assistants.

With these definitions in place, our desired outcomes can now be assessed in turn.

3.5.2 Assessing Impact

Exhibitions can address technical challenges, leading to improved accuracy in communication, by reducing the number of Transmitters, Receivers and Channels, needed to communicate information. Each Information Source has one Transmitter, an exhibit, fewer transmitters implies fewer receivers to get a message to its intended destination, and the exhibition provides the sole Channel for communication. Furthermore, its structured nature allows for multiple stable feedback cycles, providing a constant background, providing a general context against which all further communications can be located.

Exhibitions can address semantic challenges, leading to improved precision in communication, by front-loading the communication process with the information which does not require the use of technical and discipline-specific vocabulary and reference points to understand: that is, the general qualitative messages that lie behind the technical detail. The exhibits themselves become the common, visual and tactile transmitters used to communicate these messages, to actors who do not require any technical knowledge to receive them. By precisely communicating the general messages behind work at the earliest opportunity, subsequent discussion of that work (through symposia, informal meetings, exhibition guides or otherwise) and all that follows thereafter, becomes much easier, whether between one induvial or many.

Exhibitions can address effectiveness challenges, leading to improved impact in communication, by simultaneously communicating to multiple and diverse actors. For some (for example, Publics), a general sense of 'what the work is about' is the desired outcome. For others (for example Benefactors), this general sense is a precursor to a desired outcome of a more detailed understanding why this work is needed, at this time. For Specialists, this detailed understanding is also a precursor to understanding who they should work with, how they should work with them, and where they need to widen their technical understanding (or recruit the support of translators) to facilitate this. Each of these can use the same core set of transmitters, the exhibits, and the sole channel of the exhibition. The exhibition can be curated so as to allow multiple and mutually compatible routes through it. Some may view the exhibition online; others may view it in person. Some may use an exhibition guide; others take a guided tour. Some may participate in symposia; others use it as a venue for meetings. Some may spend only minutes in the space; others hours or days. All of this can happen at the same time. There is no direct analogy for this flexibility with a research paper, a seminar or many of the other traditional tools of interdisciplinary working.

Not only that, but by putting an initial emphasis on common thoughts and feelings, in an environment which lends itself to being inclusive, social and highly creative, the exhibition plays a role in building the relationships, trust and rapport that are prerequisite to good communication, in a space which can entice and motivate new audiences to join in the fun.

3.6 A New Curatorial Model

The potential of the exhibition to provide solutions to interdisciplinary communication challenges, as outlined in Sect. 3.5, is clearly encouraging, but our discussion so far is insufficient in and of itself. To support meaningful action and generate real outcomes, this potential must be pinned down and converted into the clear guidance required by exhibition curators and those responsible for making interdisciplinary communications work. Our observations need consolidating into a model, stipulating what sort of exhibitions, will deliver what sort of outcomes, for what sort of audiences, and how.

To date, there is no off-the-shelf conceptual model describing the functions of the exhibition as an interdisciplinary communication tool, and perhaps this should not be surprising. Exhibition and curatorial studies, and the discourse and theoretical models which underpin them, do not share a common genus with communication theory. They have evolved divergently, fuelled by different motivations, setting out to solve different problems and thinking about those problems in different ways.

The Show-Talk-Do Model [4] (Fig. 3.4) describes the process by which high-level analysis of opportunities for research collaboration, alongside simultaneous non-expert engagement, can be achieved in environments which are rich with technical information and highly interdisciplinary. It contains three simple steps, which can be summarized as follows:

1. *Show It*: Focuses on initial organic reactions. A public exhibition presents the organic products of the ongoing research of participating researchers, from across a variety of disciplines and interdisciplinary areas. Exhibits may include (but

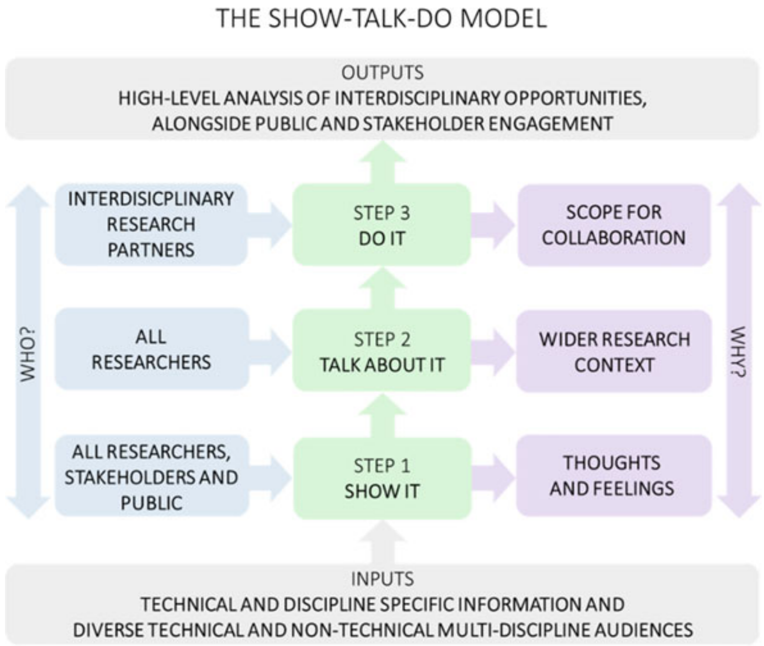

Fig. 3.4 The Show-Talk-Do Model for multi-audience engagement (© M. Corcoran and Liggett. S. 2018)

are not limited to) artworks, performances, documentation of practical research activities, visualization of 'live' research data and interactive demonstration of a process or procedure under development.

2. *Talk About It*: Focuses on developing contextual understanding. A symposium (or similar) takes place, where exhibiting researchers discuss with one another the context in which their exhibit (and by proxy, their research) is situated. This discussion should be structured (in accordance with pre-defined rules) and be located within the exhibition itself.
3. *Do It*: Focus on technical understanding and action. Research papers (or similar) are made available to researchers, and where synergy has been identified through Steps 1 and 2, the scope for research collaboration can be discussed.

The exhibition itself lives within Step 1. Open to all (with Specialists alongside Benefactors, Beneficiaries and Publics in their various capacities), its primary role is to build common understanding on the level on thoughts and feelings, free from any pre-convinced ideas and prejudices:

> The exhibition should be curated as to allow each work to be considered in isolation, as well as all considered in combination … Exhibit labels (if used) should not refer to exhibitors' subject specific disciplines, their academic status or seniority, and should provide no information about the research presented. The exhibition should be made open and accessible to all the defined project's stakeholders, including researchers, funders, policy makers, and the general

> public. Visitors (including the exhibiting researchers themselves) should be encouraged to explore the exhibition with an open mind and reflect upon their spontaneous thoughts and feelings regarding the individual works and the combination [4].

When principal actors in communication have connected on an emotional level, they are then best disposed to discuss the wider context in which research is being undertaken (Step 2), and only after that, they are best disposed to engage in a labour intensive and technical discussion regarding the scope of future collaboration (Step 3). These things can take place within the same exhibition environment, and over the same time period, but it is only when they are in this sequence, that the process will achieve its desired results. Also, different principal actors will be required to progress through different numbers of steps. For Beneficiaries, Step 1 may be enough, being inspired, challenged, provoked or otherwise by the works presented to them. For many Specialists, Step 2 will be enough, understanding their peers' motivations and objectives, and only for those Specialists committed to working closely together (in virtue of what they have learned through Steps 1 and 2), are the challenges of getting to know the technical details of one another's practice (Step 3) required.

Show-Talk-Do was developed with a focus on interdisciplinary research. However, this structure is applicable to communication in interdisciplinary contexts more broadly. It provides a simple conceptual model concerned with communication, considering the exhibition as a communication tool alongside all others, and provides a helpful foundation for assessing the potential impact of the exhibition to bring about particular outcomes in particular circumstances, well aligned with the interdisciplinary communication challenges that have been identified.

3.7 Conclusions

This work has sought to establish what role, if any, the exhibition had in overcoming interdisciplinary communication challenges.

The adoption of a conceptual model of communication identified that the challenges that arise can be grouped in terms of accuracy, precision and impact. Through discussion with those with lived experience of these challenges, eight outcomes were identified which the ideal interdisciplinary communication tool would be able to tackle. The general ways in which the exhibition is well placed to meet these outcomes were identified. The adoption of the Show-Talk-Do Model enabled discussion on where these impacts might be most greatly felt, and how.

Therefore, the exhibition, by virtue of its open, creative and engaging nature, its simple means of communicating messages and its situation at the nexus of many audiences, does have an important role to play in overcoming interdisciplinary communication challenges. It is likely to be especially significant when:

- The actors engaged in communication are large in number and diverse in nature.
- The messages being communicated are broad, qualitative and contingent on an 'emotional/experiential' understanding.

- The messages to be communicated are numerous and communicated to many actors simultaneously, each with their own objectives.
- Open and transparent communication amongst and between all actors is desirable.
- The communication process itself is intended to attract and grow its own audience.

The exhibition does not replace other tools. On the contrary, It is most likely to have a major impact when delivered in conjunction with other tools, not only achieving its own ends, but serving as a means to foster higher quality discussions, and ongoing research and partnerships.

However, if the exhibition is to consistently achieve these impacts and optimize its role as an interdisciplinary communication tool, there is still much work to do. We suggest the following three next steps are now required.

(i) **Better conceptual models**

The more mature the conceptual models, and the more articulate they can become at describing how exhibitions bring about their effects, the more useful they will become to the curators and other stakeholders in those exhibitions. Show-Talk-Do is a helpful start point, not an end. A sign of progress will be when it is rigorously scrutinized, refined and ultimately replaced, with better, more powerful models.

(ii) **Greater exhibition infrastructure**

It must become easier for those who want to use exhibition as a communication tool, to do so. Often, such tools are used not because they are the best option, but because they are the available option. Art and educational institutions, curators and research funders all have a responsibility to make exhibition an option: offering the expertise, guidance, facilities, resources and finance that are required to do exhibition well, and reap the just rewards.

(iii) **Leadership**

For exhibitions to be considered an essential communication tool, occupying the same status as a research paper or seminar in professional communication, it will require a shift in mind-set amongst the interdisciplinary community, and leaders from within that community to initiate change. Early adopters will face the biggest challenge, but each exhibition delivered will make the next one easier to deliver, and the impacts should follow closely behind.

If these challenges are met, there is no reason why the exhibition should not be the mainstay of 21st communication practice in the age of the interdisciplinarian.

Acknowledgements The authors wish to thank all those who shared their time and expertise to contribute to this chapter, most notably those we interviewed: Tal Stokes, Jessica Lloyd Jones, Rob Ashelford, Bryony Benge Abbott, and Jamie Harris.

References

1. Derrick, E., Falk-Krzesinski, H., Roberts, M.: Facilitating Interdisciplinary Research and Education: A Practical Guide. American Association for the Advancement of Science and the Colorado Initiative in Molecular Biology of the University of Colorado (2012) [online] Available at: http://researchdevelopment.byu.edu/wp-content/uploads/2012/12/Full_Report_Creating_Interdisciplinary_Science.pdf. Accessed 23 June 2019
2. National Academies.: Committee on Facilitating Interdisciplinary Research, Committee on Science, Engineering, and Public Policy. Facilitating Interdisciplinary Research. National Academy Press. p. 2 (2004)
3. Shannon, C.A.: Mathematical theory of communication. Bell Syst. Tech. J. **27** (July and October), 379–423, pp. 623 656, (1948). Available at: http://math.harvard.edu/~ctm/home/text/others/shannon/entropy/entropy.pdf. Accessed 5 March 2018
4. Liggett, S., Corcoran, M.: Interdisciplinary research unmasked: a new curatorial model for multi-audience engagement. Stud. Vis. Arts Commun.: Int. J. **5**(1) (2018) online ISSN 2393-1221
5. Derrick, E., Falk-Krzesinski, H., Roberts, M.: Facilitating interdisciplinary research and education: a practical guide. In: American Association for the Advancement of Science and the Colorado Initiative in Molecular Biology of the University of Colorado (2012). [online] Available at: http://researchdevelopment.byu.edu/wp-content/uploads/2012/12/Full_Report_Creating_Interdisciplinary_Science.pdf. Accessed 23 June 2019
6. Snow, C.P.: The Two Cultures, p. 3. Cambridge University Press, London (1959, 2001)
7. Cambridge English Dictionary.: Exhibition (2019). [Online] Available at: https://dictionary.cambridge.org/dictionary/english/exhibition. Accessed 05 July 2019

Chapter 4
Modern Communication Technologies and the Marxist Understanding of Scientific Cognition

Naira Danielyan

Abstract The bicentenary of the birth of Karl Marx occurred recently (2018). It is thus apposite and insightful to reconsider his theories that relate to modern developments in the field of communications technology. Marxism proposed the view that the basis of the human-specific attitude to the world is focused on practical activity directed to the transformation of natural and social objective reality. Scientific results focus on natural and social objects and processes and this blends into science-based technologies, interacting and being changed by humans who realize some objective or social activity. Communication practice is connected with definite forms of worldview and a definite level of cognition, which reflects practical achievements and promotes their further reproduction and perfection. According to Marx, primacy of practice means that the efficacy of its real influence on nature, society, and personality is a characteristic of the development of a subject's cognitive activity. It is concluded that Marxism's achievement is the development of the scheme: object—objective—practical activity—subject as the foundation of scientific cognition and the criterion for the correspondence between knowledge and reality. Nowadays this scheme is taken as primary while constructing and understanding communication technologies, considered as a special form of practice: this implies the dialectic unity of material artifacts on the one hand and human skills and experience on the other hand.

Keywords Co-construction · Cognition · Communication technology · Marx · Marxism · Object · Practice · Subject · Technical activity · Trans-humanism

4.1 Introduction

Humans interact with the environment in varying degrees, ranging from passivity to aggressive pursuit of possibilities to transform it actively. Active transformation can be seen as being driven by the process of personal development as a social being

N. Danielyan (✉)
Philosophy, Sociology and Political Science Department, National Research University of Electronic Technology, Moscow, Russian Federation
e-mail: vend22@yandex.ru

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_4

in the system of material and spiritual culture. The bicentenary of the birth of Karl Marx took place in 2018, and his ideas and theories still have plausibility, credibility, and relevance as tools to analyze and extrapolate from the situation today. Thus, it is relevant to consider their implications and application to the most transformative technologies of the present day.

Marx considered man's practical activity as the background of his specific attitude to the world (both natural and social). He wrote in "Economic and Philosophic Manuscripts of 1844" that man is not a product of circumstances and upbringing and we should not consider our mind as a passive sensation recipient. According to him, nature is a "*man's inorganic body with which he must remain in continuous intercourse if he is not to die*" [1, p. 87]. While transforming the world, man creates both a new reality and new conditions of his existence that are not given to him in a ready-made form by nature. He also develops and perfects himself, specifically in his creative abilities. Hence, this results in the actual transformation of the physical world, which can be considered as the foundation of other manifestations of original human activity. Marx stresses that man is an "*objective being*" and "*acts objectively*" [1, pp. 92–94]. Further, he defines the way of including man in the natural world and society surrounding him through the active transformation of real objects and phenomena in the process of his praxis. This framework gives some initial guidelines to represent Marx's interpretation of man in all the variety of his relations with the world as a whole.

According to modern epistemological tendencies, the fundamental characteristic of practice as a specific output of man's existence is its openness to objective reality, which always exceeds his abilities to master it. In contrast, there are still limitless human capabilities to develop new ways and means in order to interact with reality. As a result, the basis of the human attitude to the world is the creation of such a system that allows man to construct definite artificial renewable tools and means to influence his reality. He passes these from generation to generation; however, while creating, reproducing, and perfecting this "transformed nature" humanity transforms itself due to the formation and improvement of its appropriate skills and actions.

Marx asserted that the realization of any forms of practical and transformative activity occurs only under conditions of social cooperation [1, p. 95]. It follows that people's attitudes, as subjects of practical activity, to the objective reality that they transform always assume real human relationships as a concomitant. Thus, practice as a philosophical category is formed, reproduced, and developed in the unity of "subject–object" and "subject–subject" relations: it is a manifestation of public activity. A human's self-motivated intellectual evolution in practice is connected with the development of their communication skills and communication culture as necessary preconditions of mastering the external world.

According to the theory of communication, this approach coincides with the information interpretation of the communication process, as can be found in the works of Shannon [2]. Its main characteristic is specific attention to the linear character of communication, i.e., it is an irreversible process. Following the communication paradigm, practices influencing the mass audience intentionally, e.g., mass media, government information, political structures or marketing, are dominant. They have various forms of information-based influencing and techniques for manipulation of human consciousness in their foundations.

Hence, communication practice, as with any others, will be always connected with definite forms of perception of the world and a definite level of cognition, focusing on practical achievements and promotion of their further reproduction and perfection. According to Marx, primacy of practice means that the efficacy of its influence on nature, society, and personality is a characteristic of the development of the subject's cognitive activity [1].

Thus, practice as a specific form of human activity in the world possesses a complex system arrangement. It includes the following:

(1) real transformation of the external environment by artificial tools and instruments (subject–object relations);
(2) communication during this transformation (subject–subject relations);
(3) a complex of norms and values (value and goal-oriented structures) that facilitates the targeted practical activity.

4.2 Modern Epistemology About Subject–Object Relations

Everything that really exists and is external to the subject, can be regarded as an object of cognition. It can be not only an item, but a whole complex or a system, either natural or ideal.

> Any physical thing existing in space and time, any objective and real situation can be considered as an object of cognition. It can be the subject's body, his/her consciousness or personality in general, another person, their consciousness, any cultural items (including books) and their meanings [3, p. 157].

The spectrum of the objects to be studied has significantly widened with time, due to an evolving system of ideals and norms of the cognition process, and this has allowed the discovery of ways to research and master complex, self-regulating systems.

Special attention is currently being paid to discourse as a communication, i.e., verbal communication practice. Alexy [4] separates the following discourse rules, which he identifies as the most important points to understand the rational communication process:

- Any subject who knows a language and is capable of functioning can participate in discourse;
- Any subject can question any assertion;
- Any subject can introduce any assertion into discourse;
- Any subject can express his/her aims, wishes, and necessities.

Such an approach allows the achievement of a consensus due to the overcoming of personal subjective opinions by the participants of a discourse in favor of an agreement motivated rationally. Both language and practices outside of language become important. They generate various forms of communication among discourse participants.

As an example of substituting subject–object relationships by the process of observation, it is useful to consider the ideas of the theory of autopoiesis by Maturana and Varela [5]. According to this theory, a human as "a living system" does not just reflect the world surrounding him/her, but constructs the worldview in correspondence with his/her cognitive, existential, and social sets [5]. As an autopoietic system, a human progresses independently while broadening his/her relations with the world. Accordingly, this leads to the appearance of inner and outer relations that then form his/her personal space.

Autopoietic systems have the following features:

(1) Operational insularity—the self-organization process is possible due to feedback based on the system's inner laws: it is not guided from the outside;
(2) Informational insularity—any outer influence should be transformed into an inner cerebral activity because such a system can respond only to inner activity;
(3) Physical openness—there is an exchange of substances and energy with the environment, and its character is defined by the autopoietic system.

A system's inner state forms the subject's idea of the environment. However, there is always an outer observer who could play the role of the subject observed. In fact, this process of changing observers is limitless as there can be no last observer, i.e., an exclusive observation system does not exist. This means that absolute objective knowledge about the world cannot be achieved. Thus, it is possible to conclude that the achievement of some balance between reality and the result of a subject's cognitive activity is impossible in practice: since a subject constructs his/her worldview, everyone has a personal reality. In this sense, a subject does not feel any boundary between their own experience and their conception of reality. Hence, cognition equates to adaptation: an object exhibits something that is correlated with the subject's cognitive activity.

According to the "observation of the second order" theory of Luhmann, observation can consist of characteristics that create a complex system [6]. Cells, organisms, societies, and systems of artificial intellect are able to play the role of an observer. A second-order observation (or an observation of an observation) is different because of the circumstances of its observation, i.e., depending on whether an observer itself has performed it or someone or something has been observing him/her. According to the theory, an observer cannot see itself, i.e., it is not able to recognize itself during the observation. At the same time, however, another observer can see it. In this case, the object has the ability to see the observer and to see what is being observed. Luhmann defines this process as a second-order observation (auto-reflection concept) and believes that it is these conditions that serve as the foundation of epistemology.

The concept of observation allows us to avoid the traditional epistemological terminology that can be found in Aristotle's works, in particular, the subject–object scheme. For example, it is possible to consider the relationships between a system and its environment while observing the system. "*Countless discrete systems operate* *inside a man as a condition of his life. They define the operations they implement by means of their own structures, despite being dependent on each other*" [6, p. 11]. Thus, this explanation promotes the notion that the world of observation is created in the same way as any other system activities.

Accordingly, the answers to the ontological questions: "what is it?" and "what is its state?" depend on a definite observer, who is restricted by the world of his/her observation. We can say that the observer is similar to some empirical entity that stipulates the selection of him/her as an object by other observers. It is obvious that the subject and the environment in which it acts are interconnected constructively and therefore experience mutual formation in the process of the subject's activity.

It is possible to conclude that nowadays cognition is considered as an active process of a subject's activity. Firstly, cognition is the process of constructing the reality perceived by a subject through his/her cognitive operations, thus explaining why the knowledge that a subject receives, is a construct of the reality rather than of its reflection. According to Apel [7], the subject of perception is now becoming involved in cognitive practice rather actively, as a result of interaction between perception means and objects on the basis of "significant thought". This category requires a symbolic interaction, the nature of which is revealed most strongly in language [7]. There is such a statement in the works of Habermas, where he considers "communicative action": according to him, this helps to overcome a number of antinomies, which have not been overcome by previous concepts of rationality [8].

Thus, the cognition process organizes a subject's inner world model, but it does not solve the problem of how to describe the objective ontological reality. A subject is considered as a part of the world that s/he is going to observe or as a part of some system that is being observed by other observers. Thus, subject and object determine each other reciprocally.

According to the interpretative constructivism theory of Lenk [9, 10], the interpretations connecting cognition and action run through all approaches to the analysis of the world and the subject of cognition: "*Cognition is an action, but action is an interpretation… Hence, cognition is an interpretation. It means the process of cognition uses the results of the interpretation process or, to be exact, manifests itself in them*" [9, p. 18]. Interpretation is not realized only by means of language as it is a more complex process:

> We think we might somehow grasp things immediately by language without taking into consideration that these matters are in reality much more complex. Language developed mainly as an instrument for preparing actions which we use in a similar vein like other means and instruments [10, p. 3].

According to these ideas, any view of reality depends on theoretical concepts, specifically the linguistic models that dominate in the society concerned. They include fundamental ideas, axioms, formal and linguistic instruments, and so on.

> The concepts of how we 'grasp' these 'realities' of different sorts and levels will be one main focus. …methodologically speaking, we need a systematic approach to the processes of how the phenomena of knowledge and (re)cognition, perception, action and meaning can be analyzed from a systematic point of view [10, pp. 4–5].

Hence, interpretation is an activity to create the so-called "mind constructs" which involve both ordinary and scientifically conceptualized structures. This approach allows the making of a model that contains only the aspects relevant to a subject's purposes and its actions. The subject does not care about the model cognized: he/she thinks only of compensating the deviations while trying to achieve the appropriate purpose.

As a result, any perception of reality will depend on theoretical concepts that prevail in the surrounding society, including fundamental ideas, axioms, formal and linguistic tools, etc. Hence, the preconditions to the formulation of modern ideas concerning the possibility of knowing the world are as follows:

1. What a person takes to be the experience of the world does not dictate the concepts which can explain the world.
2. The concepts which can explain the world are products of historically situated interchanges among people.
3. The degree to which a given form of understanding prevails or is sustained across time is dependent on the vicissitudes of social processes (e.g., communication, negotiation, conflict, rhetoric).

According to this new approach, forces and relations of practice co-construct each other. This term, "co-construction", belongs to recent constructivist technology studies, which have rediscovered Marx's idea of social and technical interdependence [11]. Contemporary technology studies offer concepts useful for analyzing these developments and also for identifying what they hide. In this domain, technology is conceived not as a pure product of inventive genius or an application of science, but as a "construction" of social actors. This leaves room for social choice between different designs that have overlapping functions, but better serve one or another social interest. This means that context is not merely external to technology, but actually penetrates its rationality, conveying social requirements into the human practical activity.

According to Sukhodub [12]:

> Rationality in modern conditions serves as a method to develop critical thinking that is able to estimate crisis phenomena and to conceptualize the ways of overcoming them in social, economic, political, cultural and other spheres. It helps to make a conversion from authoritarian ideas that function formally in the society to the dialogic mind that is perceptive to 'Others' experience [12, p. 531].

Thus, it is possible to conclude that modern thinking culture is formed as a transition from the postulating mind, which is based on some sustainable content of ideologies prevailing in the society, to the communicating mind, which is founded on the multiplicity of viewpoints and openness of the rational cognition system.

4.3 Practice as a Unification of Subjective and Objective Reality

Practice is the foundation of all forms of human public activity. Its openness to the external world and its possibility to master new layers of objective reality in the process of practical transformative actions suppose an opportunity for regular development of a subject's practical skills, e.g., his/her creative attitude to reality, or participation in various forms of social life. It leads to regular revision and perfection of the fundamental programs, which form the basis of practice. As a result, all the history of mankind, including material and spiritual culture, can be considered as a process of human creative approaches to nature in the form of new programs of practical activities.

According to Hegel, subjective and objective reality contradict each other at the very beginning of the cognition process, as they constitute opposites. The life process starts with the individual necessity "to remove" objective reality that is opposed to it and, thus, "objectify" itself. This can be achieved through a subject's "violence" to an object [13, p. 824]. It is possible to suppose that practice can be taken as a kind of objectification of a subject. Marx writes: "*as objective activity everywhere in society becomes one of man's essential efforts, all objects become his objectification, realization of his individuality, his objects*" [1, p. 121]. Thus, practice is the unity of objective and subjective aspects of individual activity. It can be represented as a complex net of various acts of object transformations with the "objectification" of a human's essence. Objects from one stage of this activity turn out to be the initial ones for another stage or another activity program.

The structural characteristics of an elementary act of practice can be recognized if the labor process is taken as a pattern. Marx in his work "The Poverty of Philosophy" [14], discussing the cost of labor, reveals its following elements: man with his aims, knowledge, and skills; operations of his rational activity; and objects included in definite interactions in the course of these operations. Paying special attention to the labor object, he considers, that "*labour is qualitatively defined by object and object in its turn is defined by specific labour qualities*" [14, p. 32].

This pattern can be applied to the structure of practical activity and introduced as the unity of subjective (man with his abilities, aims, and rational actions) and objective (production means, initial materials, products of labor from initial materials) aspects of the cognition process. There are various forms of human practical activity: according to Marx, the initial form of practice that lies in the foundation of other kinds and forms of human life activity, in general, is material production as a way of getting material welfare, which, in its turn, becomes the main driving force of social development.

4.4 Technical Activity as a Special Form of Practice

Forming and developing public relationships is also a necessary form of practical transformative activity: it does not influence the environment surrounding a human, but it involves people themselves and their relationships. However, this form of practice is initially connected with the material production practice. According to Marx, "the way of producing material life defines its social, political and spiritual processes in general" [15, p. 7]. Hence, this view proposes that there is a unified practical activity that includes two aspects: man's attitude to nature and his attitude to himself. It is worth noticing that during public interactions these aspects differentiate further and further since, due to the universal character of public activity, the subject can be both pieces of nature undergoing transformation and people whose "properties" change because of their inclusion in various social subsystems interacting in society as an integrated organism. Studying the first possibility, we can conclude that humankind deals with the human influence on nature, but the second postulated subject concerns the "subjective" character of practice as aimed at the transformation of social objects. From this point of view, humans can be considered as both the subject of practical activity and as its object.

The early stages of social development witnessed the unification of subjective and objective aspects of practical activity. As the labor process became more complex, the operations that had been performed by man started to be materialized. They were carried out as a sequence of influences of one tool on another and after that on the object being transformed. Science as a special form of practice, having more narrow social significance than production or social instances, gained an increasing influence in society. It then turned into a direct production power and a means for control of social processes.

Scientific cognition by itself possesses such qualities as a reflection of existing objects and these can be received or reproduced by different forms of practical activity. It also has projective and constructive functions, i.e., it provides knowledge about the objects being mastered during production and during social activity in the future. To check the validity of the knowledge requires a scientific experiment as a special form of practice: as a rule, this is typically based on production opportunities and human social experience within the current stage of development of society, but it overcomes the contemporary level of entities and foresees future technologies and ways of control of social life activity.

4.5 Social and Cultural Perspectives of Communication Technologies

In view of the accelerating pace of technological advancement, it is appropriate to consider ideas about the likely evolutionary paths of technologies that strongly influence society (especially communications technologies) before returning to consideration of the correlations with Marx's concepts.

At first, it is necessary to understand what the term “trans-science” means. It is often used by participants of international philosophical forums and conferences. According to Weinberg, the trans-science period started with the first A-bomb tests in the middle of the twentieth century. It stipulated the shift from researching nuclear power by some scientists to team projects:

> Many of the issues which arise in the course of the interaction between science or technology and society, for example, the deleterious side effects of technology, or the attempts to deal with social problems through the procedures of science – hang on the answers to questions which can be asked of science and yet which cannot be answered by science. I propose the term trans-scientific for these questions… [16, p. 209].

Biological effects of weak radioactive influence on the environment, consequences of applying nanotechnologies to prolong the life expectancy, emergence of virtual reality, creation of artificial intelligence, changes of human ethics under new technological impacts are among such questions.

The main trans-scientific peculiarity is to unite problems from various fields of human knowledge, i.e., it is based on a trans-discipline approach. An outstanding current example is emerging and spreading of the Internet technologies. In comparison with rather rational technological methods, used in the past, modern technologies are able to provide for numerous negative effects due to the availability of mechanisms possessing an opportunity to manipulate the human mentality. Moreover, there has been no comprehensive reflection of their properties so far. So, they might be accepted as the starting point of philosophical deliberations due to the fact that the traditional approach to understanding the technology cannot reflect all the range of arising challenges. As a result, the main question is how all the spectrum of technologies and the social life are changed with penetration of the Internet technologies into absolutely all aspects of human existence.

Scientific knowledge, as viewed from the position of trans-science, is understood as suggesting probable hypotheses, which pass through bifurcation points where the choice of trajectory for further development occurs. This subject of research particularly addresses complex, dynamic systems that include technical, managerial, social, and other levels. Any cognition process turns into a social act, since communication among representatives of different knowledge fields stimulates the emergence of special norms and standards that are not connected with a specific author, but acknowledged as valid by all the scientific community involved in the process. As a result, they become a characteristic of a specific public style of thinking, with a consequential transformation of the communication language, which then acquires a universal character and influences linguistics and linguistic methods. These norms and standards permit cognizance of the complete range of science functions:

- To analyze languages of different knowledge fields.
- To discover “*scientific discourse as a net of communications with their mutual intentionality and inter-reflection*” [17, p. 496].
- To study natural sciences in the context of communicative relations: it is plausible that this view is also correct for social and humanitarian sciences.

However, these models have a number of drawbacks. Their acceleration, the extension of their mobility and flexibility and their reduction of local attachment stimulate the arrival of location-independent micro-societies and new social institutions of global communications that can exchange information globally, e.g., in the form of text messages or, more powerfully, as social media. According to Nasarchuk, "*man becomes a message generator*" [18, p. 69], hence, a message performs a role as the fundamental item of the society, not a human. The whole set of messages, depending on their intention and content, form the lifestyle of a person, a micro-society or a social institution. It does not matter who is a message carrier, because it is the content that gains a dominant significance. This means that its content and its author's (supposed) competence are more important than its sender. Yet, a message and its perception are not always correlated with each other. The example of Internet technologies indicates a conclusion that a sender often knows nothing about his/her message recipient. In turn, the recipient is often not sure that the message has been sent to him/her personally. The recipient thus frequently cannot deduce what should be perceived as the message information as contextualized by some intention, i.e., the objectification of the discussion acquires some fuzziness. Antonovsky and Emelin suggest that "*communication on the society level is still possible, but can't form self-adjusting stable successions of messages*" [19, p. 106], since the knowledge presented loses its discrete boundaries and metamorphoses regularly.

According to the above conceptions, it is possible to highlight the following social and cultural perspectives of trans-humanism predictions under the influence of communication technologies:

- Forming a new lifestyle.
- Presenting a possibility of the phenomenon of "secularized eternity" in the public consciousness as a result of blurring the borders of reality.
- Changing man's life goals due to his rapidly evolving status as creator of natural and social worlds.

Let us consider the final thesis in detail. An active role of cognition is the most important aspect of the application of these concepts to trans-humanism methodology [20]. It supposes the dominance of activity of the mind in all levels of perception, while nonstructured and nonclassified sensor data are absent.

According to the ideas of trans-science [21], modern technologies will provide new opportunities to create artificial intelligence and, as a result, to realize new social forms and psychosocial processes. The website of the Russian Trans-Humanism Society [22] cites some of its "radical possibilities" that could follow from the abovementioned trans-science issues and ways of their realization, such as the following:

- Super intellectual machines.
- Extension of life expectancy significantly.
- Transfer of human consciousness into virtual reality (or brain downloading) and similar.

Trans-humanism manifests itself in three aspects: practical activity; technological achievements and social transformations. Trans-humanism can be considered as a synthesis of discrete doctrines being applied in technological practice, especially in the field of communication technologies. In this conception, a human being is substituted by a virtual existence, i.e., there is the potential elimination of anthropocentrism principles, which were laid in the foundations of traditional humanism and traditional science.

Thus, the exploration of trans-humanism issues needs to be coordinated with the "stable development" conception [23], which can be understood as the necessity of the immediate protection of the environment, on the assumption of further convergence of natural and humanitarian sciences aimed at getting a more comprehensive understanding of a viable forward path. This approach raises a question concerning the boundaries of man's constructive activity, its involvement, and correspondence to the real world. A human being is becoming more and more "technological" with the evolution of communication technologies; however, s/he doesn't stop being sentient: the human, its body and consciousness turn into an integral part of complex eco-, sociocultural, and socio-technical systems [24].

In the context of the developing ecological and humanitarian crisis, the problem of the human future can be considered as a task of preventing the degradation of human and natural systems, achieving co-evolution of science and society, and forming a civilization based on stable evolution by means of searching out sensible answers on topical matters: this correlates with a comprehensive worldview outwith trans-humanism. Communication technologies have a great potential to dominate these issues and define future perspectives of not only science, but the whole of the development of civilization. They can be both production tools and the final product of human fabrication activity. That is why they are becoming more and more important components of the production process, defining its character and content (e.g., "Industry 4.0" [25]). Communication technologies require a range of specific skills from their participants and as a result, imply the dialectic unity of material artifacts on the one hand and human skills and experience on the other hand.

4.6 Extrapolation into the Future

The development and introduction of new technologies have led to the emergence of a new sociocultural reality that raises new ethical issues. They are closely connected with the realization of various projects, e.g., complete description of thinking processes and perception of reality by the human brain; the slowing down of aging processes; the opportunity of human organism rejuvenation; the development of brain/brain or brain/computer interfaces; the creation of robots and other devices possessing at least partial individuality; and similar speculations. Ethical problems arise from the realization of the above projects and the ethical principles that are conventionally followed nowadays will be transformed. Development and penetration of these new technologies will provoke a cultural effect that is likely to see the intensification of some ethical values and the devaluation of others.

For example, the future achievement of neurointerface technology would lead to the unification of human and machine on a qualitatively new level. It could change the level of virtualization of the human mind and social relations. Penetration of virtual technologies into human sensibility will create the situation of "hybrid reality", which could obliterate distinctions between man's virtual personality and his physical localization in a body. However, the current virtual world of social networks, and especially social media, leads to egocentrism and the human's preoccupation with itself and its thoughts: the result of this can be the loss of relationships between the human and reality. For this reason, discussion of change of the spatial conception concerning the physical boundaries of interpersonal communication and identification is very desirable. This change will involve a reconsideration of the human presence in the communication environment: whether it should be treated in both real and virtual forms simultaneously. Such an approach indicates a potential trend toward a completely new phenomenon of human existence: the boundary between real and virtual exists rather clearly nowadays.

Thus, sociocultural perspectives of the current development of communication technologies include the following:

- The evolving appearance of a new lifestyle.
- Introducing a phenomenon of "secularized eternity" in public consciousness;
- Changing the meaning of human life in a substantial way as humans will be able to feel themselves to be creators of their world.

Marx died in 1883. The telephone was invented in 1876, although the practical deployment of the telegraph dates from 1838. Thus Marx was alive at the beginning of near-instantaneous electrical communications, although the means of propagation of ideas most familiar to him would have been printed works: books, newspapers, and broadsheets. Extrapolation of his ideas to the circumstances of the present day must, therefore, be seen in this light. For him, the industry would have meant the making of hardware products and the concept of the "knowledge economy" would have been difficult to embrace: it is significantly different from material production as a way of getting material welfare (see Sect. 4.3, above). On the other hand, Marx's assertion "the way of producing material life defines its social, political and spiritual processes in general" (Sect. 4.4, above) represents a more information-oriented view and his view that the realization of any forms of practical and transformative activity occurs only under conditions of social cooperation (Sect. 4.1, above) correlates closely with modern concepts of social media and co-production of media artifacts.

4.7 Conclusions

The philosophical exploration of social and cultural results of current technological development is becoming more and more topical. Today there is a real necessity to bring out the distinctive features of these technologies and to analyze their impact on social reality. It is also very urgent to consider a new approach to humanism, as still understood traditionally, to clarify transformations of social values and the meaning of human life in the perspective of these developments, to study new cultural stereotypes emerging nowadays under the influence of communication technologies and emerging so-called "virtual reality", social media, and artificial intelligence.

Latour demonstrated the relation between technology and society [26] and the theme of democratization of technology has recently begun to receive the attention it deserves. As Latour has argued, the exclusion of technology from the social scientific concept of society is untenable. But once technology enters the picture, the issue of rationality appears in a new guise. It was Weber who introduced the concept of rationalization to explain many of the processes Marx had earlier identified as central to modernity [27]. Whereas in Marx's works such processes were examined as potentially opposing (capitalist or socialist), Weber argued that they were the same for all modern societies. When there is a strong focus on technologies as there is today, a basis for questioning Weber's simplification emerges again. It is clear that the modern world does not provide a unified view on the question of whether mankind is able to get a single homogeneous outcome to both technological and social development. The traditional practice activities as highlighted by Marx are blurring more and more as there is no sharp division between objective reality and the subjects of practical activity. The scheme "object– objective –practical activity–subject" as the foundation of scientific cognition and the criterion for the correspondence between knowledge and reality introduced by Marx has undergone a number of transformations in modern epistemology. Communication technologies with their new sociocultural reality erase differences between material and nonmaterial, nature and culture, theoretical and practical, etc. [26]. We do not need them anymore as the transition to "hybrid reality" and trans-humanism due to the equal interaction of living objects, social structures, theories or scientific-research programs, etc., generates a network consisting of a number of active elements. Its main characteristic is their collective actions. The coordination of their functioning in the network occurs due to the connections among elements, which makes all components interact.

It is possible to conclude that there is a special meaning in these circumstances for such a form of practice as technical activity in the field of communication, and the analysis of Marx continues to give useful insights. This can be directed to the creation of not only material values and artificial environments, but also thinking, cultural, and cognitive processes.

References

1. Marx, K.: Economic and Philosophic Manuscripts of 1844. Works, Marx, K., Engels, F., vol. 42, pp. 43–174. Publishing House of Political Literature, Moscow (1974) (in Russian). English edition: Prometheus Books, New York (1988)
2. Shannon, C.E.: A mathematical theory of communication. Bell Syst. Tech. J. **27**, 379–423, 623–656, July, October (1948)

3. Lektorsky, V.A.: Classical and Non-classical Epistemology, 256 pp. Editorial URSS, Moscow (2001) (in Russian)
4. Alexy, R.: Legal documentation as rational discourse. Russ. Yearb. Law Theory **1**, 446–456 (2008) (in Russian)
5. Maturana, H., Varela, F.: Der Baum der Erkenntnis: Die biologischen Würzeln des menschlichen Erkennens, 217 pp. Scherz, Bern, München (1987). English edition: The Tree of Knowledge: The Biological Roots of Human Understanding. Shambhala Publications, Boulder, Colorado (1992)
6. Luhmann, N.: Erkenntnis als Konstruktion, 74 pp. Benteli, Bern (1988)
7. Apel, K.-O.: Types of rationality today: the continuum of reason between science and ethics. Rat. Today 307–340 (1979) (Ottawa)
8. Habermas, J.: Aspects of rationality of action. Rat. Today 185–204 (1979) (Ottawa)
9. Lenk, H.: Handlung als Interpretationskonstrukt: Entwurf einer konstituenten und beschreibungstheoretischen Handlungsphilosophie: Handlungstheorien interdisziplinar, pp. 18–317. Karl Alber Verlag, München (1978)
10. Lenk, H.: Grasping Reality: An Interpretation-Realistic Epistemology, 282 pp. World Scientific Publishing Company, Singapore (2003)
11. Feenberg, A.: Marxism and the critique of social rationality: from surplus value to the politics of technology. Camb. J. Econ. **34**(1), 37–49 (2010)
12. Sukhodub, T.D.: Rationality in philosophical tradition and modern culture: the problem of non-incumbency. In: Kiyashchenko, L.P., Stepin, V.S. (eds.) Post-Non-Classics: Philosophy, Science, Culture, pp. 519–538. Publishing House “Mir”, St. Petersburg (2009) (in Russian)
13. Hegel: Science of Logic, 912 pp. Publishing House ACT, Moscow (2018) (in Russian). English edition: Prometheus Books, New York (1991)
14. Marx, K.: The Poverty of Philosophy, 160 pp. Publishing House “Э”, Moscow (2017) (in Russian). English edition: International Publishers Co., New York (1999)
15. Marx, K.: A Contribution to the Critique of Political Economy. Works, Marx, K., Engels, F., vol. 13, pp. 1–167. Publishing House of Political Literature, Moscow (in Russian) (1959). English edition: Lawrence and Wishart, London (1969)
16. Weinberg, A.: Science and trans-science. Minerva **10**, 209–222 (1972)
17. Ogurtsov, A.P.: Philosophy of Science: XXth Century: Concepts and Problems, vol. 1, 744 pp. Publishing House “Mir”, St. Petersburg (in Russian) (2011)
18. Nasarchuk, A.V.: Net society and its philosophical understanding. Russ. Stud. Philos. **7**, 61–75 (2008) (in Russian)
19. Antonovskiy, A.Y., Emelin V.A.: Informational society and the technology of adaptation to its structure. Epistem. Philos. Sci. **XXXI**(1), 90–107 (2012) (in Russian)
20. More, M. Transhumanism: Toward a Futurist Philosophy. Originally published in Extropy #6 (1990, revised 1996). https://www.scribd.com/doc/257580713/Transhumanism-Toward-a-Futurist-Philosophy
21. Danielyan, N.V.: Internet technologies and trans-science: orientation for future. In: RPTSS2017—International Conference on Research Paradigms Transformation in Social Sciences, pp. 246–253. Future Academy, UK (2018). https://doi.org/10.15405/epsbs.2018.02.28/
22. Russian Transhumanist Movement. http://www.transhumanism-russia.ru/
23. Los, V.A., Ursul, A.D.: Stable Development, 254 pp. Publishing House “Agar”, Moscow (2000) (in Russian)
24. Danielyan, N.V.: Scientific Rationality. Publishing House MGOU, Moscow (2010)
25. Lasi, H., Fettke, P., Kemper, H.G., Feld, T., Hoffmann, M.: Industry 4.0. bus. Inf. Syst. Eng. **6**, 239–242 (2014). https://doi.org/10.1007/s12599-014-0334-4
26. Latour, B.: On recalling ANT. In: Law, J., Hassard, J. (eds.) Actor Network Theory and After, pp. 15–26. Blackwell, Oxford (1999)
27. Weber, M.: Gesammelte Aufsätze zur Wissenschaftslehre. Mohr, Tübingen (1968); Wirtschaft und Gesellschaft, Bd. 1. Mohr, Tübingen (1956)

Chapter 5
Use of Digital Holography to Re-Encode and Image Chinese Movable Type Printing

Shuo Wang, Ardeshir Osanlou, and Peter Excell

Abstract In the long history of the development of civilization, Chinese movable type printing has played a pivotal role for disseminating information and it can be seen as the ancestor of the modern information age. From traditional engraving to type, from clay to lead type, from laser printing to 3D holographic printing, the techniques of encoding have been gradually developed and recorded, and these printed texts convey the progress of mankind. A brief introduction to encoding in the context of Chinese cultural communication is presented and, specifically, the role of encoding will be explored. In addition, digital holographic printing is introduced as a new approach and new medium to explore the enlightenment conferred by Chinese movable type printing on today's society and especially the information revolution. Further, the future of encoding through the advanced technology of digital holographic printing is discussed. Two holographic artworks are presented to illustrate the principles expounded and the response to their display in national museums discussed.

Keywords Chinese movable type · Digital holography · Holographic printer · Printing technologies · Textual encoding

5.1 Chinese Movable Type Printing

5.1.1 Introduction to Chinese Movable Type Printing

The invention of Chinese movable type is a remarkable milestone in the history of printing, as it ushered in a new printing era, well before the well-known developments in Europe. Chinese movable type printing has been used for nearly one thousand years and greatly promoted the development and exchange of world culture; in addition,

---

S. Wang
Beijing Institute of Graphic Communication, Beijing 102600, China

A. Osanlou · P. Excell (✉)
Centre for Ultra-Realistic Imaging, Wrexham Glyndŵr University, Wrexham, UK
e-mail: p.excell@glyndwr.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_5

it contributed to the historical progression of world civilization [1]. Movable type involves making individual movable characters in advance, which can then be chosen according to the manuscript, arranged in line on plates and finally printed on paper. All of the movable characters may be used repeatedly, as each of them can be separated and rearranged.

According to historical records from the ancient book MengXiBiTan [1] (see Appendix), Chinese movable type originated in the Qingli period (1041–1048 CE), during the Song Dynasty, with clay movable type characters invented by Bi Sheng (Fig. 5.1) [2]. It should be noted that this was around 400 years before the introduction of movable type in Europe by Gutenberg [3]. Later, with the progress of technology, movable type characters made of wood, tin, lead, copper, and further derivatives appeared [4]. Figure 5.2 shows the Uighur wood movable type examples which were found in cave sediments of the northern Dunhuang area of China in 1908: these were the earliest surviving examples of wood movable type in the world [5].

The invention of Chinese movable type printing enabled the simplification of the process of printing plate creation, reducing labor requirements, and improving production efficiency. However, Chinese movable type printing did not immediately replace engraving-type printing until the Qing Dynasty, when the government began to promote text-based cultural transmission. After this, the number of movable type books greatly increased. Printing techniques also varied, as the Qing government directly organized human labor and material resources to support the development.

Fig. 5.1 Replica of clay movable type characters based on Beisheng's technology, in the Chinese Printing Museum

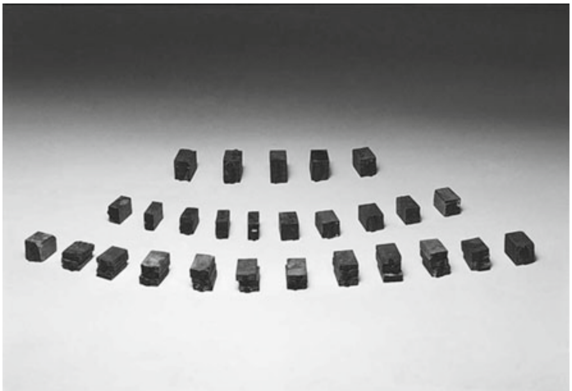

Fig. 5.2 Ughur wood movable type examples, as found in 1908

For instance, during the Yongzheng period in the Qing Dynasty, copper movable type was used to complete as many as 160 million words on the integration of ancient and modern books [6] (Fig. 5.3). Further, in the Qianlong period, wooden movable type was used to print several thousand volumes of the Hall of Martial Valor book [6] (Fig. 5.4). Government participation was central in promoting the application of movable type and cultural communication with other countries.

Today, movable type, embracing many of the ideas of the ancients, still has great value. Its most valuable point is its encapsulation of creative ideas, that is, the transfer of whole-plate engraving printing into individual units, whether phrases or characters. In today's language, this may be called a code, symbol, or material carrier. This idea, in computer typesetting, is widely accepted as a general principle, which drives forward modern printing techniques [5]. Moreover, movable type printing is still popular among Chinese people.

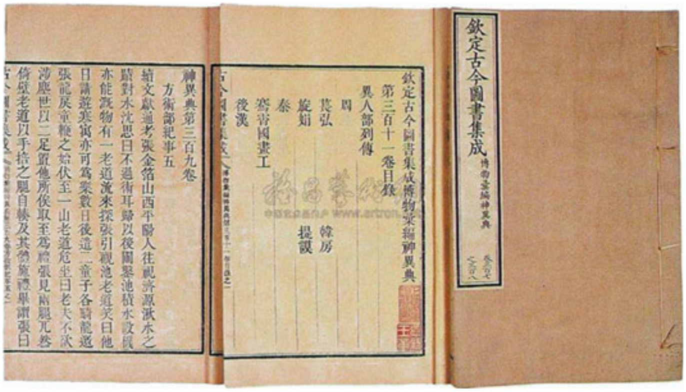

Fig. 5.3 The reference book—Qingding Ancient and Modern Integration

Fig. 5.4 The book—Hall of Martial Valor (Wuyingdian), one of the largest quantity of books produced by wooden movable type printing in China

5.1.2 *The Influence of Chinese Movable Type Technology in the Wider World*

Movable type was introduced into Korea not long after Bi Sheng invented it during the Song Dynasty. The original reason for using such an innovative printing technique in Korea was that Buddhist scriptures and Confucian classics imported from China were in short supply. In the beginning, Korea used ceramic movable type characters, but they were made in different sizes and this led to unsatisfactory printing quality until the Goryeo Dynasty, when copper movable type was gradually developed, which not only enhanced cultural identity between the two countries, but also promoted a new development of Asian culture [7].

After the invention of Chinese movable type printing, Japan adopted the technique, mainly using wooden movable type printing characters to produce Buddhist scriptures for use among monks. A large number of Japanese books were printed, including the Japanese scripts modeled on Chinese cursive script [8]. Movable type printing was a major turning point during the process of social development as it improved the efficiency of mass book production and greatly promoted the dissemination of scientific, technical, and cultural knowledge. The spread of knowledge expanded from the aristocratic classes to the general population [8].

Vietnam commenced the use of movable type around 1841–1847 when the Vietnamese Dynasty bought a pair of Chinese wooden movable type sets and printed a large number of national legal books with it. This can be seen as the direct manifestation of Chinese type printing in Vietnam [7].

Besides Korea, Japan, and Vietnam, Chinese movable type printing also had a great influence on nations in other countries. In particular, Christian books in the Philippines were originally made by the ethnic Chinese people in local printing presses;

however, after 1608, the Filipinos set up their own printing houses. In addition, Iran was a transit station on trade routes, facilitating the introduction of China's printing technology into Europe and hence making great contributions to the westward spread of the technology [6].

Europeans' first contact with Chinese printing began in the Yuan Dynasty (1271–1368 CE), with the paper money brought by European businessmen and travelers returning from China [7]. Around 1450, A German inventor, Johannes Gutenberg, derived inspiration for a form of movable type printing from the technology of wine pressing machines [3]. Although this was more than four hundred years after Bi Sheng's invention, the European movable type printing techniques introduced significant progress in the use of fatty ink, movable type made of lead, etc. Its mechanical printing technology laid the foundation for modern printing. These machines greatly increased the speed of production and promoted the formation and dissemination of new ideas: this became the driving force of modern civilization, and advanced the modernization of European society.

5.2 Encoding in the Context of Chinese Cultural Communication

5.2.1 Re-Definition of Encoding Concepts

Encoding in semiotics can be interpreted as the process of creating a message transmission from an addresser to an addressee [9]; in psychology, encoding can be interpreted as the process of entering the memory system, storing, and subsequently retrieving [10]; in computers, encoding can be interpreted as the process of efficiently transferring or storing a sequence of characters (letters, numbers, punctuation, and symbols) into a professional format. In the book "Encoding and Decoding in the Context of Television Discourse," by contemporary cultural researcher Stuart Hall, encoding is interpreted as meaning production of a media message and this plays an important part in cultural communication, and similar processes [11]. Based on these concepts, encoding is a specific process and has different definitions in different discipline areas.

The present work attempted to identify the encoding of movable type printing in the context of Chinese cultural communication, hence encoding is defined for the present purpose as a transferring process from one role to another during the historical development of China's movable type printing. In a physical view, movable type printing breaks the earlier whole-plate engraving printing into individual units and this may happen during the processes of deconstructing phrases or words. In the psychological view, movable type printing evolves from transmitter to protector of information (in cultural context), and from protector to inheritor.

5.2.2 *The Role of Enlightenment*

The appearance of words can be regarded as the gestation phase of encoding. The invention of words was a great advancement for human civilization. In primitive ages in China, humans tied a number of different knots or different shapes of knots on ropes to express specific meanings: the so-called knot note (Fig. 5.5). Afterward, ancient humans portrayed certain things on stones and stone walls to convey certain meanings. This kind of pictogram directly gave birth to the origin of human writing: the archeological discoveries of ancient Egyptian hieroglyphic characters, Sumerian cuneiform characters, Chinese characters, and similar are all such.

Chinese characters have a long history, but the exact time of their emergence is still a historical mystery [5]. Judging from the archeological findings, the Oracle script system was fully developed in the Shang Dynasty, around 3500 years ago. Chinese characters are ideograms whose form and meaning are closely connected. Early characters were of pictographic form: with such a glyph, people could easily know what it stood for.

The usage of Chinese characters is closely linked with their transmission medium, but there were some limitations for expedient information transmission [12], for instance, scattered oracle bones were composed of animal bones with engraved symbols (Fig. 5.6); bronze inscriptions were heavy and difficult to move (Fig. 5.7); the words on bamboo slips were hard to modify (Fig. 5.8); silk as a writing substrate was expensive and susceptible to be eaten by insects (Fig. 5.9). The invention of paper was convenient for text recording, but it was not able to change the transmission mode of manual copying and thus still constrained the efficiency of transmission. Until the invention of whole-plate engraving printing, information could not be spread widely. Compared with manual copying, engraving printing had great advantages in saving time and improving efficiency, but it also had shortcomings: it was very costly as each version of the text required creation of a new set of plates. However, with the invention of movable type printing, whole-plate engraving printing was divided

Fig. 5.5 An example display of a knot note

Fig. 5.6 Oracle bone with inscription in the China Printing Museum (late 2nd millennium BCE)

Fig. 5.7 Bronze tripod bowl cast for Duke Mao during the King Xuan period of the western Zhou Dynasty (828 BC–782 BCE): the vessel has 497 characters in 32 lines. (China Printing Museum display)

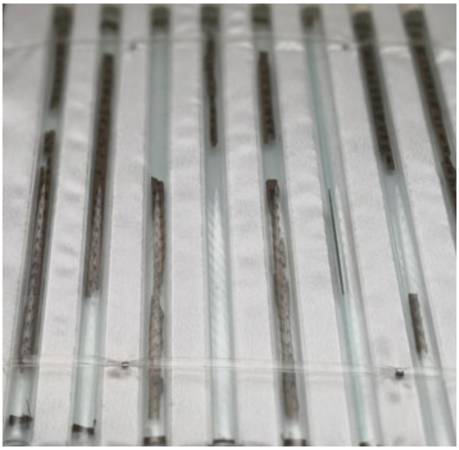

Fig. 5.8 Words on bamboo slips in China Printing Museum (140–110 BCE)

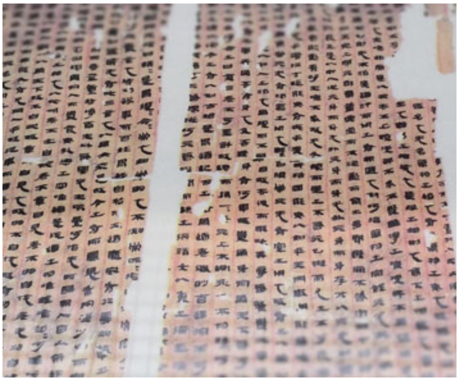

Fig. 5.9 Lao Zi silk manuscripts in the China Printing Museum, dated around 2000 years ago

into separate re-usable units, overcoming many of the above problems and starting widespread information transmission.

5.2.3 The Role of Encoding

With the development of information dissemination, the role of encoding evolved from transmitter to protector then to inheritor, or in a global view it can be considered as a navigator, directed toward civilization.

Whether as whole-plate engraving or movable type printing, the most obvious role at the beginning is as the information transmitter. In this process, information is transferred from one form or format to another. It is also a medium for a communicator to translate its message or meaning into languages, images, symbols, and so on. In view of relationship between language and literacy, printing provides a platform for converting spoken language into written language, which promotes the development of language, especially the development of written language in the Chinese literary and grammar frameworks. Considering the relationship between written language and communication efficiency, movable type printing provides an acceleration effect, and a new language experience can be built on its platform. This process of evolution with experience is also a role of the transmitter. In other words, the transmitter influences the efficiency improvement between language and literacy.

If the transmitter only transmits information and lacks cultural connotation, it cannot assist in advancing human civilization. Therefore, during the encoding process, the dominant role is held by the transmitter while the recessive role is that of the culture protector. In ancient times, the advancement derived from printing could be identified with history, religion, politics, military matters, and many other issues where printing had important historical and cultural values. The role of protector is crucial in the transfer process, for instance there are still preserved the Vajra cchedikā Prajñā Pāramitā (in English: The Diamond Sutra) (Fig. 5.10) based on engraving printing. This was made in the Tang Dynasty (868 CE), while the encyclopedia MengXiBiTan [1] (see Appendix), based on movable type printing, was written in the Northern Song Dynasty (written c. 1086–1093 CE) [6]. There can be little doubt that the ancient imperial system also contributed in establishing special rules and orders for specific cultural preservation.

Protection aims at re-dissemination and then assured inheritance. As the foundation of modern printing, movable type printing is the basis of pre-digital era printing technology (digital printing can be argued to be closely connected—see Sect. 3.1).

Fig. 5.10 Vajra Cchedikā Prajñā Pāramitā (The Diamond Sutra), printed in the Tang dynasty: this is a well-preserved piece with the name of the carving master and the year of carving (868 CE), it was discovered in the cave of Dunhuang in 1900. The picture on display is of a replica

Fig. 5.11 Brush pressing by a local craftsman onto wooden movable printing type in the Rui'an area of Zhejiang Province

Here, another role of encoding is linked to deep ethnic cultural conventions. For instance, wood type printing was derived from the custom of renewing genealogy records, especially in the southern part of Zhejiang Province, China: the clan concept of root-seeking remains quite strong there. Every clan's family tree is renewed every 12 years or so. Figure 5.11 shows the use of wooden movable type printing in the Rui'an area of Zhejiang Province. In the wider view of communication theory, the expansion of social and cultural communication has promoted the popularization of education and the exchange of knowledge. Additionally, mass production of printed books increases the chances of book retention, reduces the possibility of handwritten copies becoming extinct due to limited collections, and has a huge positive influence on cultural heritage.

Looking at the role of movable type printing in the history of civilization, it has always guided humans toward civilized societies. As a driver of social progress, movable type printing has effects on almost every aspect of modern civilization. Due to its roles as transmitter, protector, and inheritor, new ideas are quickly disseminated and popularized, and speculative thoughts are promoted.

5.3 Digital Holographic Printing

5.3.1 Modern Digital Printing

The rise of computer-mediated printing has caused a radical change in printing technologies, although this did not happen immediately. For many years the standard computer printers were the line printer and the electric typewriter, both of which used metallic characters of a similar form to movable type, although not assembled in the same way as in a printing press: the daisy wheel printer can be said to be similar. Toward the end of the twentieth century, however, raster-based printers (e.g., laser and inkjet) became common and now totally dominate the market. These do not use hardware type characters in the same way as the earlier technologies, but the philosophical difference is not so great, since they store a vast range of characters in software, made available to the user as “fonts”, exactly mimicking the jargon of the traditional movable type printing technician. The fundamental point here is that human readers have become completely attuned to the use of discrete characters, as established by movable type, and the raster-based systems have to display text in the same way for it to be meaningful.

A more radical difference with this technology is the ease of inclusion of illustrations, as these can be printed with exactly the same raster technology.

5.3.2 Digital Holographic Printing

Holograms can represent objects and scenes in three dimensions without the need for special viewing glasses. Computer-generated or computer-mediated holograms are intrinsically digital and hence also have a raster structure, but in three dimensions, hence the two-dimensional raster pixels are replaced by three-dimensional voxels in the software. However, the hologram is a two-dimensional object which contains the three-dimensional information. This means that a different implementation of raster pixels is required. Thus digital holographic printing is composed of a matrix of holographic pixels, also termed holopixels or hogels. Holopixels are created by the interference of three-color lasers in a holographic medium, such as a photopolymer or silver halide film.

A digital printed hologram can visually represent an object in a realistic way and it also can be a creative medium to re-interpret the object in a narrative way. In addition, digital holograms can be duplicated repeatedly through a digital holographic printer.

A digital holographic printer includes several components, such as the data source, tri-color lasers, a spatial light modulator (SLM), beam-steering optics, and a computer to show the images on the SLM and to control the whole system. The data sources should include a selection of resources, such as general artwork and illustrations, photographs taken by people, or digital imagery produced by software such as Maya, Sketch-up, 3D Studio Max, point clouds, and laser scans. The laser-writing scheme utilizes an object and reference beam pair. The object beam is modulated through the SLM using two-dimensional (2D) information synthesized from a scene.

Digital holographic printing as an artistic medium has been practically developed and applied in cultural presentations. For example, Fig. 5.12 shows a holographic artwork created by author Shuo Wang: in this artwork, the digital printed hologram, as an innovative medium, not only enables the viewer to recover an archeological excavation space as it appeared in 1980, and to have a realistic spatial visualization of it, but also the losses of archeological detail owing to the difficulties of conditions

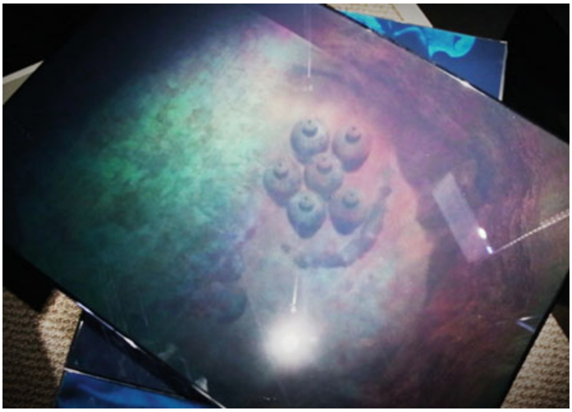

Fig. 5.12 Digital holographic artwork representing a reconstruction of an archeological scene, by Shuo Wang

at that time could be bridged, bringing a profound influence upon archeological, historical, geological, and artistic representation of the priceless cultural relics that were recovered [12].

5.3.3 *The Evolution of Chinese Movable Type Printing to Digital Holographic Printing*

Understanding the past is an essential component for projecting developments in the future. Chinese movable type printing has developed in the course of its historical changes. The process has been complex and diverse with both positive and negative aspects, which are closely related to the social system, philosophies, aesthetics, and humanity of Chinese society in the context of historical development at the time [13]. With the initiation of the modern information age, the rise of digital holographic printing also needs to be explored in the context of today. Since the development of digital holographic printing and movable type printing occurred in very different historical periods, it is hard to compare them. However, if they are regarded as transmission media and linked in their aspect as information carriers with their respective medium characteristics, then they appear to have some similarities in particular periods in their history. Thus, some comparisons and suggestions of similarities may be attempted:

On the positive side:

1. They both are carriers of information, that is, media.
2. In different historical periods, both movable type printing and digital holographic printing have provided a new information dissemination platform for societies and have promoted language development globally. Compared to movable type

printing, digital holography carries more information or data and has the potential for the inclusion of highly realistic graphics.

3. Both movable type printing and digital holographic printing have opened up a new mode of information transmission in their respective times. With the development of movable type printing, efficient replication using various materials has been created; digital holographic printing will also replicate with more materials in the future, not be limited to glass and photopolymer, but the digital generation of characters gives infinite scope to replicate not only the entire Chinese alphabet, but characters from other languages, mathematical symbols and new, fictitious, creations.

On the negative side, neither of them has had a great speed of popularization. Chinese movable type printing was invented in the Song Dynasty but it was not widely used to replace engraving printing, which required intensive labor [4]. Currently, digital holographic printing is not widely used either. The main reasons are as follows:

1. From the perspective of aesthetics, Chinese scholars advocated the beauty of carving, so, movable type printing was not rapidly developed after engraving printing [14]. Similarly, the digital printed hologram is not at present as realistic as the traditional analogue hologram, and it cannot provide the same beauty and verisimilitude. This deficiency is expected to disappear as holopixel resolution increases.
2. From the perspective of the development period, after the invention of engraving printing, people constantly improved its technology. In the Song Dynasty, it was the golden era of engraving printing when Bi Sheng invented movable type printing [1]. Digital holographic printing also seems to have its rival technologies, such as head-mounted virtual reality displays, but the usage scenarios for these are very different.
3. From the perspective of economics, due to the features of Chinese characters, it is difficult for ordinary people to invest in the necessary labor and material resources (excepting the very wealthy) as it is very costly for one-time use. Before the emergence of movable type printing, there were numerous engraving workers. Because of that, the cost of engraving printing was lowered, but the cost of movable type printing was effectively increased. At present, it costs a great deal in time and money to produce a digital printed hologram, and digital holographic printers are at present very rare.
4. From the perspective of media-use habits, after movable type printing was invented, handwritten and engraved books were still generally used at that time. Now digital color printers and 3D display monitors are also competitors for digital holographic printing.

5.4 The Exploration of Encoding in the Future

The encoding of digital holographic printing can be seen as paralleled by movable type printing in some cases. In view of the medium features and advanced applications, digital holographic printing will also experience the roles of transmitter, protector, and inheritor. However, due to the rapid growth of information and the diversification of information media, digital holographic encoding ideally needs to be combined with artificial intelligence, so as to optimize it. For example, throughout the whole process of digital holographic modeling, this process can be performed with a large number of databases based on people's creative ideas, functioning as a replacement of manual modeling, improving the models, material, lighting, rendering and other steps, and designing the frame narrative through smart thinking. During the printing process, smart devices can hasten transmission speed, shorten printing time, and achieve efficient replication.

5.5 Artistic Works

5.5.1 Three Manifestations of a Chinese Movable Type Text

Based on the research on encoding of movable type printing, as well as the relationship between movable type printing and holographic printing from the perspective of media analysis, an artwork entitled "CUBES" was created to further explore the different roles in the future. The name "CUBES" involves two levels of significance: the straightforward meaning is descriptive of the artwork represented by different pieces in the form of small cubes; secondly, CUBES is an acronym, meaning "CUlture Broadly Encoding Spreading". The work was reproduced in the form of collocated wooden movable type, 3D printed movable type and holographic movable type, and the record of movable type printing in MengXiBiTan [1] was taken as the content (see Appendix). This follows the philosophy of the four "RE" creation methods (Re-definition, Re-creation, Re-construction, and Re-presentation) devized by author Shuo Wang [12], as well as holographic montage ideas. Each individual text component has been created in the 3D software: initially, the length, width, and height of the components have been calculated based on the wooden texts; furthermore, the polygonal modeling method follows the style of Chinese wooden engraving and the corresponding writing style, Fig. 5.13 shows holographic modeling of the content of MengXiBiTan and Fig. 5.14 shows the holographic rendering result, which simulates the effect of Chinese wooden engraving.

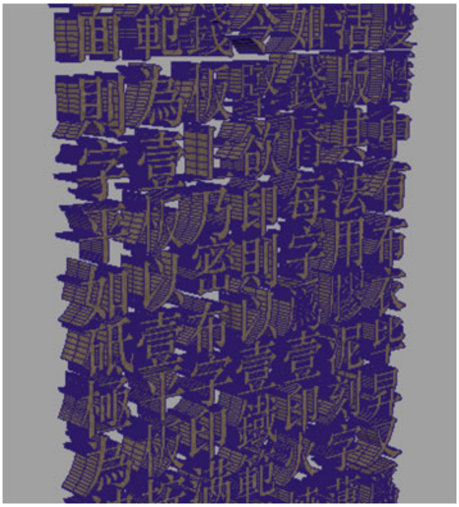

Fig. 5.13 The "CUBES" artwork: holographic modeling in Maya

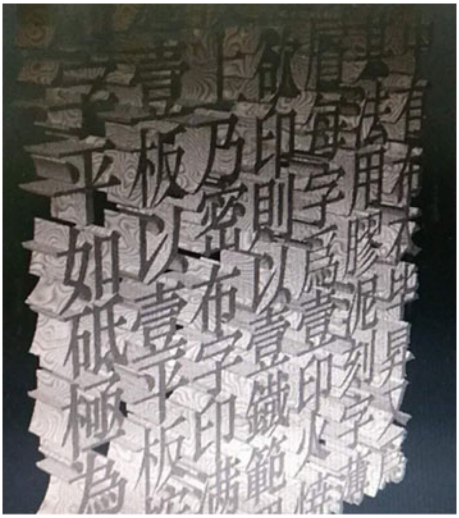

Fig. 5.14 The "CUBES" artwork: rendering effect in Maya

5.5.2 Four Manifestations of Chinese Movable Type in a Hybrid Timeline

This artwork (Figs. 5.15 and 5.16) explores the different roles in the context of encoding. In addition, digital holographic printing was used as a new approach and

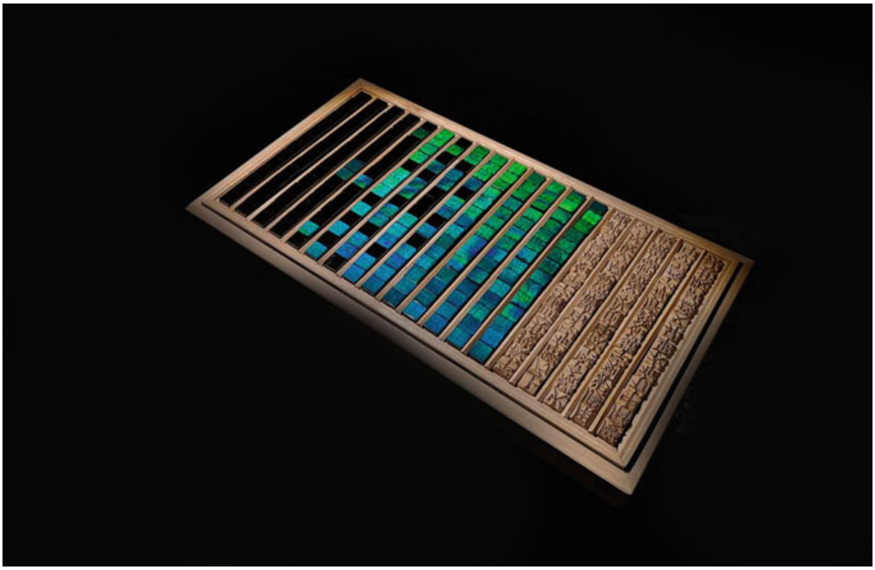

Fig. 5.15 Artwork: Hybrid Plate as a timeline

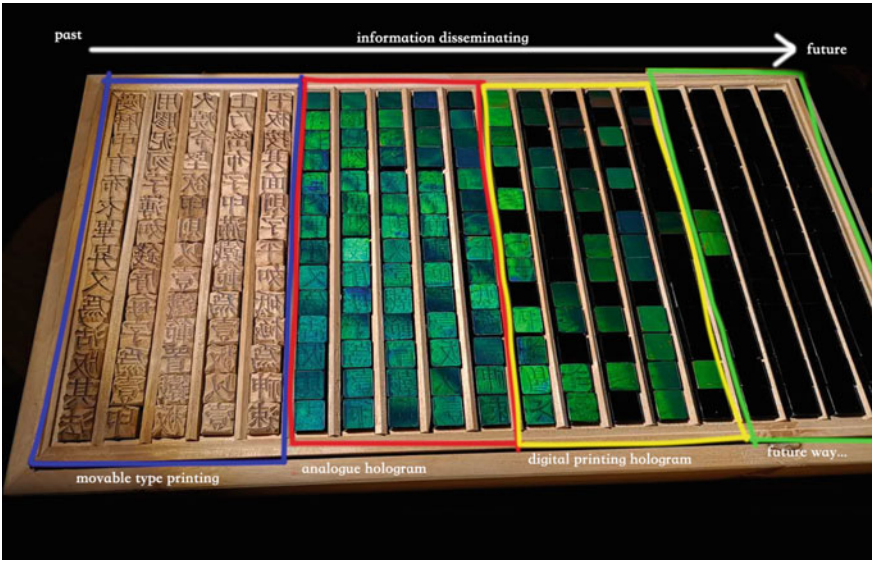

Fig. 5.16 Interpretation of this artwork

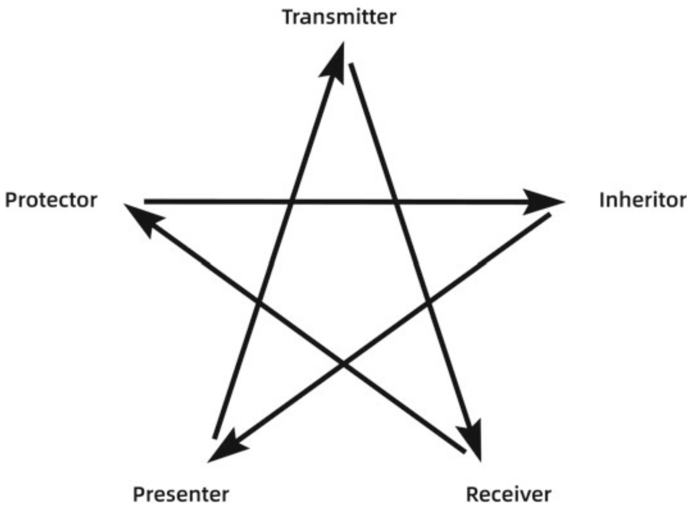

Fig. 5.17 The psychological and philosophical view of encoding

new medium to explore the enlightenment conferred by Chinese movable type printing on today's information revolution. This artwork consisted of a wooden plate and 266 individual blocks, including wooden movable type blocks, analogue holographic blocks, digital holographic blocks, and black blocks, these four parts (Fig. 5.2) briefly present a timeline of the information dissemination from ancient times to the future.

In creating this work, the author Wang assumed two roles/identities in the creation process: information receiver and information presenter. Furthermore, he attempted to explore the relationships among transmitter, receiver, presenter, protector, and inheritor to address the psychological and philosophical views of encoding (Fig. 5.17).

Considered as a receiver, the information received was drawn from the content of the "Ancient Chinese Wikipedia"—MengXiBiTan [1], In the process of receiving the information, the whole content has been summarized into 70 characters, and the these characters have been engraved into wooden blocks, based on the traditional method of Chinese wooden engraving: this aims to present the ancient method of information transmission for audiences.

Considered as a presenter, two approaches have been explored, based on the medium characteristics of analogue holography and digital printing holography. Initially, the 70 characters were produced using a Holo-Camera (Fig. 5.18): these holographic blocks can be seen as one of the modes of protection for wooden blocks (via substitution, since the 70 wooden blocks are considered as heritage objects); additionally, they can encapsulate the moment of creation of the wooden blocks, which provides a spatial view for audiences.

As a further insight, in the process of the digital holographic modeling, other spatial aspects of the characters can be discerned, as well as the opportunity to re-interpret the character in a narrative way. In this artwork, when each character was

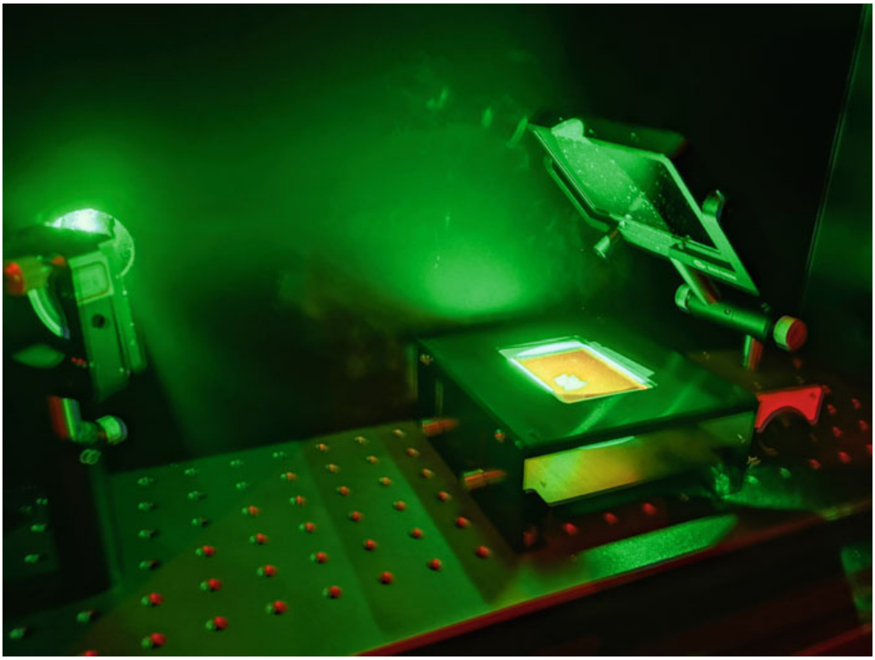

Fig. 5.18 Using a Holo-Camera to produce the analogue hologram

in the processing of being created, the structure revealed a layer of new meaning and spirit.

In such an era, facilitating the production of the hybrid printing plates, each individual block carries different dimensions of time and space, from the ancient wooden type block to the latest digital holographic blocks. Thus technology, medium, and culture have been developing together: they act the different roles in the process of information dissemination. Hence the development of printing technology and culture has always been developing in a synergistic way.

5.6 Conclusions

The historical development of Chinese movable type printing has been reviewed and its influence on the World's culture emphasized. The encoding of movable type printing has been explored and this expanded to include the evolution of Chinese movable type printing to digital holographic printing, including reinterpretations of the concept of encoding. Art works have been presented that demonstrate the coexistence of ancient movable type printing and modern digital holographic printing and the insights that can be drawn from this. The power of the holographic image has been demonstrated since, when the artwork was illuminated by the appropriate light source, virtual (holographic) character cubes, and real character cubes were combined together, thus presenting a new form of encoded space within the culture of human communication. In addition, the artwork reflects the passage of thousands of years of historical space and time, linked through the continuity of Chinese characters. The re-encoding of Chinese movable type printing reveals that this printing technology continues to develop from the past to the future—in digital holographic forms—with the potential to inform new interpretations of human communication.

Appendix: Records of Movable Type Printing in MengXiBiTan

MengXiBiTan is a book written by Shen Kuo, a scientist in the Northern Song Dynasty. It was written around 1086–1093 (CE) and documented Shen Kuo's views and opinions in his life. It is regarded as an Encyclopedia of ancient China by western scholars, with many foreign language versions published around the world.

In the Tang Dynasty, people had not yet adopted engraving printing to print books on a large scale. In the Five Dynasties (907–960 CE), namely, the Later Liang Dynasty (907–923), the Later Tang Dynasty (923–936), the Later Jin Dynasty (936–946), the Later Han Dynasty (947–950), and the Later Zhou Dynasty (951–960), Feng Dao began to print the Five Classics with the engraving printing technique. After that, various classics and books were printed. During the Qingli period, a civilian named Bi Sheng created movable type printing. His method was to use clay to engrave characters and the thickness of each word was like the edge of copper coins. Each character was a matrix, hardened by firing. Firstly, he set up a piece of iron plate, covering it with turpentine and wax mixed with burnt paper ash. When printing, he put an iron frame on the iron plate, then arranged the word (i.e., character) matrix appropriately and closely. He filled the iron frame as one printing plate, then held it near the fire to bake; when the rosin and other bonding materials began to melt, he pressed the surface with a flat plate. In this way, the pattern on the plate was flat and smooth. If people wanted to print only two or three books, this method would not be convenient; but this method would be particularly efficient for tens or even hundreds of books. Usually two iron plates were produced while printing. One plate was used for printing and the other one for arranging the matrix. As soon as one plate finished printing, the other one would be ready to use. The process was quite fast with two plates. Each word had several matrix elements. For example, the Chinese words "之" and "也" usually had more than twenty matrix elements in case of repetitive characters in one plate. When the words were not used, they would be marked by pronunciations with paper strips. Each rhyme part was marked with a label, then stored in a wooden lattice. If an unfamiliar character was needed but unprepared, people engraved it and then grilled it with a grass fire, hence it could be made very quickly. The reason why people did not use wood to make movable type matrices was that the texture of the wood varied between sparse and dense. Once stained with water, it would expand, and easily got stuck to the frame, making it hard to remove. Thus, clay was a better choice. After the matrix was used, the coating material could be melted by fire. Wiped by hand, the matrix would fall off and not be contaminated by coating material at all. Bi Sheng's matrices were understandably still treasured by his cousins and nephews after his death.

References

1. Shi, Jinbo.: The history of movable type (in Chinese). J. Guyuan Teachers College (Soc. Sci.), 39–40 (2001)
2. Hao, Liu.: Movable Type: The Rebirth of Wood Movable Type—The development and Innovation of Wood Movable Type Under the Modern Aesthetic Demand. Design (J. China Ind. Des. Assoc. Beijing). ISSN 1003-0069. (2016)
3. McLuhan, M.: The Gutenberg Galaxy: The Making of Typographic Man (1st ed.). University of Toronto Press (1962). ISBN 978-0-8020-6041-9
4. Zheng, Yefu.: The origin of movable type printing (in Chinese). Social Sciences of Beijing. ISSN 1002-2054. (2015)
5. Shi, Jinbo.: The history of movable type (in Chinese). J. Guyuan Teachers College (Soc. Sci.), 41 (2001)
6. Shi, Jinbo.: The earliest extant printing products in the world (in Chinese). J. Beijing Lib. (1997)
7. Wang, Xiaoxue.: Review and Reflection on the research of Gutenberg's metal movable type printing (in Chinese). Research on the History of Publishing in China, pp. 59–67 (2016)
8. Xu, Yinong.: The Significance of East Asia Typography in World History (in Chinese). Nanjing: New Century Library (2016)
9. Encoding (semiotics). https://en.wikipedia.org/wiki/Encoding_(semiotics). Last accessed 14 March 2018
10. Encoding. https://www.alleydog.com/glossary/definition.php?term=Encoding. Last accessed 14 March 2018
11. Encoding and Decoding in the Television Discourse: Centre for Cultural Studies. University of Birmingham, UK (1973)
12. Wang, S., Osanlou, A., Excell, P.S.: Case Study: Digital Holography as a Creative Medium to Display and Reinterpret Museum Artifacts, Applied to Chinese Porcelain Masterpieces, Chapter 6. In: Earnshaw, R.A. (eds.) Research and Development in the Academy, Creative Industries and Applications, pp. 65–88. Springer, Cham, Switzerland (2017), ISBN: 978-3-319-54080-1
13. Li, Bin.: Looking for the living fossils of movable type printing. Human. Photogr. 5–10 (2016)
14. Zhu, Qin.: Discussion On the Reason of the Slow Development of Ancient China Printing (in Chinese). China Publishing Update (China News Publishing & Media Group, Beijing), pp. 40–42 (2002)

Part III
Interactions Between the Arts and Data

Chapter 6
The FOREVER-DO *Game*: A Big Data Fishing Expedition

Jill Townsley and Carlo Ferigato

Abstract The FOREVER-DO *Game* is a participatory visual artwork, that takes the form of a relational game and installation. It is one outcome from an art science collaboration supported by the European Commission's Joint Research Centre in Italy. The artwork was developed under the theme of 'Big Data and Identity' it considers the causal chain that our individual and social actions may have as they flow across the interface of the human and the digital network. The work focuses on data flow that has some correspondence with coordination and communication, as identified by Petri Nets theory. Carl Adam Petri introduced the Nets in the 1970s, they are one of the techniques used today for the analysis of Process Data. When data is ordered in time, the causal chains of data are collected in 'processes'. One simple representation of a process net is the 'bucket chain' used to represent two fundamental aspects of data flow: selection and transfer. By using the bucket chain as a platform this project is focussed on a discipline of data where some 'causal flow', possibly represented by nets, has a role in the data analysis game. The resulting artwork encourages the viewer/participant to flow through an installation following a set of rules on a box, their actions coordinate according to the incidence of chance, selection, transfer and the similarity or difference of everyday objects.

Keywords Petri Nets · Coordinated behaviours · Data · Flow · Communication discipline · System · Time · Space · Repetition · Difference · Unfolding · Folding · Selection and transfer · Participation

J. Townsley (✉)
University of Huddersfield, Huddersfield, UK
e-mail: jill@jilltownsley.com

C. Ferigato
European Commission, Joint Research Centre (JRC), Ispra, Italy
e-mail: carlo.ferigato@ec.europa.eu

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_6

6.1 Introduction

> Artistic activity is a game, whose forms, patterns and functions develop and evolve according to periods and social contexts; it is not an immutable essence [1].

The FOREVER-DO *Game* is a socially relational public artwork or happening, in which people flow around a space, moving between a network of coloured doormats, according to a set of instructions printed on a box. This seemingly absurd game activates interactions between players, who meet randomly in space and time. The coordinated nature of the rules-based system dictates the path that the players travel, it is in itself a socially related construct. A construct that rationalises data flow, making visible the hidden nature of all data flowing within our big data systems. The work presents us with a symbiotic relationship between scientific theory and art practice, while also raising questions about socially mediated, rules-based interactions, especially those that cross the physical and digital interface.

The game is positioned within today's digitally networked age, it mirrors the theoretical construct of a 'Bucket Chain' network, a simple form of Petri Net system, proposed by the computer scientist Carl Adam Petri in the 1970s. In theoretical Computer Science, nets are instruments used for the analysis and design of systems, distributed in time and space. The strength of these nets is their explicit representation of fundamental situations of coordination and concurrency among system agents. Agents can be anything: objects, computers and/or human beings.

The first manifestation of this work was played/exhibited during the Milan Digital Week in March 2019, in the *Palazzo dei Giureconsulti*, near the Duomo, in collaboration with the MC3 research group on concurrent systems at the University of Milan Bicocca. The game was repeated in October 2019 for the Resonance III festival, at the European Commission's Joint Research Centre (JRC) in Italy, this time with additional digital visualisations developed through the application of Radio Frequency Identification tracking (RFID). Trackers were placed inside each of the 2,000 boxes used to play the game, the feedback from the trackers was detected by antennas with the data then displayed digitally alongside the installation (Fig. 6.1). It is the first presentation of the FOREVER-DO *Game* in Milan that we discuss here.

The cross-disciplinary collaboration between artist Jill Townsley and computer scientist Carlo Ferigato was important to the way that the artwork has developed. The work was commissioned by SciArt, an art science organisation embedded within the JRC. The JRC is the European Commission's science and knowledge service which employs scientists to carry out research in order to provide independent scientific advice and support to EU policy. The SciArt mission:

> brings together scientists, artists and policy makers to discuss matters of concern from various points of view, not only to the JRC and the European Commission but also more widely to society [2].

Additionally, SciArt set the agenda of 'big data and identity' as the theme for the collaboration, stating:

Fig. 6.1 The FOREVER-DO *Game* (2019 October JRC exhibition) Copyright © J. Townsley 2019

> Big Data have erupted in our daily lives and we want to join the discussion on how to turn Big Data into culture, not leaving it only in the hands of technicians, trolls and corporations. We want to become hackers of our own future. We think it is time we make them ours, these Big Data, this digital transformation, in a vast collective effort open to all [2].

To do this SciArt have proposed a new concept 'DATAMI':

> We see the datami as a virtual tatami [a Japanese mat], made of the data that we cherish, our data and those of our families and friends, our discoveries and curiosities, our roaming and conversations, all of these making up our new identities [3].

This is the theme for the Resonances III Festival and Exhibition held at the JRC in October 2019, and it is within this overarching context that the FOREVER-DO project was formed (Fig. 6.2).

In order to help convey the significance of the FOREVER-DO *Game* we look to the work of art critic and curator Nicolas Bourriaud and his concept of relational aesthetics. This supports the identification of some formal qualities in the artwork especially the interpersonal cooperation that is present within the FOREVER-DO *Game* and the significance of this model of interaction as a creative tool, to critically reflect on

Fig. 6.2 The FOREVER-DO *Game* (2019 October JRC exhibition) Copyright © J. Townsley 2019

society. We also look to the media theorist, critic and philosopher Boris Groys and his writing on ‘flow’. The flow of people and objects within the game is important and Groys helps identify how flow may define moments of temporary happening. Happenings that can have some governance over social interaction, presenting as ‘an event not as a thing’ [4]. Groys’s theory helps us draw some conclusions about the way that the game mediates the viewer/participant in order to highlight the interface of the digital and physical realm, especially in relation to big data operations and to net theory.

Finally, to help us consider how the artworks analogue process interacts with the human digital interface we will be looking not only to Petri Nets theory, (as the inspiration for the way that the game has been developed), but also reading Carl Adam Petri’s writing as a critical tool. Looking specifically at his *Communication Disciplines* delivered as a set of twelve conceptual tools. He proposed them in a lecture in 1976 to support reasoning in communication systems design, and suggested that they could help build the ideal computer system [5]. A system that could enhance human cooperation and overcome some of the many problems he foresaw for a computerised world going forward. Petri’s principal aim was to help realise a computer system whose applications could support humanity to develop its best possible future. It is this call from the 1970s that dovetails so significantly with the concept of DATAMI proposed by the SciArt team and motivates the creation of the FOREVER-DO project.

6.2 A Fishing Expedition—the Method

Meeting within the context of the JRC, and in response to the SciArt theme of Big Data and identity, we (artist Jill Townsley and computer scientist/researcher Carlo Ferigato) realised that 'process' held an important position within both of our working practices. Ferigato's research around the process design of communication systems, specifically systems identified by Petri Nets theory, and Townsley's artwork emphasising the process of the art object, definitive beyond subject and object. The process presented us with common ground to articulate our practices in language that cut across our respective fields, producing a rich dialogue and exchange of creative thinking. It identified important key words beyond the process itself, such as *system, time, space, flow, coordinated behaviour, repetition, difference, unfolding, folding, selection and transfer.*

Through analysing our processes, nets became a key link between the art and science used in our collaboration. Put poetically, we became fishermen casting our nets, to fish across disciplines into the sea of big data sets in order to extract coherent patterns and procedures. We found patterns pertinent to Petri Nets theory, that could be visualised as art. From this, we have developed two symbiotic artworks the FOREVER-DO *Game* and the FOREVER-DO *Infestation.*

While we consider only the FOREVER-DO *Game* here, it is important to know that the placement of boxes within the game became data that has driven another artwork, the FOREVER-DO *Infestation*. The data, gathered from one piece of work flows on to inform the realisation of another. In this way, authorship is shared with every person who has played the game by placing a box on a pile.

While the FOREVER-DO *Project* as a whole (the *Game* and *Infestation*) explores the idea of 'fishing' into data sets, the nets we use are multifariously allegorical. Beyond being a fisherman's tool, the word 'net' has reference to our digital networks, the Internet. Nets are also the title given to the formal computer science tools 'Petri Nets' (as outlined in the introduction). One of Petri's examples, the 'Bucket Chain' is the main source of inspiration for the FOREVER-DO *Project*. It is outlined in some detail in the theoretical context below but is an explanation of the mechanics of the FOREVER-DO *Game*.

6.3 The FOREVER-DO Game—the First 'Catch'

This artwork propels its human participants on a physical journey that mirrors a 'causal flow' of data (Fig. 6.3). The basic idea of causal flow is to understand how factors influence one another. The game seeks to envision the invisible influence between human action and data. As the game is played, a sculptural installation consisting of towers of boxes develops in the gallery space. These box-towers simulate a data pile, presenting a physical object that records the coordinated meetings of each individual who (following a set of instructions on the box) encounters another

Fig. 6.3 The FOREVER-DO Game (2019 October JRC exhibition) Copyright © J. Townsley 2019, included by permission

player at a coloured mat and finds (through random chance) that their boxes contain identical objects.

The mechanics of the game are as follows. In a large room there are placed a set of objects:

- Sixteen coloured doormats, placed randomly around the room, specifically,
  - 4 Yellow,
  - 4 Red,
  - 4 Blue and
  - 4 Black doormats.
- 2,000 boxes (made to hold a ream of A4 paper).
  - 1,000 brown boxes—randomly dispersed through the installation,
  - 1,000 white boxes—randomly dispersed through the installation.
- Each box has instructions (the rules of the game) printed onto the top.
  - There are 6 sets of rules offering slight variations.
  - The 6 sets of rules are randomly distributed (shuffled) throughout the 2000 boxes.
- Each box contains (randomly) one item of mass-produced wooden cutlery:
  - a knife,
  - fork or,
  - spoon.

With this absurd combination of objects, the game is ready to be played.

Visitors to the exhibition are invited to pick up a box and follow the instructions printed on the top (Fig. 6.4). The instructions send people on a journey travelling

Fig. 6.4 Boxes and Instructions Copyright © J. Townsley 2019

through the space from coloured mat to coloured mat. There are 6 sets of instructions, all presenting a different order of coloured mats to visit:

(1) go to the closest BLUE mat;
(2) go to either a RED or to a BLACK mat;
(3) go to another mat that is the same colour as your present one;
(4) go to any YELLOW mat;
(5) repeat forever from rule one above.

Players physically 'flow' through the space of the gallery, moving according to the rules on their box. The brown or white boxes contain an everyday object: a knife, a fork or a spoon. When individuals meet at a mat, they open the box to compare the contents. Depending on the 'local' circumstance around the similarity or difference of those contents, players encounter one of two consequences:

1. They continue to flow around the game:
   - this happens when their compared objects are different (non-repeated)—then the objects are exchanged and the flow continues according to the rules.
2. They stop and exit the game:
   - if the objects are the same (repeated) then players are asked to leave their box and object behind, placed on a tower at the point of coordination.

Fig. 6.5 Players of the game Copyright © J. Townsley 2019, photograph Pierre-Stuart Rostain, included by permission

In this way a 'causal flow' happens, when non-repeated coordination occurs, objects are exchanged and continue their journey, independent of player or box—flowing on, to continue the FOREVER-DO. Alternatively, when repeated coordination occurs (people meeting with the same objects), the flow is halted and boxes build up around the mats. Over time the number of boxes in the towers gather randomly around the mats, infesting the space and forming a sculptural installation (Fig. 6.5).

The installation makes visible a poetic data trail of coordinated human interactions, recording the incidence of two people meeting at a mat, to find that through random chance, their boxes contain identical objects. The coloured doormats act like nodes in a giant network. Receiving the flow of information as people and boxes move from mat to mat, enabling coordination and a place for human interaction (Fig. 6.6).

As the box-towers grow, data may be extracted from the game in many different ways. The piles of white and brown boxes could be interpreted as binary code. The number of boxes clustered around a coloured doormat also give that mat an integer value. From this data, new digital, conceptual and physical constructs may be developed. Reorganised data is used to form a new sculpture: the FOREVER-DO *Infestation*. Alternatively, a new event or happening could be derived as presented in the FOREVER-DO *Game* 2. In other words, a new fishing expedition can begin (Figs. 6.7 and 6.8).

More generally, the gathering, reorganisation and extraction of information, as presented in the FOREVER-DO *Game*, is indicative of the way data flows today. Data (collected in a myriad of ways) flows forever through our digital systems. Systems and data unimaginably vast in form, yet invisible in time and space. This data can be organised and extracted in whatever way society chooses: it can be reorganised and

Fig. 6.6 Players of the game and the box-towers Copyright © J. Townsley 2019 included by permission

extracted to help us do great things for humanity, such as understand diseases; or it can be used less responsibly, to smartly target us to purchase more mass-produced goods.

6.4 Petri Nets, Communication and the Bucket Chain

The structure of the FOREVER-DO *Game* takes its principles from Petri Nets theory, in experiential and analogue terms it makes visible a form of communication that is happening across the interface of our physical and digital worlds. The installation presents a data trail made from the flow of people around a room, flowing until random instances of coordination happen between players. This has resonance with Petri Nets theory, in its desire to rationalise information flow as a resource in communication.

The history of Petri Nets can be traced back to the Ph.D. thesis of Carl Adam Petri in 1962 [6]. His aim was to establish a new theory of communication-based on two assumptions:

(a) there exists an upper limit on the speed of signals;
(b) there exists an upper limit on the density with which information can be stored.

These assumptions can be considered as natural ones today, but they were not so natural in the 1960s, when the theory of abstract computing machines (automata) was

Fig. 6.7 Image of towers around a mat Copyright © J. Townsley 2019 included by permission

developing rapidly and, sometimes without regard for its potential limits in actual hardware realisations.

As a consequence of these natural assumptions, Petri analysed the subject of 'information flow' in a new way, based on the relations between the structure and behaviour of automata and on the role of information as a resource in communication. In his view, communication becomes an *organised activity* involving automata and people. *Communication with automata*, the title of the thesis, refers precisely to this organised activity where 'with' has the double meaning of 'between automata and people' and 'using automata as communication medium'. Considering automata as *organised communication mediums*, as we do today through the Internet for example, Petri opened the way to new applications of the discipline 'pragmatics', as a branch of linguistics, in view of a modern theory of communication systems [7].

Petri's bucket chain is a simple example of net theory and one way of rationalising data flow. It presents a scenario of coordinated behaviour between firemen extinguishing a fire. Figure 6.9 shows figures coordinating a task to carry water from a tank to a fire, using a chain of buckets.

The sequence in Fig. 6.10 explains how the coordination of behaviour (the figures) and the flow of data (the water from the tank to fire) operate. The theoretical net

Fig. 6.8 Image of towers around a mat Copyright © J. Townsley 2019 included by permission

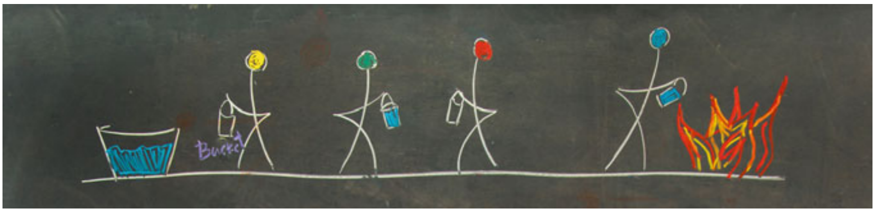

Fig. 6.9 The Bucket Chain (drawing from Ferigato's blackboard, 2019) Copyright © J. Townsley 2019

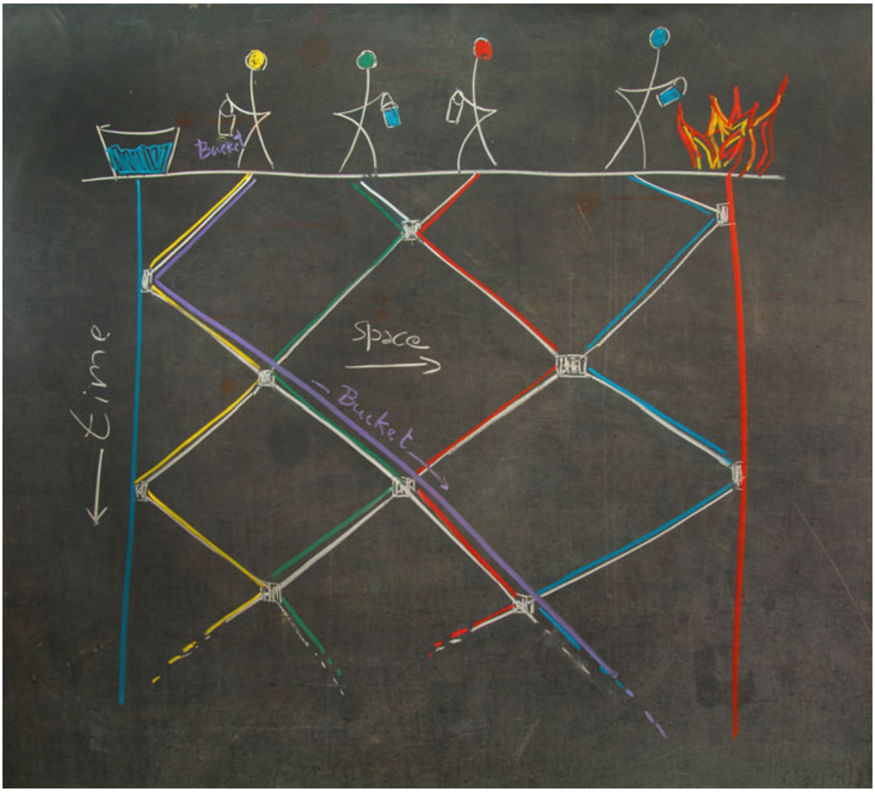

Fig. 6.10 The Bucket Chain and its unfolding in space and time (Ferigato 2018) Copyright © J. Townsley 2019

'unfolds' through time and space to illustrate how the coordination of the figures putting out the fire operates. This is Petri's clever graphical way of explaining simple net theory through the bucket chain scenario.

As the information, in this case, the water in bucket B, flows smoothly from the water tank to fire, it is also possible to see how each fireman moves left and right until they meet to exchange the buckets (Fig. 6.11).

The proposition: '*A walks in the direction right*' can be represented, following the formalism of Petri's Occurrence Nets, by a circle, representing in an abstract space the persistence of the proposition.

Importantly, the truth (or value) of the proposition '*A walks in the direction right*' is changed by the occurrence of events. For example, as in Fig. 6.10, two men walking in opposite directions along the same line will eventually meet at points in space represented as squares in Fig. 6.11. This 'meeting event' changes the respective directions of the two men, as if they were bouncing balls. So, we can represent a chain of firemen extinguishing a fire by carrying back and forth buckets of water in an abstract way, as in Fig. 6.11.

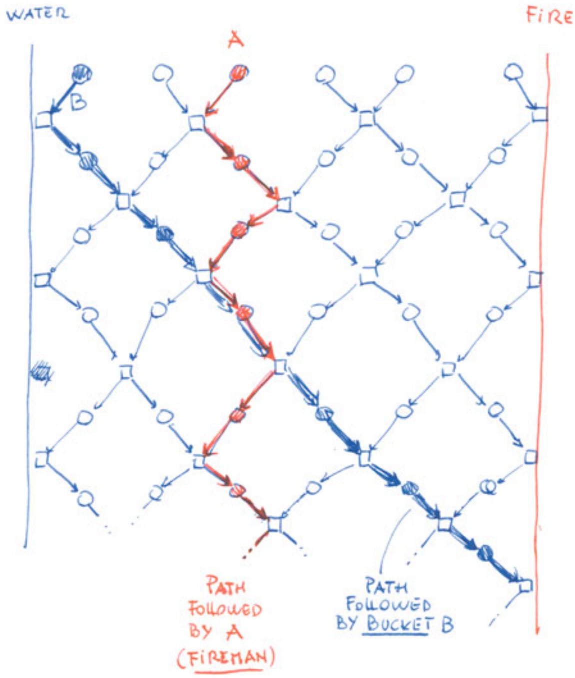

Fig. 6.11 The bucket chain as a net (Ferigato 2018) Copyright © J. Townsley 2019

The net presents *events,* the meetings between two firemen, or, at the edge between the first fireman on the left and the reservoir of water and the last fireman on the right and the fire. Note that meetings between firemen do not happen in exactly the same place, nor are they regulated by any definite intervals of time.

This is the principle illustrated in the game, people flowing from coloured mat to coloured mat according to a set of rules on a box. They are moving through the space as if in a deep fog, meeting other players outside of a determinate system of time and space. The rules written on the box propel the player according to a networked system, but when another player is encountered, the meeting event happens outside of the rule of a clock or defined by a specific determination of place. Also, the proposition for flow is changed with each encounter as objects are exchanged. In our digital world information also flows forever, it can be extracted at any time or place that interaction happens. This model also presents the basic principle of artificial intelligence, where the information has the ability to change according to an occurrence or meeting event.

6.5 Theoretical Context: Design and Analysis of (Coordinated) Communication Systems

> computer technology supplies us not [just] with a medium for artificial intelligence nor with a machine which may be used solely for computation, but with a medium for communication and for strictly organised information flow, a medium which may induce major changes in the modalities of co-operation between human beings [5].

The contemporary designer of communication systems is forced, in his profession, to consider relations between computers and society that are not yet consolidated in a unique practice or competence. Along the history of design of communication systems, plain consideration of measurable components like memory, throughput and availability, has shown its weakness in respect to less measurable subjects like delegation of tasks to computers, keeping control on copies of data and identify data as belonging to a given category.

Petri proposed the first set of twelve *communication disciplines* that are today still a valid starting point for designing and analysing communication systems. He addressed the design of communication systems from a wide perspective, as coordinated activities involving humans and computers.

The 'Communication Disciplines' were presented in September 1976 during a lecture given at Newcastle University and later published in 'Computer Systems Design: Proceedings of the Joint IBM-University of Newcastle upon Tyne Seminar (B. Shaw editor). He stated:

> I tried to classify practical problems from my long list, according to my stated viewpoints of the role the computer [5].

His categories were:

1. Synchronisation
2. Identification
3. Copying
4. Addressing
5. Naming
6. Cancellation
7. Composition
8. Modelling
9. Authorization
10. Valuation
11. Delegation
12. Reorganisation

His principal aim was to look into the future of computer systems and their applications, in order to support humanity to develop towards a brighter future. His conclusion was that computer system design should ideally be developed to 'organise information flow' in order to support 'cooperation between human beings'. As the true maverick he was, Petri proposed a list that he hoped computer systems developers could potentially use to 'concentrate our attention on' building a computer system that would enhance human cooperation and solve some of the problems he foresaw for a computerised world in the future.

6.6 Fishing the Net of the Communication Disciplines

To identify some of the processes and functions operating within the FOREVER-DO *Game*, we will use a selection of the 12 Communication Disciplines (highlighted in bold) as critical tools. In doing so we are also contextualising the game within a broader critical framework.

Petri states that the discipline of **identification** '*covers the question of pattern recognition'* [5]. The installation is a result of pattern recognition, specifically, a record of all the players whose **synchronised** meetings resulted in the **identification** of **copied** objects. Identifying sets of objects also indicates a destination at a mat. This is most obvious as the **composition** of stacked boxes grows around the mats in the room. Petri proposes that **composition** '*is concerned with determining the structure of documents relative to a material or conceptual carrier*' [5]. In traditional art terms, there is a strong correlation here between 'function and form' in material composition. The towers are subject to the rules of the game, the rules act as a 'conceptual carrier' determining the number of boxes in a pile. This takes the form of an ever-emerging flow of data, offered through time, as boxes move around the installation.

> Contemporary art escapes the present not by resisting the flow of time but by collaborating with it. It produces artistic events, performances, temporary exhibitions that demonstrate the transitory character of the present order of things and the rules that govern contemporary social behaviour. Imitation of the anticipated future, may manifest itself only as an event not as a thing [4].

Groys's observation is a good way of thinking about the game, especially in the many ways flow can be identified. Flow happens in the **reorganisation** that ensures the slow evolution of the installation. Petri talks about reorganisation in relation to mechanised tasks within a nuclear power plant, he highlights the potentially 'disastrous' consequences if the flow of tasks and information are not adequately reorganised to meet changing situations. In the game, reorganisation is the process of becoming, an ever-changing contingent object. Reorganisation is embedded within the flow of the game and also enforced by external contingencies.

The idea of artwork adapting to contingent conditions is not new, artwork can exist for just a moment within a definitive contingent space, temporary artwork such as: Allan Kaprow's happenings and environments, or the installations of Doris Salcedo, Olafur Eliasson and teamLab et al. Martha Buskirk considers 'The Contingent Object of Contemporary Art' in her book by the same name [8]. She refers to the artwork *Gnaw* (1992) by Janine Antoni where the artist chews, over many days, two 600-pound cube's, one made of chocolate, the other of lard. The action of gnawing results in a constant reorganisation. Buskirk says:

> Thus the experience of the work, including the relationship of its components to one another, changes depending on when and in what part of the cycle one sees it, and also diverges from photographic records of its appearance [8].

This is pertinent to the FOREVER-DO, not only from the position of a passive viewer, but also for the player who is not only witnessing the reorganisation of boxes in a room but accepting active agency within that reorganisation. This implicates the player as an author within the ongoing realisation of the game. Petri says of **authorization**:

> this discipline is concerned not only assigning and schematically representing access rights but also with scheduling obligations [5].

By thinking about authorization in this way, a parallel can be drawn between authorization within a system, such as Petri indicates, and authorship commonly placed within art production, the 'authorial' process of an artwork. If, within the FOREVER-DO *Game*, authorship is shared across participants, objects, systems rules and networks, it cannot be solely located. Rather, obligations are shared, there is no single owner or receiver. Petri died in 2010 yet his inspiration is still implicit in the game, an authorial obligation through time. Authorial agency is delegated across all the agents of the game, flowing across the human, object and conceptual realm.

In this way **Delegation** is forming an ever-changing collaboration between the mechanics of the game and the society of people who participate in it, Petri identifies in his networks a '*delegation of tasks from one agency to another*' [5].

This shared social context is fluid, outside of a singular vision. There is, however, a fixed position in the **naming** of the groups of objects: a knife; a fork; a spoon. '*Naming is understood as denoting objects structures*' [5, p. 177]. Naming—becomes the subject of coordination, the similarity or difference, triggering the selection or transfer and the **cancellation** of the player in the game. As players track objects in the game they also have an experience of a route travelled and can anticipate a future route to travel. The pattern of flow through the network is in this way an experiential one, as infinite possibilities for coordinated behaviour are generated through random instances.

The **synchronisation** is 'partially' controlled by the system mechanism, which embraces chance, ensuring that synchronicity happens outside of a deterministic time or place. In this way, the game is mirroring Petri's premise that synchronisation is based on the '*partial ordering in terms of causality as opposed to an ordering to time*' [5]. This mirrors Groys's observation on flow being collaborative of time rather than fixing it [4].

Value, such as it is in FOREVER-DO, resides in the moment of participation or observation, not in a fixed object. Petri's consideration of **valuation** states: '*the instant the information is registered by the observer it already loses its value because it may not be presented anew.*' [5]. With this definition, valuation offers a very tricky problem to the traditions of an art market. Traditionally value in art has been placed on the object but, in the game, creative value is in the performative relational aesthetic of the work; it is essentially objectless, a process rather than an object. In this way, value is transient, unable to be 'presented anew' a data value, that can only be experienced within the moment.

In an attempt to contextualise art made in today's global context, the French curator Nicholas Bourriaud coined an art movement, the Altermodern. He defined it as a moment when it is possible to produce something:

> from a vision of human history as constituted of multiple temporalities … a positive vision of chaos and complexity [1].

In the Tate triennial exhibition by the same name, 'Altermodern' (2009). The triennial presented artworks from artists such as Marcus Coats, Mathew Darbysher and Franz Ackerman whose artworks offered a document, narrative or engagement with change. Earlier in his book 'Relational Aesthetics' (1998), he offers examples of art practice as a game:

> Artistic activity is a game, whose forms, patterns and functions develop and evolve according to periods and social contexts; it is not an immutable essence [1].

Art practice, based on the relational form, is presented in FOREVER-DO as a meeting point of exchange, a physical human interaction, within a networked system. In our digital age, these exchanges are often an opportunity for data mining. Points, relational in time and space, where data is gathered, producing much of our big data; data that is held outside of our physical realm.

> The role of artwork is no longer to form imaginary and utopian realities, but to actually be ways of living and models of action within the existing real, whatever the scale is chosen by the artist [1].

The FOREVER-DO *Game* also represents a 'model of action within the existing real'. Big data, whose functions control us beyond our everyday perception, is here and is real. And yet, the otherness of the nature of big data, its invisible procedures, make it hard for us to perceive our own individual relationship with it—our essential role within the phenomena of big data systems. Without us, our relational interactions, big data would not exist while at the same time human life is becoming more dependent on the information big data feeds back to us. In reality, perhaps, we are already cyborgs in a close and symbiotic relationship with big data itself.

The art historian Edward A. Shanken, in his essay *Art in the Information Age* (2001), considers work by artists such as Hans Haacke and Joseph Kosuth, he says:

> 'meaning and value are not embedded in objects, institutions, or individuals so much as they are abstracted in the production, manipulation and distribution of signs and information' [9].

The process of the FOREVER-DO offers a distribution of signs and information, through the search for repetition. Repetition here is the key to unlocking the FOREVER-DO *Game*. It is the **copying** of objects (two knives, forks or spoons) that signifies the end of the player's participation, while the process of the game continues. Copying for Petri is a '*message—occurrence in a definite pragmatic context*' [5]. In the game, this is a process held within an unfolding never-ending chain of events, Nietzsche like in its eternal return. In '*Thus Spake Zarathustra*' *(1917)* Nietzsche describes two eternal paths '*This long lane backwards: it continueth for eternity. And that long lane forward—that is another eternity*' [10]. Most importantly the paths come together at a gateway: '*The name of the gateway is inscribed above: This Moment*' [10].

In the game, the most significant 'moments' are the coordinated meetings accumulating to model the towers of boxes. Petri utilises the discipline of **modelling** to guard against rigidity of implementation of established systems across different fields. He states:

> our 'models of thinking', tend to gain some illegitimate independence once they have proved successful on a particular field, and are then – per analogy but without care – transferred to other fields [5].

Perhaps this is a warning against the transformative analysis between Petri's disciplines (as pertinent to computer systems) and the FOERVER-DO *Game*. However, the very temporality of the FOREVER-DO *Game* can perhaps embody modelling, where:

> we are able to deal with mathematical models in which notions of a temporal ordering is replaced by that of an ordering in terms of causality [5].

Whether you are an active participant in the game or a viewer on the periphery of the game, you are in communication with the model of the game and its objects. This is not a fixed exchange but a communication flow (a causality), with all agents causally influencing one another in a relational sense.

Nicolas Bourriard draws on such symbiotic forms when he proposes that through the act of 'inclusion'—the art object is causally significant to the participation of the viewer. Indicating that there is an energy exchange between the art object and the participant.

The game is a destination in flux, a place directed by the rules, e.g. '*go to the closest blue mat*'. Petri offers a fluidity of destination with his discipline of **addressing**: '*by this we mean the description of routes or systems of paths through the net of channels and agencies*' [5]. This flow of address as a destination, is an agency of the ever becoming. Addressing within the flow of the game drives it on to new beginnings, this chimes with Groys when he says:

> Being immersed in the flow of things, one cannot return to previous moments in time or experience the events of the past [4].

Addressing also happens in a subtler way too, as social address between players in the game. The form of address has a systemic origin beyond the game, residing in the social etiquette of human behaviour. This presents us with a wider network of behaviours and systems. Petri has proposed that his net systems could have a role in conflict resolution. He suggests, nets could help reconcile complex human problems, emotionally driven problems, beyond the mechanical, systematic or digital, by offering clear alternative channels of communication.

6.7 Conclusion

> Art does not predict the future, but rather demonstrate the transitory character of the present – and thus open the way for the new [4].

By thinking about art as a process or event, as relational, societal and social, a new place is offered for authorship and realisation. This is not only the post-modern reform of authorship, deferred or shared, but authorship within the moment of a contingent ever flowing process—the FOREVER-DO.

This conceptual space made real through event also requires a temporal place. For the FOREVER-DO *Game* the place of the Palazzo Giureconsulti at Duomo in central Milan, and temporarily occupied by Milan digital week, is important. Milan Digital Week is itself a social construct, a temporal event into which interested parties' (visitors and participants) occupy space temporarily. Visitors are in this way already complicit within the flow of events.

The historically embedded definitions of art and art practice, particularly the traditional consideration of value in relation to object, are being challenged through utilising digital systems as integral tools. By visualising, in analogue terms, this relationship between the participant (the player of the game) and the system (the rules and network of the game), the FOREVER-DO highlights our individual complicity within the greater whole. Places of meeting within the game indicated by simple coloured doormats are also nodes within a networked system. When individuals meet through a flow of random incidents, objects are either exchanged or offloaded onto the data pile. The piles of boxes record the incidents of two humans meeting and randomly possessing a repeated object. This process presents a digital and analogue description of events through time and offers a visualisation of a similar scientific modelling that the Petri Nets identify.

Petri's Communication Disciplines, written in the 1970s still 'concentrate our attention on' building a computer system to enhance human cooperation and overcome some of the many problems brought about by our human digital interface. Problems for culture arising from irresponsible systems, technicians, trolls and corporations. We are all complicit in society's broader data communications. As Petri outlined, we must all consider the relations between computers and society that are not yet consolidated in a unique practice or competence. The FOREVER-DO opens a discussion about the interactive trail we leave behind and the systems acting upon us. By reclaiming our digital identity, being aware of the symbiotic relation of self to our larger networks, maybe we can hack our future in a positive way, for the benefit of all.

Acknowledgements The FOREVER-DO project and its resulting artwork (including the FOREVER-DO *Game*) is a collaboration between Jill Townsley (University of Huddersfield) and Carlo Ferigato (Joint Research Centre of the European Commission—JRC-Ispra, Italy). The project is supported by advice from the MC3 research group at the Milano-Bicocca University and Otolab, Milano. The project is funded by the EU Commission through its SciArt initiative.

References

1. Bourriaud, N.: Relational Aesthetics. Les Presses Du Reel (1998)
2. Joint Research Centre (JRC). Available: https://resonances.jrc.ec.europa.eu/. Accessed Oct 2019
3. Joint Research Centre (JRC). Available: https://resonances.jrc.ec.europa.eu/datami. Accessed Oct 2019
4. Groys, B.: In the Flow, Verso Books. London (2018)
5. Petri, C.A: Communication disciplines. In: Shaw, B. (ed.) Computing System Design: Proceedings of the Joint IBM—University of Newcastle upon Tyne Seminar, September 1976, pp. 171–183. University of Newcastle upon Tyne (1977)
6. Petri, C.A.: Kommunikation mit Automaten, Dissertation, Schriften des IIM 2, Rheinisch-Westfälisches Institut für Instrumentelle Mathematik an der Universität Bonn. (Eng. transl. Communication with Automata, Technical report RADC-TR-65-377, Volume I, Final Report, Supplement I) (1962)
7. Bernardinello, L., Cardone, F., Pomello, L.: L'eredit'a di Carl Adam Petri: dagli automi alla comunicazione, Mondo Digitale, febbraio, p. 175 (2016)
8. Buskirk, M.: The Contingent Object of Contemporary Art. The MIT Press, Cambridge, MA, USA (2003)
9. Shanken, E.A.: Art in the Information Age in LEONARDO, vol. 35, No. 4, pp. 433–438 (2002)
10. Nietzsche, F.W.: Thus Spoke Zarathustra. Modern Library, New York (1917)

Chapter 7
Searching for New Aesthetics: Unfolding the Artistic Potential of Images Made by the Scanning Electron Microscopy

Anastasia Tyurina

Abstract The visual arts have become a powerful tool for alternative approaches to scientific outputs, but it is crucial that both science and art cultures are aware of their interdisciplinary capabilities and limitations. It is necessary to differentiate between images captured by devices designed as resources for scientific investigation and images that exploit the 'visual elements' of scientific images. A great example of a device designed for scientific exploration is the Scanning Electron Microscope (SEM), which was introduced to scientific research in the mid-1960s. This chapter outlines the procedures, processes, and methodologies used in developing a body of studio work that investigates the artistic potential of scientific images made by the Scanning Electron Microscope (SEM) with a view to its possible social and cultural impact of this practice. It also outlines the developed theoretical findings and proposes that certain images made by the SEM can have esthetic value apart from that of scientific documentation. The use of artistic manipulations in experiments with the SEM fuses science and technology with art, and the SEM-based images that result provide a new meaning for scientific photomicrographs.

Keywords Science-art · Visual arts · Photomicrography · Interdisciplinary · Microworld · Interactivity · Aesthetics · Self-organizing processes · Coffee ring effect · Alternate visualizations · Visual coalescing · Creative coding · New media · Scanning electron microscope · Water

7.1 Artist Statement

My art practice involves interplay between photography and scientific imaging, photomicrography in particular. Originally being a technical discovery, photography has been widely used in almost all fields of human activity, acting as a research tool and as an independent artistic direction. Modern times offer "modern" interpretations of

A. Tyurina (✉)
Queensland University of Technology (Brisbane), Brisbane, QLD, Australia
e-mail: anastasia.tyurina@qut.edu.au

National Research University MIET (Moscow), Moscow, Russia

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_7

scientific photographs and attitudes toward them. Scientific photomicrography is a powerful tool for receiving and storing information and for providing solutions to a variety of tasks in many areas of science and technology. At the same time, the artistic application of photomicrography is capable of revealing a set of complex and interrelated principles that underlay the materiality of the human environment. Photomicrographs also expand human visual vocabulary, revealing principles of beauty which are difficult to access with the naked eye.

Water is the main subject of my research project. I believe that an interdisciplinary approach is the most appropriate one for deepening knowledge about unique properties of water and building a sustainable practice of water management through enhanced visualization of water contamination. My focus is on interconnected artistic thinking and by developing alternate forms of visualization, I aim to transcend disciplines and contribute to the new ways of seeing water.

My visual artworks consist of series of images made by the SEM depicting the nature of water (water chemistry), which is invisible to the naked eye, through using the SEM utilizing the phenomenon of drop evaporation. However, it was not the purpose of this research to claim that the created images of water after evaporation are scientifically valid forms of documentation; rather, this research takes an esthetic approach to scientific photomicrography.

7.2 Introduction

This research was undertaken during my Ph.D. study at Queensland College of Art, Griffith University and involved esthetic approaches to scientific photomicrography. Scientific photography is commonly perceived as a way of recording scientific data through techniques such as photomicrography, high-speed photography, time-lapse photography, X-ray photography, and aerial photography, among others.

Images made by the SEM are not photographs in the traditional sense; they go beyond what can be captured with light because the process of producing a picture is camera-less. Imagery produced by the SEM can confuse the viewer because the microscopic sample seems as if it is observed in the eye aperture when illuminated, and light seems to come from a particular illuminant. SEM photomicrographs are constructed out of pixels synchronized with a distribution map of the intensity of the signal being emitted from the scanned area of the specimen [1].

Interestingly, the last decades' use of SEMs in creating scientific images formed a new, well-established visual culture within a variety of scientific disciplines. As Klaus Hentschel explains, it became "*an image centered science in the sense of being even totally dependent on photographic images as basis of all further processes of inference*" [2, p. 315].

By exploring the interplay between the indexical and iconic modalities in scientific photomicrographs, I try to imbue them with new meanings. Both art and science are experimental in nature. There are different ways of artistically representing and perceiving an object, some of which may be valuable for science. My practice aims to draw attention to the qualities of water through enhanced visual details that aid in the interpretation of and differentiation between water samples.

This project investigates how to reinterpret photomicrographic images made by the SEM of micro-scale drops of water after evaporation and thus turns scientific photography into an art form.

In recent decades, there have been increasing concerns over the ecological management of water. Waterway pollution is recognized as placing urban ecosystems around the world at risk. Rainfall that washes oils, metals, and nutrients directly from streets into rivers and seas is hard to treat [3]. This is a challenging problem for science and technology. The health and well-being of present and future generations are dependent on how quickly and well it is managed.

Photomicrography has a particular potential to respond to this issue from both a scientific and a cultural perspective. SEM-made photographs are capable of visually representing features related to water composition and, in some cases, the contamination of water. At the same time, they can transmigrate from science into the domain of art and draw attention to water issues.

7.3 Water Represented by the Scanning Electron Microscope

The variety and frequency of the unusual properties of water are determined by the physical nature of its atoms and their association in the molecule and the group-formed molecules [4, 5]. The composition of water, even that which is entirely free from mineral and organic impurities, is complex and diverse because water is constantly in contact with many substances.

During my experimentation with the water droplets collected from different aquifers, I aligned the scientific method of revealing water composition (the so-called ‘Coffee Drop Effect’) with my artistic practice. The drop evaporation phenomenon, the so-called ‘Coffee Ring Effect’, has been the subject of studies in the last few decades. It was first mathematically described by Robert D. Deegan in 1997 as a natural model for studying the dynamics of self-organizing processes and is actively used in physical experiments [6]. When the liquid is ‘pinned’ to its contact surface, the liquid evaporating at the exterior edge is replenished by the constant flow of liquid from the interior to the periphery. This flow carries nearly all dissolved solids toward the edge [7].

During experiments for my project, the structure of the water impurities visually transformed, leading to a unique connection between the processes of evaporation and solidification. These two processes are shown in Fig. 7.1. This natural process of drying reveals the unique informative capacity of droplets through the shapes, patterns, details, and characteristics resulting from each water sample.

At the University of Chicago Materials Research Center, scientists are exploring the driving mechanism responsible for this phenomenon that is found in many

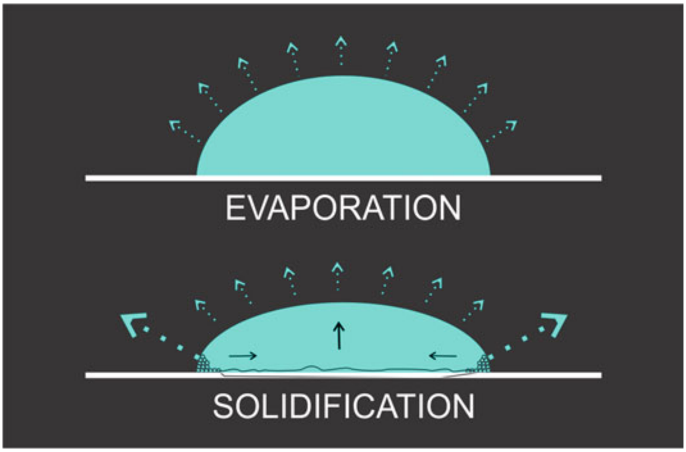

Fig. 7.1 Anastasia Tyurina, *Drop Evaporation and Solidification Scheme*, 2015. Image copyright © A. Tyurina 2019

varieties of liquids. This research validated my process of exploring variations in water composition for my project. On its webpage, the Center states: "*We have determined that ring formation is a ubiquitous and robust phenomenon. It doesn't depend on the solute, the solvent, or the substrate so long as the solvent is partially wetting and volatile, and the contact line is pinned*" [8].

An interesting observation made by the researchers is that "*By controlling the speed and spatial variation of the evaporation, this model predicts that we can control the shape and thickness of the deposit*" [7]. This was particularly important for my practice because it meant that experimenting with various modes of evaporation could lead to different visual formations of the drops after they dry.

Specifically, for this research 'science' can be described as a process through which new knowledge about the world is built. The scientific process relies on the testing of ideas through experimentation. Scientific photography, as a tool, aims to support the scientific process by capturing data about the world for examination.

Reflecting on the scientific findings, the primary purpose of my visual art project was to depict the inherent features of water that are invisible to the eye through using the SEM. To do so, I used the process of evaporation as an alternative and unusual artistic method of visually presenting the composition of water. My approach is unique in the specific way in which I use water to create images using the SEM. During experiments for my project, it became evident that the structure of water impurities is visually transformed after evaporation and reveals a unique connection between evaporation and solidification. This process of revealing the nature of water (water chemistry) allowed me to play with the process like an artist [9].

One of the technical requirements when taking a microscopic image with the SEM is that any object placed in the chamber of the SEM must be completely dry, because the SEM operates in a vacuum. As explained in Under the Microscope: A

Hidden World Revealed (1987), "*Turning to biological specimens for the SEM, it used to be necessary first to fix and dehydrate them, and then dry them either on air or by the use of liquid carbon dioxide ('critical point drying')*" [10, p. 199]. After the evaporation process, water is no longer a liquid; dry solids or other substances become watermarks that represent its previous composition.

The main difference between 'Artistic' and 'Scientific' use of the SEM in this project is that the artistic approach has a focus on making aesthetic images. Within this is the substance of the scientific idea about showing water state and how it is changing. In my work the results of imagery processes become art pieces with both artistic and scientific applications (Fig. 7.2).

My artistic intervention into a scientific process through experimenting with the SEM was a way to find out what different things my images could reveal about water to a viewer. There was an opportunity to explore some concerns related to the environmental impact of water pollution in an artistic context and to communicate the significance of water.

By exploring the integration of art and science in this way, my project focuses on the use of scientific tools to create science-based art. However, it must be recognized that my approach was primarily one of artistic research and experimentation: a search for new aesthetics, exploring spatial and temporal dimensions, engaging with materiality, and involvement of modern technologies in the formation of esthetic experiences for the viewer. In my project, images are highly variable in what they show and how they show it because of changes in water content.

7.4 Photomicrography as an Art Form

Contemporary practices in photomicrography are making significant contributions to the dialog around aesthetics and artistic components in science. As far back as 1963, in his article "The Esthetic and Pictorial Applications of Photomicrography" for The Photographic Journal, Douglas Lawson wrote:

> When mentioned within the hearing of some pictorialists they immediately think it is only for the scientifically minded, or the record worker. Nevertheless, the so-called record photograph can be made to look quite attractive. Some of you may remember Mr. H. A. Murch, one of our great pictorial photographers, once saying, 'I do understand the desire to apply pictorial ideas in record work, which is a very different objective, and we ought to welcome such an application when it can be done without losing anything of the essential factual value of the record' Photomicrography offers expression not in what the painter has already done but in what the painter cannot do. Because this application of photography is highly scientific there is perhaps a tendency to think of it as being without scope for the artistic application. May I suggest that a work of art in any medium can be the deliberate creation of unity, and nature through the microscope is one medium provides us with plenty of scope for such unity [11].

To effectively engage with photomicrography as a social phenomenon, it is crucial for an artist to demonstrate an understanding of its 'scientific' protocols of representing. But will the viewer be familiar with what he or she sees in scientific images? If

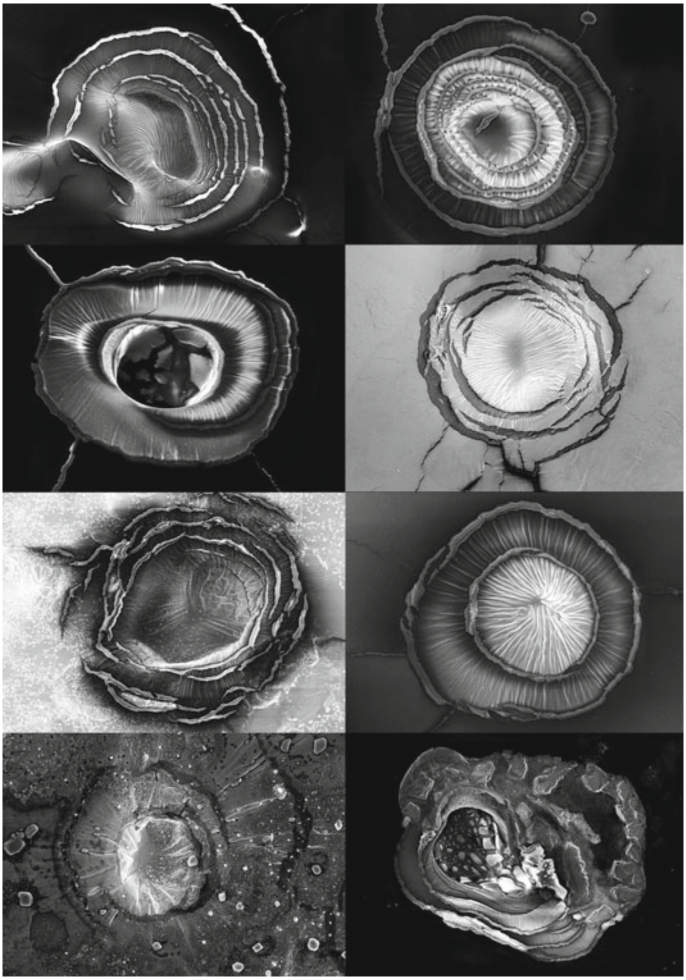

Fig. 7.2 Anastasia Tyurina, *Watermarks Series*, 2015 (From left to right: *Brown Lake, Brisbane River, Raby Bay, Rainwater, Mount Gravatt Pond, Mimosa Creek, South Bank Pond, Cylinder Beach*). Image copyright © A. Tyurina 2019

not, how will they perceive such images? Do the images need to be explained or are they capable of conveying messages in a different context?

Artistic photomicrographs of water after evaporation call upon the viewer's creative ability to perceive previously unseen water composition after evaporation as well as to observe natural phenomena over and beyond the directly visible.

My images transform the microworld to a macro-level and evoke an interest in water chemistry that is shown as being beautiful. This causes a dilemma for viewers, particularly because the gallery space is different from a laboratory. The captions for my photographs refer to the sites where the water samples were collected. It is intriguing that they can resemble aerial photographs of topographical features of particular water reservoirs (Figs. 7.3 and 7.4).

Today, the practice of visually pleasing photomicrography is more mainstream. The most popular international photomicrography competition is Nikon's Small

Fig. 7.3 Anastasia Tyurina, *Photo documentation of the artistic installation for H2O + exhibition, PoP Gallery, Queensland College of Art, Griffith University, 30 March–16 April* 2017. Image copyright © A. Tyurina 2019

Fig. 7.4 Anastasia Tyurina, *Photo documentation of the Shifting the Posts exhibition, Webb Gallery, Queensland College of Art, Griffith University, 27 November–7 December December* 2018. Image copyright © A. Tyurina 2019

World Photomicrography Competition, which dates back to 1975. Participating images are judged for "*their scientific and artistic merits*" [12] and represent a broad range of visual studies of the microworld. Some of these photomicrographs have allegorical titles, a fact that highlights the relation of artistic intentionality in producing images and the scientific objectivity underlying the concept of the competition.

Participation in the competition is restricted to images made by optical microscopes of any kind, which are capable of revealing natural colors of objects. As mentioned above, the SEM apparatus is camera-less; there is no light involved in the process; it is not an optical instrument. Thus, colors cannot be reproduced. Rather, artificial colors can only be added with the help of graphic software such as Adobe Photoshop. While there is a whole range of possible manipulations available in Photoshop, it is worth mentioning the coloring tools. Through different algorithms, it is possible to apply different colors to different details of the image. There are many sources both in the technical literature and on the Internet providing scientists and artist with various tutorials on image coloring. But the author of the image makes the final decision of which color to apply to a particular point of the presented object and thus color choice is very individual. Experimenting with such coloring, I have tested two options: the coloring algorithm available in Photoshop and the software offered by Recolored, which was designed for the purpose of recoloring black-and-white photographs (Fig. 7.5).

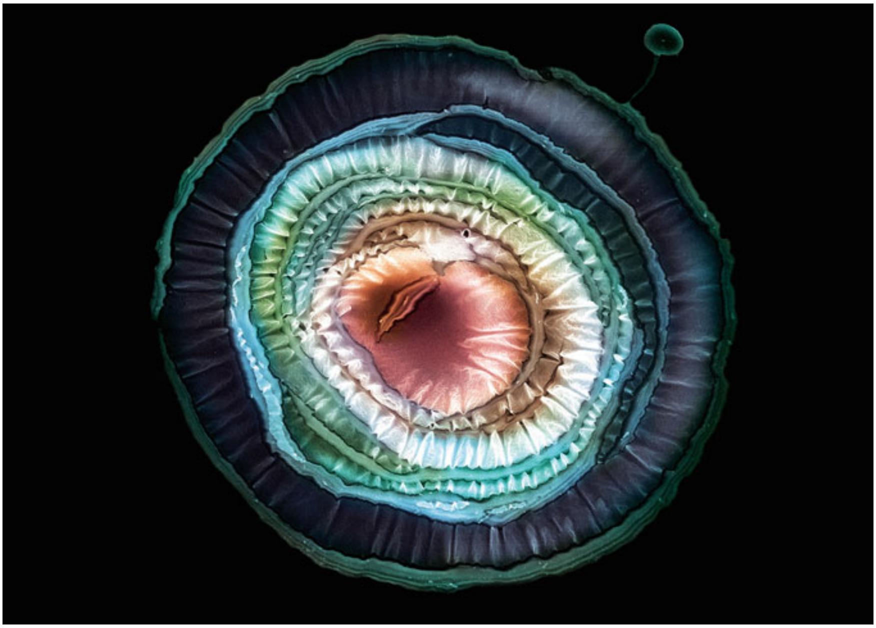

Fig. 7.5 Anastasia Tyurina, *Colour 32*, 2017. Image copyright © A. Tyurina 2019

7.5 Photographs or not Photographs?

It is important to examine the process of image formation in relation to the imagery obtained by the SEM in modern microscopy. It is also crucial to distinguish image generation by SEM considering that the process is not one that is based in code. The image generation process can be seen as a work of high-energy electrons that create a range of different signals when hit the specimen. Converted into pixels signals result in image formation appeared on the screen.

Technically, the SEM produces electron micrographs because the image is developed by either secondary electrons (electrons ejected from the material by the incoming electron beam) or backscattered electrons (electrons from the electron beam, which have 'bounced' off the material into the detector). Dee Breger explains:

> Scanning electron microscopes don't merely use electron beams to illuminate objects so small they can't be seen by light. Since they are electronic devices, SEMs can manipulate isolated groups of electrons from the sample-beam interaction to create separate pictures (such as secondary and backscatter images) that contain different kinds of information about a single object. This variety can lead to a 'compound reality' or, since no version tells the whole story, a kind of 'ironic nonreality' [13, p. 11].

Images produced by the SEM are beyond light; captured by a focused beam of electrons, they are not photographs. The apparatus tries to recreate a reality that is not a visual phenomenon, which scientists then try to analyze through its visual representation: the photomicrograph.

However, the most commonly used SEM electron detector, named Everhart-Thornley (E-T),[1] typically uses a material that produces light when an electron collides with it—a scintillator.[2]

Therefore, the SEM does use photons, but they are converted back into electrons, which are accelerated onto the electrodes of the photomultiplier, producing an increasing stream of electrons until the final collector is reached [14]. The image formation in scanning electron microscopy consists of the scanning system, the signal detectors, the amplifiers, and the display [1]. A physical, material connection of the SEM apparatus with the studied object is gained by the interaction of these four elements (Fig. 7.6).

---

[1] "The E-T detector operates in the following manner: when an energetic electron (≈10 keV energy) strikes the scintillator material (S), light is emitted. Light is conducted by total internal reflection in a light guide (LG) (a solid plastic plastic or glass rod) to the photocatode of a photomultiplier (PM). At the photocatode, the photons are converted back into electrons, which are accelerated onto the successive electrodes of the photomultiplier, producing an ever-increasing cascade of electrons until the final collector is reached" [14].

[2] "A scintillator is a material that accepts incident high-energy electromagnetic or charged particle radiation and in turn uses that energy to fluoresce photons whose peak emission wavelength is longer than the wavelength of the incoming radiation. In the case of a SEM, the scintillator disc collects the secondary electrons that are produced as the electron beam scans the surface of the sample. These electrons are converted into photons which travel through the light pipe to the photomulitiplier tube (PMT) so that the signal may be amplified to the level required for viewing" [15].

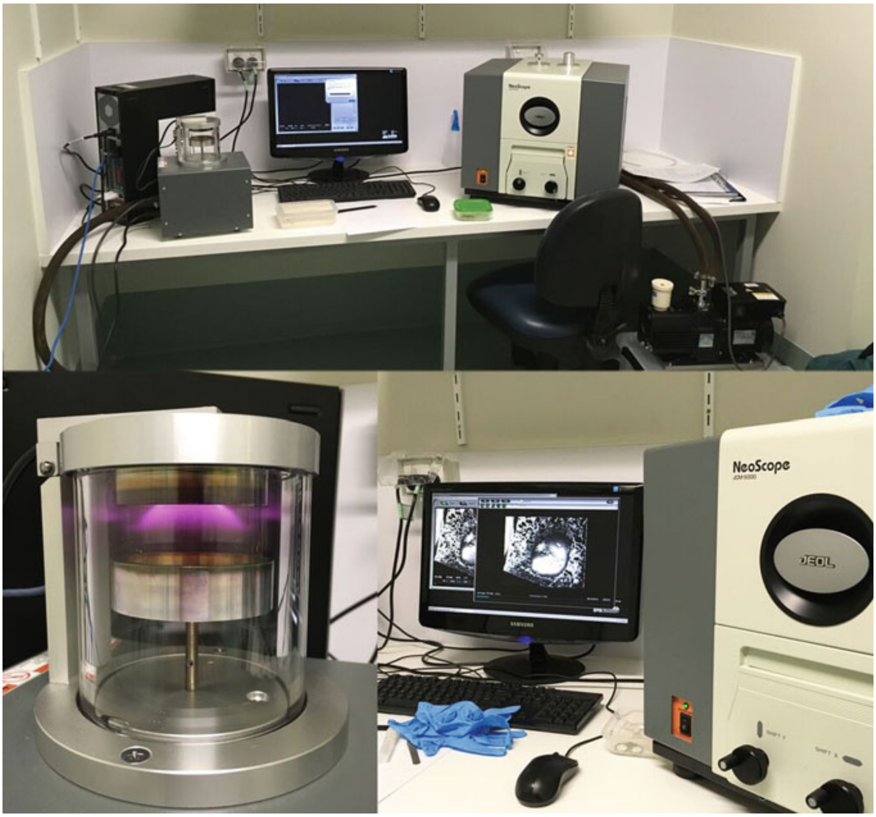

Fig. 7.6 Anastasia Tyurina, *Scanning Electron Microscope Imaging Facility*, 2016. Image copyright © A. Tyurina 2019

During the imaging process, the energy exchange between the electron beam and the sample results in the reflection of high-energy electrons, the emission of secondary electrons and the emission of electromagnetic radiation, each of which can be measured by specialized detectors. The detectors interpret these signals by the algorithm and the resultant image appears constructed out of pixels. This algorithm is defined by each quantum of signal information but it is also implemented in the physical world in apparatus, computer, and screen [1]. In some sense, the SEM apparatus interprets (transforms) signals and visualizes signals.

7.6 Scientific Images and New Media

The artworks employ two kinds of medium, comprising two different applications of SEM photomicrography: still photomicrographs and interactive digital installations. They can be perceived differently in terms of the esthetic response they generate in the viewer, but both draw attention to the qualities of water through enhanced visual details that aid in the interpretation of water samples. I use static SEM-generated photomicrographs of water, then apply a digital code which allows the image to be altered by the audience's interaction with its touch-sensitive interface. Thus, anyone who touches the screen can create, display, and experience a ripple effect, which is very similar to the effect we can see and observe when we interact with water surface by touching or disturbing it. Interacting with the scientific photomicrographs in this way offers a layered meaning and can enhance the audience's perception of scientific data, scientific photography, and water.

Exploring the idea of 'interactivity' for my project, I looked for a method that allows viewers to interact with photographs by altering the work's visual content. Utilizing the programming language Processing, I developed an algorithm which allows viewers to physically interact with my photomicrographs so that they become direct objects of manipulation. Using the random human touch of some areas of the developed algorithm alters the static image, which in some senses visually represents non-visual elements: scientific data.

Through my research, I have explored different digital tools and realized that creative coding suits my goals because this type of computer programming is designed to create something expressive instead of something functional. Using creative coding tool such as Processing, it is possible to create art installations, projections, sound art installations, and much more within the context of the visual arts.

The interplay between virtual ripple effects and the resemblance of physical interaction with water can be seen as embodying the "artist–display–user" paradigm seen with regard to computer art [16, p. 10]. In their article "The Post-Display Condition of Contemporary Computer Art," Toby Juliff and Travis Cox attempt to re-conceptualize the relationship between artistic intentionality, coding, interface, and user input. They suggest that the relationship between the artist and computer code should be reconsidered so that the paradigm becomes "*artist–code–display–user.*" They state that "*the code takes input from the user and subjects it to internal semiosis between distinct elements of the code, before being output to the display. This code, having been written by the artist, or an agent of the artist, contains within its structure an inbuilt intentionality, a way of approaching input that is integral to conveying the intended meaning*" [16, p. 10]. In line with artists using code to activate new experiences and with Juliff and Cox, who argue that the code is not only a product of intention and meaning but also a producer of them, I seek in my practice to explore the role of code in the production of meaning, in particular for the scientific photomicrograph of natural phenomena.

In the series of live images for my project, the photomicrographs displayed on the screen seem to be still when viewed from a distance; yet, as the audience comes closer and start touching the screen, the ripples appear.

The photomicrograph transforms into a live picture, producing varying forms of ripple that seem both ordered and random at the same time. Such transformations occur continuously until the user-viewer stops touching the screen (Figs. 7.7 and 7.8).

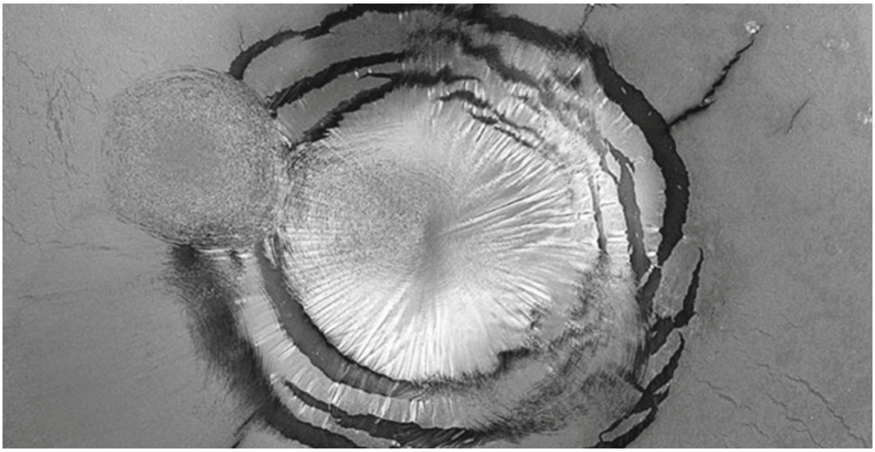

Fig. 7.7 Anastasia Tyurina, *Rainwater* (detail) 2016, Digital mixed media. Image copyright © A. Tyurina 2019

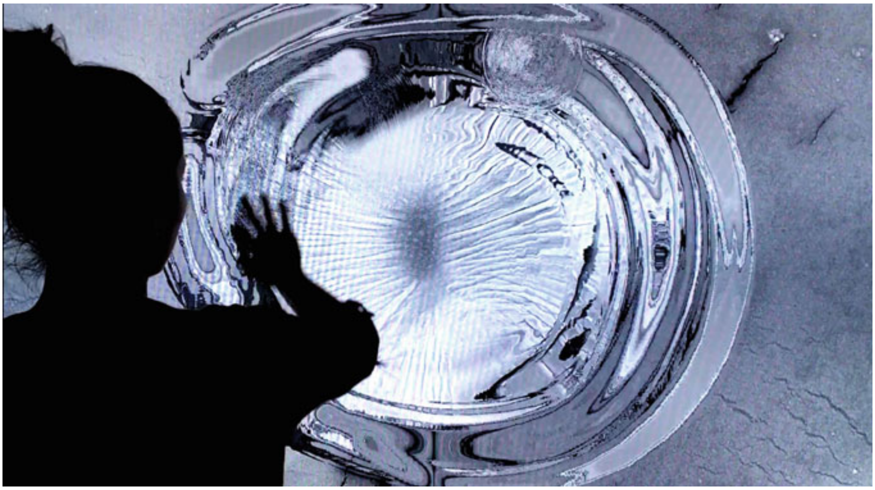

Fig. 7.8 Anastasia Tyurina, *Rainwater* (detail) 2016, Digital mixed media. Image copyright © A. Tyurina 2019

Interacting with the image in this way transforms the work into something that transcends disciplines. It offers a layered meaning, providing audiences with the opportunity of experiencing the fluid and animated qualities of the effects that connects with these qualities in the subject matter: water. The addition of the interactivity and animation introduced by the ripple effect is the expanded mode of ‘reading’ or appreciation. As well as offering a visual engagement, the work offers an embodied

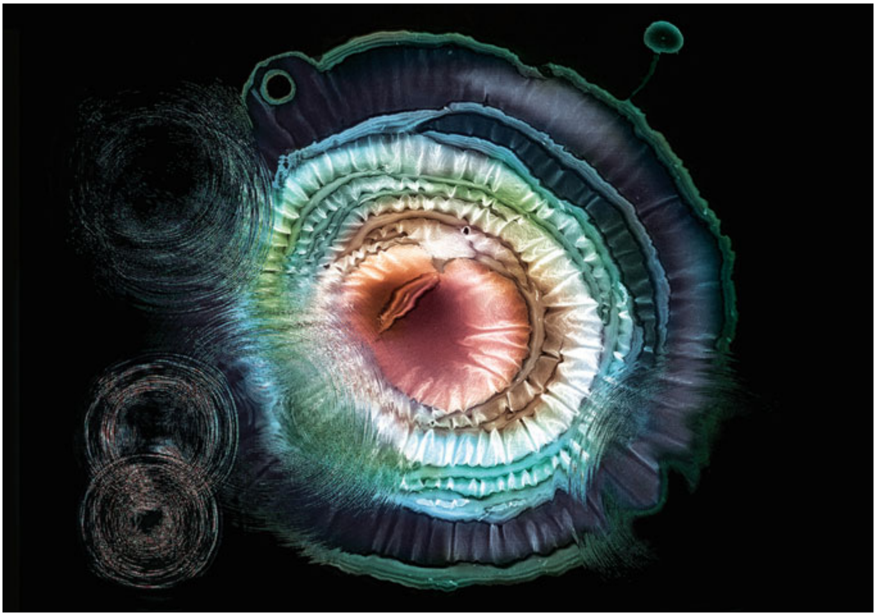

Fig. 7.9 Anastasia Tyurina, *Colour 32* (detail) 2017, Digital mixed media. Image copyright © A. Tyurina 2019

engagement: an important connection to the material significance of water in our lives.

Colour 32, one of the artworks, portrays a drop of Brisbane River water. This artwork was exhibited at various venues displayed as both interactive work and video at screens of different scale (Figs. 7.9, 7.10 and 7.11).

Such digital installations allow the transformative power of water to be explored; they offer new perceptual experiences and, by the artist–code–display–audience interaction, are capable of providing a new meaning for scientific images through their ever-changing visualization.

7.7 Conclusions

Not every image is art, and art is far more than just an image. Originally a technical discovery, photography has been widely used in almost all fields of human activities, acting as a research tool and as a form of artistic practice. Scientific tools have brought new ways of seeing the world. Although usually reserved for scientific use, such technology is now being used in the creation of art.

The primary purpose of this research was to show that the artistic use of SEM-made photomicrography can shift the visual outcomes of scientific photomicrography

Fig. 7.10 Anastasia Tyurina, *Colour 32*, North Spine Plaza, Media Art Nexus, Nanyang Technological University (NTU), Singapore, 2017. Image copyright © A. Tyurina 2019

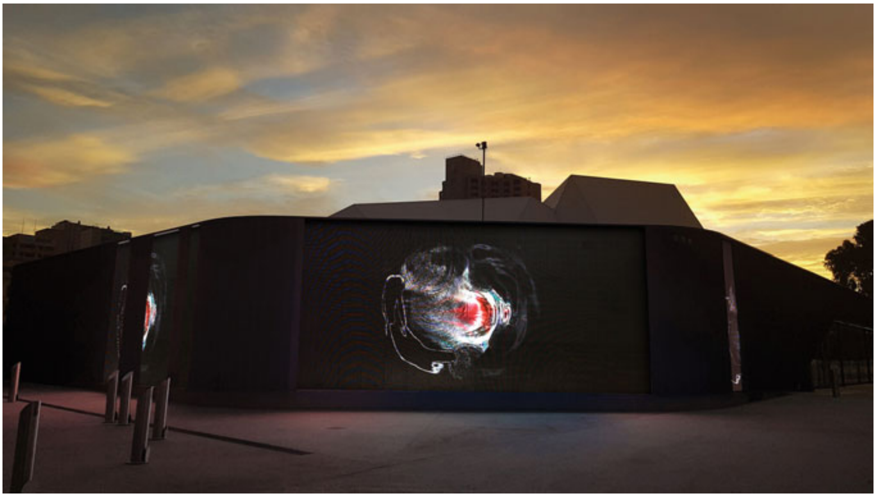

Fig. 7.11 Anastasia Tyurina, *Colour 32*, public screening, Adelaide Festival Centre, 2018. Image copyright © A. Tyurina 2019

to function within the context of art. Drawing on literature, visual analysis, and theoretical findings, it was possible to develop my artistic practice using the SEM to visualize the microworld of water. As Breger states, the microworld exists beyond our cognition; its beauty is hidden but it can be explored using appropriate tools, such as the SEM [13].

Not many people have access to complex research technologies that can widen their daily experience such as the SEM. Mostly, people passively receive scientists' dry results and the interpretations they are exposed to. My work in the field of photomicrography aims to expand human visual vocabulary, revealing principles of beauty which are typically difficult to otherwise access. Thus, my artistic intention is to expand the visual representation of the composition of water, its chemical features, and their patterns after evaporation. My aims are to also communicate issues related to the ecological management of water and to raise and deepen responsible attitudes toward consuming and managing water resources.

During this project, I have placed (both virtually and physically) scientific images into a 'hostile' artistic environment. In the gallery space, the significantly greater scale of photomicrographs, their impeccable details, the artistic materials used, and the digital, still and interactive modes of presentation uncover the novel artistic potential of the scientific image. This leads to the image being disconnected from pure data and objectivity and allowing the viewer to perceive it as art, helping them to interpret photomicrographs of water in different ways. Most importantly, through these images, I hope to uncover the horizon of meanings previously unseen.

Today, many institutions and organizations host scientific photography and visualization competitions (and associated exhibitions), which encourage scientists from different disciplines to contribute. The images are not only judged by professionals (scientists and photographers) but often the audience is also invited to evaluate the competing images. By doing so, all three groups apply their own esthetic judgment criteria. This illustrates how scientific images can be evaluated from different contexts. Examples of such events include the annual the Visualization Challenge, National Science Foundation; the Wellcome Image Awards, Wellcome Trust; Nikon Small World Photo Competition; The Royal Photographic Society International Images for Science, just to name a few.

This popular trend indicates the growing interest in the visual coalescing of science and art through photography, particularly through photomicrography. Nevertheless, the idea that the photographic scientific image can be artistic and that the arts can serve science and vice versa still generates skepticism, and the debate will surely continue. Regardless, it is obvious from the discussion that the arts have the potential to reveal important aspects of the complex world in their own way, which is complementary to what scientists do and may be useful for both disciplines. Scientific photography aims to record and illustrate data and experiments that differ according to specific disciplines. Although the main purpose of scientific photography is to convey accurate information rather than beauty, its ability to record material in addition to that which is merely informative allows it also to serve expressive, subjective, and esthetic purposes.

The new definition other than photographs (or photomicrographs) for SEM images should be sought considering the nature of the process of image generation by the SEM. This is particularly interesting due to the complex nature of the apparatus. Different ways in which images made by SEM can be interpreted create layered meaning in them especially if they are given in the artistic context.

References

1. Goldstein, J.I., Newbury, D.E., Echlin, P., Joy, D.C., Fiori, C., Lifshin, E.: Electron Microscopy and X-Ray Microanalysis: A Text for Biologist, Materials Scientist, and Geologists. Springer Science + Business Media, New York (1981)
2. Hentschel, K.: Visual Cultures in Science and Technology. A Comparative History. Oxford University Press, New York (2014)
3. De Haan, F., Rogers, B., Frantzeskaki, N., Brown, R.: Transitions through a Lens of Urban Water. Environ. Innov. Societal Transitions **15**, 1–10 (2015)
4. Chaplin, M.: Water Molecule Structure. Water Structure and Science (blog). Last updated 30 October. http://www1.lsbu.ac.uk/water/water_molecule.html (2016). Last accessed 19 Jan 2017
5. Chemical Association: Accessed on 6 June 2019. https://www.britannica.com/science/chemical-association (2019)
6. Yakhno, T.A. Yakhno, V.G., Sanin, A.G., Sanina, O.A., Pelyushenko, A.S., Egorova, N.A., Terentiev, I.G., Smetanina, S.V., Korochkina, O.V., Yashukova, E.V.: The informative–capacity phenomenon of drying drops. IEEE Eng. Med. Biol. Mag. **24**(2), 96–104 (2005). https://doi.org/10.1109/memb.2005.1411354
7. Deegan, R.D., Bakajin, O., Dupont, T.F., Huber, G., Nagel, S.R., Witten, T.A.: Capillary flow as the cause of ring stains from dried liquid drops. Nature **389**, 827–829 (1997)
8. The Coffee Ring Effect Accessed on: June 6, (2019). Available: https://mrsec.uchicago.edu/research/highlights/coffee-ring-effect (2019)
9. Tyurina, A.: The unseen water: experimentation with scientific photomicrography and creative coding. In: Proc Electronic Visualisation and the Arts (EVA 2017). Available http://dx.doi.org/10.14236/ewic/EVA2017.15
10. Burgess, J., Marten, M., Taylor, R., McNamee, M., Stepney, R.: Under the Microscope. A Hidden World Revealed. CUP Archive, New York (1987)
11. Lawson, D.F.: The aesthetic and pictorial applications of photomicrography. Photogr. J. Off. Publ. Roy. Photogr. Soc. G B **103**(1), 1–11 (1963)
12. Thompson, N.: Tiny Photographs from the 'Limbo Between Art and Science', CNN News, 30 October (2013). Available: https://edition.cnn.com/2013/10/30/world/nikon-small-world-photo-contest/index.html (2013). Accessed on 6 June 2019
13. Breger, D.: Journeys in Microspace: The Art of the Scanning Electron Microscope. Columbia University Press, New York (1995)
14. Electron Detectors. Available: https://www.scienzemfn.unisalento.it/c/document_library/get_file?uuid=639f02da-34b4-43b5-b595-13978bae6164&groupId=10122 (2015). Accessed on 31 May 2019
15. Scintillators. Available: https://semicro.org/collections/scintillators. Accessed on 6 June 2019
16. Juliff, T., Cox, T.: The post-display condition of contemporary computer art. EMAJ **8** (2015)

Chapter 8
Interspecific Interactions: Interaction Modes Between Sound and Movement in Collaborative Performance

Manoli Moriaty

Abstract Collaboration between composers and choreographers is an approach possessing a long history and expansive list of creative outcomes. In recent years, such collaborative endeavours have further engaged with knowledge and practices from scientific disciplines, consequently giving rise to an emergent field of research focusing on novel modes of interaction between the expressive media of sound and movement as facilitated by new technologies and methodologies; from analogue proximity devices permitting dancers rudimentary control over recordings in the 1965 *Variations V*, to Marco Donnarumma utilizing biophysical sensors and machine learning algorithms as means of maintaining detailed command of digital signal processing (DSP) through specific body postures in the 2016 *Corpus Nil*. Whilst the contributions by this relatively new transdisciplinary field have produced practice and research outcomes of unquestionable value, its main focus concentrates on the expression of sound through movement, with lesser emphasis placed on perspectives of practitioners utilizing interactive sound as means of informing the arrangement of movement. This chapter aims to reflect those perspectives through the research conducted during my collaborations with dance practitioners, where we have together examined areas such as each performer's role while operating interactive systems, employing different modes of system operation according to the desired determinacy of resulting material, and simplification of discipline-specific language when engaged in polydisciplinary collaboration. The contribution of this research concerns a novel taxonomy of interaction modes informed by the biological phenomenon of symbiosis. Defined as close and persistent relationships between organisms of different species, symbiosis manifests in three core types—mutualism, commensalism, and parasitism—with each type determined according to the change in fitness outcome experienced by each of the engaged organisms. In the context of my collaborative practice, the biological notion of fitness outcome is interpreted as the expressive range allocated to each performer and their respective media, while simultaneously relating to the level of determinacy from the score and choreography. The symbiotic modes of interaction are firstly described through examining three contemporary precedents, each showcasing distinct approaches in

M. Moriaty (✉)
University of Salford, Salford, UK
e-mail: e.moraitis1@salford.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_8

collaboration and use of gesture recognition technologies (GRT), followed by a practical demonstration of each mode by its activation during a practice outcome resulting from my collaborations with two dancers, including a detailed analysis of the developed interactive system and its principles of its operation.

Keywords Polydisciplinary · Collaboration · GRT · Interaction · User interface · Symbiosis

8.1 Introduction

For the better part of the past decade, a significant portion of my practice and research has been concerned with polydisciplinary (see note 1) collaboration in performance practice, with a particular focus on the processes by which practitioners expressing through sound and movement engage in collaboration. Since its early conception, my approach in examining such engagements stems from a perspective of biological associations, namely the phenomenon of symbiosis. My preoccupation with symbiosis is fuelled in equal parts by the phenomenon's scientific significance towards evolution, and the way it has informed seminal philosophical observations on social organization among humans [1]. The outcome of this artistic research resulted in two publications [2, 3] with symbiosis informing a framework through which I went to analyze the process of and the social dynamics observed within the collaborative engagements conducted as part of my practice, largely concerning live performance works involving interaction between music and dance. At the same time, however, these publications provided scarce details on the technological means used to facilitate the interaction between our respective expressive media. Considering the fundamental role of technology in developing our joint practice outcomes, further reflection on the conceptual debate between symbiosis and performance practice complemented the existing framework for interaction between disciplines and practitioners resulted in findings that appear salient towards identifying distinct modes of interaction between the expressive media of sound and movement.

The findings presented in this chapter have been reached through a Practice Research methodology, and are presented through a process of analytic autoethnography, that is the active reflection of one's experiences in creative work through the wider context of associated practices. The contribution of these findings on technology focus on the application of well-established GRT devices and associated software suites within a novel set of interaction modes informed by the taxonomy of symbiotic relationships, with the activation of these modes presented through both precedent examples, as well as a representative outcome developed through my collaborative practice. In other words, rather than aiming towards creating new technologies for creative expression, this research aims to present new ways of appropriating existing technologies, particularly in manners accessible to practitioners of diverse levels of technological proficiency.

My motivation towards this research approach stems from my previous practice as a performer of Electronic Dance Music, where the limited possibilities presented by analogue disc jockey equipment were a driving force to develop new ways for sonic manipulation. This exploration continued during my first steps within sonic arts, albeit this time through predominantly digital tools, with the addition of modulation devices (e.g. Envelope Generators (EG), Low Frequency Oscillators (LFO), Step Sequencers), as means of predefining and accurately recreating certain sonic gestures in the performed material. However, the accuracy of digital devices made away with the organic and ephemeral feel borne of the imperfections of human movements. This observation coincides with my first forays into collaboration with dancers, as well as my initial experimentations with GRT in sonic performance through the widely used Nintendo Wii Remote (or Wiimote). These early experiments were conducted in collaboration with contemporary dancer Shona Roberts, an already close personal friend, with whom we began exploring ways for motion sensors to manipulate and modulate sound (see Fig. 8.1).

At the time, my main focus was to explore the potential of using physical movement as means of affecting, guiding, and enriching sound, with the connection between the two expressive media being a lesser concern. In essence, my perspective at the time could be described as sonic-centric, where the performer's actions were utilized as merely another source of modulation to augment the previously used devices. Contrary to reducing my collaborator's contributions to the programmed actions of a machine, this approach allowed Roberts unrestricted range of expression

Fig. 8.1 Performance with Shona Roberts at Anatomy, Edinburgh Summerhall, April 2014 (Copyright Richard Dyson, reproduced by permission)

through her choreography, while I enjoyed similar liberty in creating sonically meaningful interpretations of the dancer's arm movement through the data captured by the pair of Wiimotes.

8.2 Interactivity in Performance—Origins and Recent Developments

On reflection, this mutual independence during our earliest experiments with Roberts echoed the collaborative relationship between composer John Cage and choreographer Merce Cunningham, who in developing their joint works would 'intentionally segregate the creation of the sound from the creation of the movement until the performance' [4]. Dubbing this relationship 'autonomous complementarity', Andrew Uroskie explains that this separate development of disciplinary material was an effort in alleviating the dependency of movement to embodying sound in a manner that was to an extent literal, and certainly perceivable by the audience:

> Music was understood to govern, implicitly or explicitly, the movement of the dancers. Choreography, within this propulsive conception, was a kind of musical interpretation, judged on its ability to form a singular synaesthetic coherence in the experience of the audience. [5]

Challenging the traditional notions of audience experience in the work of Cage and Cunningham is further evident from the presentation format of the Black Mountain 'Happenings', a series of events where the combination of music, dance, and visual arts was such as to allow each audience member to experience a unique perspective [5, 6]. The two artists' focus was shifted from the experience of the audience to that of the performers, and the manner in which the latter embodied the received aural and ocular stimuli.

Having explored independence between sound and movement throughout their work in the 1950s, in 1965 Cage and Cunningham developed *Variations V*, arguably the first performance to feature technologically facilitated interaction between music and dance. Working alongside the artists, engineers Billy Klüver and Robert Moog developed two distinct approaches in motion-activated control of music equipment. Respectively employing photosensitive cells and proximity antennas [7], the system was designed as to react to dancers' movements by operating the transport controls of several tape machines storing Cage's sound palette. As such, the notion of sound governing the 'propulsion' of movement was all but eliminated in *Variations V*. However, as Uroskie points out, the dancers were not in conscious control of the sonic palette, which would imply that 'one model of subordination would have merely been exchanged for another'; instead, movement was utilized to 'set a certain train of sonic events in motion' [5]. In other words, while dancers performed Cunningham's precisely rehearsed choreography [7], the sounds triggered from the interaction between movement and the two motion-detecting systems resulted in an indeterminate sonic outcome, an approach in music score that is often associated with the practice of Cage.

With the benefit of more than fifty years of technological developments, a modern look on the modes of interaction between sound and movement in *Variations V* could deduct that the artists were not able to implement a precise control of sound through movement due to the limitations of the relatively crude analogue system in interpreting movement into actuating commands. Nowadays, interpreting movement into digital data has given rise to GRT devices that allow a detailed level of controlling software through physical movement. Such systems are implemented in diverse applications within the fields of computing, manufacturing, as well as arts. On the latter field, researchers and practitioners exploring interaction between sound and movement have formed dedicated communities, such as the annual conference New Instruments for Musical Expression (NIME).

While much of the focus of this research field has been the development of new technologies and methodologies facilitating the expression of sound through movement, implementing these contributions demands a certain level of technical proficiency and knowledge of the associated language and vocabulary. In my practice, I was faced with this issue during my early collaborations with Roberts. To further contextualize the aforementioned independence between our respective material, our approach resulted from the lack of a shared vocabulary. In other words, while *Variations V* presupposed a degree of freedom between sound and movement due to imprecise technology, that freedom in my work with Roberts was dictated due to imprecise language. Although my mapping of the Wiimotes' motion data to sound processing parameters made sense to practitioners familiar with audio software, communicating these mappings verbatim to my collaborator was inefficient in allowing Roberts to understand how her movement affected sound, an issue further compounded by my own lack of knowledge in the language of choreography. While we were able to overcome these issues due to our prolonged collaboration and personal familiarity, I was aware that the privilege of time and patience will not always be present. This realization prompted me to explore a way of communicating my desired intentions in shaping sound through movement via the use of GRT. Prior to this specific research question, my research contributed a framework comprising of a set of strategies and precepts towards guiding polydisciplinary collaborative process [2], with its core concept being the biological phenomenon of symbiosis. From its serendipitous appropriation as the name of our initial collaborative engagement, examining the scientific research of the phenomenon in the context of artistic practice allowed for the development of a system derived from a disciplinary-neutral field, thus avoiding presupposing greater importance to neither of our disciplines.

8.3 The Symbiotic Phenomenon

The lexicological definition of symbiosis (Oxford English Dictionary) suggests two elements existing in a sustained harmonious relationship. However, in the context of biological associations, harmonious coexistence is merely one of the many manifestations of symbiotic relationships. Biologists define symbiosis as the close and persistent relationships between organisms of different species [8]. Organisms engaged in symbiosis are identified as the host and its symbiont, with the engagement most often initiated by the symbiont becoming attached to the typically larger host, motivated by the former's desire to extract benefit from the relationship. In line with the different levels of extraction of benefit, or fitness outcome [9], symbiosis manifests in a variety of types. The three core types are mutualism, commensalism, and parasitism, with each type identified according to the effects it has on the engaged organisms. And since the symbiont is always benefited, it is the effect on the host which defines the type (see Table 8.1).

This taxonomy of relationships refers to symbioses as they are observed at a specific moment in time, described as research on ecological scale [10]. However, examining symbiosis over longer timescales reveals its function as an evolutionary mechanism, with the organisms' evolutionary trajectory reacting to the close and persistent interactions with their partner's specific traits. For example, while a particular partnership may have begun as parasitic (which is often the origin of most interspecific associations [9]), the host will eventually evolve ways to extract benefit from the relationship, while the symbiont will also manage its exploitation of the host with the aim of prolonging the relationship. This reactive evolution serves as proof for an evolutionary trend from parasitism to mutualism, which is nowadays widely accepted by biologists [10].

Having explained the core taxonomy of symbiotic relationships, the next step towards drawing parallels between biological and creative associations is to firstly identify the elements making up each partnership, and secondly establish a relationship between these elements. The first shared aspect among the two forms of association concerns the partners' motivation towards establishing a relationship; that is to combine their individual traits as means of jointly overcoming limitations, respectively borne of environmental [8] and disciplinary [11] factors. From this starting point, the remaining elements are placed through a process of conceptual debate, and finally become organized opposite each other, as summarized in Table 8.2.

This subjective interpretation assumes the symbiotic relationship as the collaborative engagement, with the organisms as the collaborating practitioners. The interspecificity of the engaged organisms is reflected through the different disciplines employed by each practitioner, with each discipline's specific expressive media related to the biological traits carried by each species. In interpreting the roles of host and symbiont, these are allocated respectively on the practitioner instigating the collaboration and the one who is guided according to the former's direction. As will become clearer later on, the used nomenclature applies to engagements which

Table 8.1 Symbiosis typology and fitness outcome

Type of interaction	Fitness outcome	
	Symbiont	**Host**
Mutualistic	Positive	Positive
Commensalistic	Positive	Neutral
Parasitic	Positive	Negative

Table 8.2 Related elements of symbiotic relationships and polydisciplinary collaborations

Symbiotic relationships		Polydisciplinary collaborations	
Organisms	Symbiont	Instigator	Practitioners
	Host	Directee	
Interspecificity	Biological traits	Expressive media	Polydisciplinarity
Fitness outcome		Expressive range	

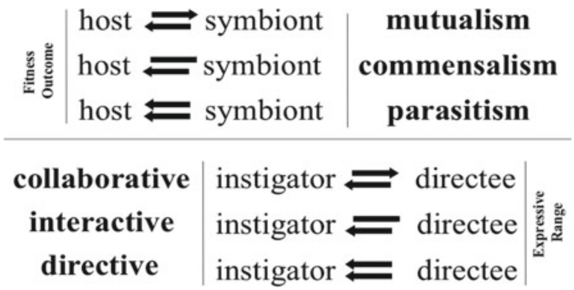

Fig. 8.2 Effect direction in the different types of symbiosis and collaborative process

feature a higher level of dependency, be that a parasitic relationship in symbiosis or a directive collaboration [12] (see note 2) in artistic practice, with the prescriptive meaning of these roles diffused during commensalistic/interactive engagements, and almost entirely absent in mutualistic relationships and collaborative modes.

The final interpretation concerns the element of fitness outcome into expressive range. As mentioned, the types of symbiotic relationships are identified according to the host's fitness outcome, or the level of benefit that organism experiences as a result of its engagement with the symbiont. In the context of my interpretation, expressive range refers to the level of creative input allocated to each practitioner during their collaboration (see note 3). Figure 8.2 showcases the shared direction of effect between the two types of association, with the partner' extraction (or reciprocal exchange) of fitness outcome in symbioses, and delimitation (or conversation) of expressive range in collaborations. In the context of polydisciplinary collaborations, this approach presents an efficient way of understanding and allocating each practitioner's liberty in developing their respective disciplinary material during the process of collaborative engagements (see note 4), with the same principle available towards organizing the relationship between musician and dancer while operating an interactive system.

8.4 Interactive Taxonomy: Theory and Precedents

As mentioned in the introduction, the typical approach of using GRT in music-dance interaction concerns the change of sound through movement. This effect is achieved by mapping movement data to various parameters of DSP devices, with the sound consequently affected as a result of the movement data performing alternations on the parameter's values. Considering this relationship between the two media, sound can be understood as the symbiont medium, with movement being the host governing the development of sound. With this principle in place, and taking into account a host's different fitness outcomes during each type of symbiosis, an equal number of interaction modes can be derived, where the 'host' movement can be 'benefited', 'harmed', or 'unaffected' by its 'symbiont' medium of sound. In line with the previous subjective interpretation between the elements making up each association, the biological notions describing changes in fitness outcome are related to the restrictions, or lack of, placed on the expressive range of the associated media and their respective practitioners during a performance. The most efficient way to establish these relationships is by first observing the resulting sonic outcomes, followed by the restrictions placed on the movement, the provision in which the two performers develop their respective sonic and movement material, and finally the dancer's awareness of how their movement affects sound while operating the system.

Looking at the first association, when the collaborative performance requires a determined sonic outcome (akin to a fixed music score), the dancer must perform a specific set of movements in order to alter the values of the DSP parameters in a predefined manner. As a result, this interaction mode imposes restrictions on the movement's range of expression in order to accommodate the desired sonic outcomes. Furthermore, with the mappings between movement data and DSP parameters having been created by the music practitioner, she or he needs to communicate to the dancer the required movements needed to achieve the determined development of sound over the duration of the performance. Consequently, the dancer is relieved from having to fully understand the ways her or his movements may affect sound beyond the predefined movements. As such, this interaction mode assumes movement as a predefined modulator for the sound. In other words, through the previously discussed subjective interpretation of the biological notions describing fitness outcome, the 'host' movement is 'harmed' in order to 'benefit' its 'symbiont' sound, thus establishing a parasitic symbiosis between the two expressive media.

On the opposite spectrum of sonic outcome, an indeterminate score entirely alleviates any requirement for the dancer to become familiar with the mappings between movement data and DSP parameters, with movement remaining independent to sound. However, from the musician's perspective, the mapping must be designed as to accommodate the dancer's full range of movements which she or he may deploy in any manner and time throughout the duration of the performance. In a way, the randomized alteration of DSP parameters during this interaction mode can be related to a generative music system, or to provide a further simplified reflection, to the modulations derived by an LFO set to random or noise waveform. In the context of the symbiotic interpretation, the 'host' movement is 'unaffected' due to enjoying a full range of expression, while the 'symbiont' sound extracts 'benefit' in the form of randomized modulations that can be used to develop and expand its outcome. As such, this interaction mode forms a commensalistic symbiosis between sound and movement, which on reflection can be associated with the interaction employed in

Variations V, when dancers had an effect on sound despite being unaware of the ways their movements specifically controlled Cage's tape players. However, while Cage revelled in employed indeterminacy as a compositional approach, Cunningham directed his dancers through an explicit choreography. Nevertheless, this is but one manifestation of a commensalistic interaction mode, and as I present later in this chapter, free improvization presents itself as fruitful provision for the dancer to follow, with the musician tasked with designing a system able to generate meaningful sonic outcome through random modulation inputs.

With mutualism being the remaining type of symbiotic relationship, such an interpretation into the context of collaborative performance requires for both sound and movement to mutually extract 'benefit' from their interaction, which considering the earlier connection between fitness outcome and expressive range, suggest a simultaneously full range of expression for both media. While the provision of free improvization may at first appear salient to this mode, developing this mode through practice showcased that an intermediate provision is more appropriate, that of structured improvization. Examining this provision in the context of music performance, structured improvization differs from its free counterpart by the approach of creating real-time compositions by connecting pre-established material over an arrangement which is not predefined [13]. As such, while the resulting sonic outcome is not determined, its characteristics can be anticipated. Structured improvization shares a slightly different meaning in the context of choreography, with dancers adhering to a predefined temporal arrangement in relation to stage placement and clustering, while retaining freedom towards their performed movements during each section of the arrangement [14]. Considering these provisions for music and dance respectively, in the context of GRT-facilitated interaction the dancer is allocated freedom towards her or his movements, with the caveat that these movements need to result to anticipated sonic outcomes. As such, the dancer must be well-familiarized with the system's mapping, and be aware of the ways each movement may affect sound. In other words, the mutualistic interaction mode presents a mutual compromise between the expressive ranges allocated to sound and movement, with both media mutually extracting 'benefit' up to the level at which one of them can be said to experience 'harm', thus resembling the mechanisms by which mutualistic symbioses are developed over evolutionary scale in the natural world.

The three symbiotic modes of interaction are summarized in Table 8.3, with each mode identified according to their specific effect awareness, provision,

Table 8.3 Taxonomy of symbiotic interaction modes with associated elements

	Interaction modes		
	Mutualism	*Commensalism*	*Parasitism*
Affect awareness	High	Low	Moderate
Provision	Structured improvisation	Free improvisation	Score/choreography
Operation	Exploration	Detachment	Instruction
Outcome	Anticipation	Indeterminacy	Determinacy

operation, and outcome borne of the interaction between the two media. At this stage, it is worth pointing out once again the subjectivity and conceptual nature of this interpretation, and furthermore the Practice Research methodology employed towards reaching these findings, with the latter derived through the accumulated knowledge from numerous years of collaborative practice alongside several practitioners. As presented later in this chapter through the work *Symbiont Zero* [15], in addition to employing distinct modes of interaction, multiple modes can also manifest during a performance, either consecutively during different sections, or simultaneously while operating different layers of sound, each controlled via a different mode. Prior to describing our collaborative outcome and designed interaction system, I demonstrate the taxonomy's theoretical standing by examining three interactive works as means of identifying their specific modes of interaction. Rather than providing a conclusive literature review of the field's practical outcomes, the presented precedents were selected as to represent distinct uses of GRT, collaborative processes, and employed aesthetics.

8.5 Symbiotic Interactions in Precedent Practices

Stratofyzika is a Berlin-based collective, with its founding member comprising musician Lenka Kocisova, visual artist Alessandra Leone, and dancer Heather Nicole (Hen Lovely Bird). Their 2016 work *THÆTA* [16] presents a dialogue between the three media of sound, movement, and visual. In the context of the symbiotic concept, the dancer serves as the host modulating sound and visuals, with the interaction facilitated through a wearable Inertia Measurement Unit attached on the dancer's arm, with the movement data simultaneously modulating the two software suites generating sound and visuals. According to Leone, rather than having a constant flow of movement data into the system, this flow is interrupted by altering the correlation between movement data and resulting value alteration via algorithms [17], as well as activating the data stream only during predefined moments. With the dancer aware of the way her movement affect the other two media, it is during those moments of activated interaction that the dancer is able to freely employ movements that result anticipated sonic and visual outcome, such as the floor roll (see [16], 1:10–1:20) resulting in a white spire and a tone of descending pitch.

The second precedent is one of the audio-visual installations developed with the danceroom Spectroscopy (dS) visualization system. Using an array of depth perception cameras (Microsoft Kinect) as its GRT devices, the system is able to extract movement data from multiple participants, with the date used to modulate the visualizations. While dS was designed primarily as a research tool for molecular dynamics, allowing researchers to visualize particle movement, as well as interact with their visual representations [18], it then became the basis for a series of creative outcomes with the addition of a sound-generating system sharing the data modulating the visualizations, with the movement data coming from a troupe of dancers. In addition to the performances, the team behind dS also presented the system in the configuration of a public multi-participatory installation, where audience members are invited to interact with the system. The result of this interaction is that sonic and visual events are manipulated by movement without the controllers having any prior training with the system [19], thus demonstrating a commensalistic interaction mode. A point of interest here is that once an audience member began exploring the system, they would attempt to understand what their effect is on the media, resulting in an adaption of the interaction mode. While this does not in itself form an undesirable aspect, I later present a solution devised towards maintaining commensalism during interaction.

Finally, as an example of practices displaying parasitic interaction between sound and movement, Marco Donnarumma's *Corpus Nil* [20] is a work which appears to absolutely appropriate the notion. For this work, Donnarumma devised a choreography comprising of 'five key bodily postures' [21], each designed as to force the system to generate a specific response from the sound and lights it controls. With the system operating through machine learning algorithms able to identify specific positions by their duration, the performer must sustain these positions as to progress through the arrangement. As such, Donnarumma is restricted by the design of these key positions, or more accurately, is able to move only within the restrictions posed by each position. Understanding this approach through the symbiotic framework, the performer possesses a detailed awareness of the ways their movement affects sound and lights, and is able to perform the determinate sonic outcome through their movements. This sits in contrast to the approach employed by Stratofyzika and danceroom Spectroscopy; in the latter, audience members are unaware of the ways the system interprets their movements as modulations for the other two media, whereas in the former, the dancer is aware of the effects her movements have on the interacting media, and is allowed to explore movements along with the effects these have on sound and visuals. In the case of *Corpus Nil*, the performer's movements are intended to achieve predetermined changes to the other two media.

8.6 Symbiotic Modes of Interaction in *Symbiont Zero*

As mentioned earlier, the findings presented in this chapter stem from my collaborative practice alongside several dancers. Following the development of the theoretical frameworks for polydisciplinary collaboration and symbiotic modes of interaction, my aim was to activate the entire spectrum of interaction modes within a single creative outcome, with the additional purpose of serving as a demonstration of the framework. In order to satisfy both purposes, *Symbiont Zero* has been documented both as complete performance, as well as a set of demonstration videos, with the latter displaying a simplified version of each interaction mode, with additional perspectives providing simultaneous views of the musician's inputs via external controllers, as well as the effects both performers conduct on the mapped parameters (see Fig. 8.3 for a representative example).

Fig. 8.3 Demonstration video with multiple views: dancer (Cunliffe), external controller, and mapping distribution matrix

The work was initially developed with my long-term collaborator Roberts, and subsequently performed with contemporary dancers Lucie Lee, Joseph Lau, and more recently Kelsea-Leigh Cunliffe. The premise concerns a musician-dancer duet featuring interaction between their respective expressive media through GRT. With a total duration of approximately fifteen minutes, the piece develops over three movements, or sections, of equal duration, and while each section predominantly focuses on a single mode of interaction, the performers have gone to implement areas of adaptation through simultaneous employment of different modes while controlling multiple layer of sound.

In describing the path of the movement data into the system, the concerned GRT devices comprise a pair of Wiimotes tethered on the dancer's forearms as means of performing alterations to the sound-generating system. This system is hosted within Ableton Live, receiving a total of eight data streams from the two Wiimotes, following their capture and conversion into MIDI CC messages through the application OSCulator. These continuous messages are then mapped onto two Max for Live devices, namely, Map8 and Multimap, which serve two purposes; firstly, acting as a distribution matrix from which to map each data stream onto multiple DSP parameters, and secondly, allowing the musician to toggle the activity of each mapping, as well as alter the range, direction, and curve of each mapping's effect on their destination during the performance. The musician's inputs are achieved through two hardware MIDI controllers combining continuous and toggle controls. The data path is graphically represented in Fig. 8.4, (albeit for the data from a single Wiimote

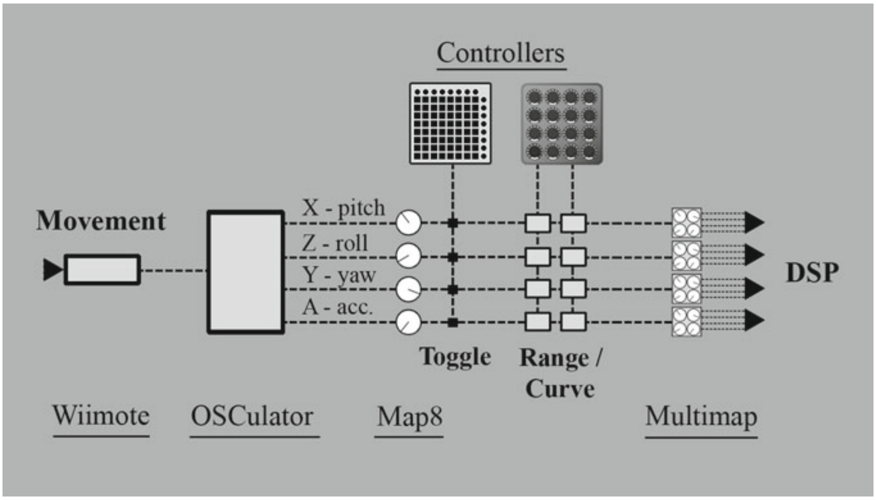

Fig. 8.4 Path of gesture data, from dancer's movement to DSP mapping

only), with the following subsections describing the work's three sections in terms of both system operation and performance planning. Each section is described under the title of their predominant mode of interaction.

8.7 Mutualism

In line with the aspects of mutualistic interactions, the dancer has been familiarized with the system, and is able to anticipate the ways her movements may affect sound. Furthermore, the performers have noted certain combinations of movements and specific ranges in the distribution matrix which resulted in interesting sonic outcomes, which the performer has memorized and able to deploy at will.

The main interactive sound during the mutualistic section is generated by a feedback delay (Amazing Noises Dedalus Delay), with its parameters mapped to the Wiimotes' eight continuous messages, these being X-axis (vertical position), Y-axis (roll), Z-axis (yaw), and acceleration. In this case, the X-axis of both devices is assigned to the delay's two filters, low pass and high pass for left and right arm, respectively. This particular mapping ensures that the performer maintains control over the overall signal amplitude, which subsides by simultaneously pointing both arms upwards due to the removal of high or low frequencies by either filters. The remaining mappings are arranged to parameters such as pitch shifting, size and frequency of grain, and addition of parallel distortion and reverberation.

The musician's role during this section is to adjust the range by which each continuous message affects the mapped parameters. This is achieved by adjusting the range parameters on the Map8 device, thus altering the dancer's level of influence on each mapped parameter. The section begins with the filter ranges restricted middle frequencies, while the dancer concentrates on upper body movements. Halfway through the section, the musician broadens the range of the filter mapping, causing a sudden increase in amplitude. This serves as a signal for the dancer to initiate weight transfer movements, resulting longer movements across the stage.

8.8 Commensalism

As described in previous sections, commensalistic interactions alleviate the need for the dancer to possess prior knowledge of the ways movement affects sound. However, as mentioned in the description of dS, participants in control of sound will naturally begin to discover the connections between their movements and changes in sound, resulting in an adaptation of mode. Aiming to avoid this adaptation during the commensalistic section of *Symbiont Zero*, I designed a system able to dynamically alter the mapping during the performance. This is achieved by mapping a single movement stream of continuous change message to several DSP parameters by inserting an instance of Multimap between one of Map8's outputs and the DSP inputs. Furthermore, toggles are assigned to toggle each of the Multimap's outputs. The result of this design allows the musician to continuously alter the movement data stream distribution among the mapped DSP parameters, and thus avoid the dancer to gain a fixed relationship between her movement and specific sound modulations.

The sound generation is based on a series of granulators (Audiority Grainspace) processing recordings of synthesized percussive patterns, with the Wiimotes' CCs mapped to parameters such as start–end of input sample, pitch and tone variations, saturation, size of and distance between grains, and level of parallel reverberation.

While the dancer is entirely at liberty to freely improvise her movements, she is also motivated to 'forget' the interaction, and instead treat the resulting sound as recording, akin to improvising to a fixed (non-interactive) composition. The only cognisant interaction of the performer occurs after a new layer of sound appears, made of two percussive samples (respectively kick drum on the left arm and snare drum on the right arm), each activated by the acceleration streams going over a set threshold which triggers a MIDI Note on message mapped to an instance of Ableton's Drum Rack containing the percussive samples.

Once the performer becomes aware of the new layer, she is able to interact with the two sounds through a mutualistic mode, while simultaneously maintaining her commensalistic interaction with the previous sound layer. The section ends with the initiation of a further sound layer made of arpeggiated synthesiser pattern, signifying the transition into the final section.

8.9 Parasitism

The parasitic interaction presents the highest level of accuracy from the dancer, while at the same time imposes the highest level of restriction on their movements. The Wiimotes' CCs are mapped to a synthesiser (Ableton Analog) generating a fixed arpeggio pattern, with the left arm controlling the synthesiser's low pass filter cutoff frequency on the X-axis and envelope attack duration on the Y-axis (rotation), while the right arm controls reverb depth and delay feedback on X- and Y-axis, respectively. In line with the approach during parasitic interaction modes, the sonic outcome is determined, in this case being a slow modulation between the wet–dry balance of the reverb, followed by a filter frequency sweep of equal duration. At the same time, the determined outcome requires for staccato (sudden jumps in value) modulations on the two remaining parameters, resulting in altering the note's envelope shape and feedback level. Finally, the two percussive samples from the previous sections are required to be activated at the end of each filter sweep cycle, resulting in the dancer interacting with this layer through a parasitic mode, as opposed to the previous mutualistic engagement.

With the determined sonic outcome providing a limited range of movements for the dancer, the latter is then free to develop their own choreography within this restricted range. Having performed the piece with four different dancers, a particularly interesting finding is that while each dancer were able to achieve the determined sonic outcome, each reached that through distinct sequence of movements. For example, Roberts maintained her core still while only moving her arms (as to achieve the modulations on the synthesiser's parameters), Lee continued to move across the stage while limiting the movement of her arms in line with the score. Similarly, while Lee activated the percussive samples by performing waving movements with her arms, Cunliffe opted to perform sudden contractions and extension, akin to punching motions. This showcases that despite the imposed restrictions during parasitic interactions, dancers are able to interpret the score through different choreographic movements.

In describing the remaining section, once the filter sweep sequence has been performed twice, the dancer is instructed to resume a mutualistic interaction with the percussive samples, while at the same time the musician limits the mapping range of the synthesiser parameters, who is then able to assume control of these parameters through their external controller. As a result, the musician 'takes' away control from the dancer while she breaks free from the previous restrictions. This continues for around one minute, before the dancer assumes the previous position, and the musician returns the control of the synthesiser back to the dancer, who repeats the previous movements twice. *Symbiont Zero* concludes with a short section of commensalistic interaction, where the performer's movements influence a pair of granulators (New Sonic Arts Granite) processing two segments of recorded music, namely, the 'Amen' and 'Hot Pants' drum breaks. As with the previous section, the performer is unaware of the effect their movements exert on the newly introduced sounds, and is instructed to perform an improvized sequence, with its intensity influenced by the overall level of sound made of the combined elements, which begins to fade until silence to the end of the piece.

8.10 Conclusions

Although the analyzed precedents do not constitute an exhaustive review of the field, the interactive works portray a selected collection of practices displaying diversity in GRT (Inertia Measurement Units, depth perception cameras, and biophysical sensors), in the make up of their collective creation (inter/multi/trans-disciplinary respectively), and as explained earlier, in the employed interaction mode between physical movement and digital audio-visual material. Appropriating the typology of symbiotic relationships towards forming a new taxonomy in technologically facilitated interaction allows for the diversity in which interactive performances manifest to be identified within just three modes of interaction, each comprising of thee aspects—provision, operation, and outcome—as well as the level of training or familiarity with the system required by the dancer. This serves as an efficient approach towards communicating the purpose of each mode, particularly assisted by the lack of convoluted terminology, which can often be counterproductive when used to communicate the desired outcome to practitioners whose expertise focus on other areas of practice.

This research has thus far focused on dyadic collaboration, with future view of assessing the symbiotic concept with multiple partners. Furthermore, while the use of consumer GRT devices was implemented as means of making the research outcomes more inclusive (due to being both reliable and inexpensive), the limited accuracy and expansion of these devices have become to emerge in my practice, which serves as motivation to look into developing bespoke devices, in line with current trends in the field of interactive arts research.

Most importantly, however, it is my strong belief that the future of interactive arts will greatly benefit from researchers combining technological innovation with artistic Practice Research, a symbiotic relationship if you will. In my experience, although some steps are already taken by few brave individuals, the two fields' distinct approaches, cultures, sensitivities, and nomenclature result in hesitation towards tighter integration. But akin to the parasitic beginnings from which most symbioses begin their evolutionary journey, persistence and closeness will eventually manifest in mutual aid among the two domains of creative practice, artistic and scientific. In the words of Pëtr Kropotkin, 'In the practice of mutual aid… we thus find the positive and undoubted origin of our ethical conceptions; we also see the best guarantee of a still loftier evolution of our race' [1].

Notes

(1) The term polydisciplinary is used to denote the multiple modes by which disciplines interact, as an alternative to the more popular 'interdisciplinary', which I consider to be erroneously habituated for this purpose, as it ignores established principles of taxonomy. I provide a more thorough discussion on this subject in Sect. 2.2.2 of [3].

(2) The referenced modes of collaboration are derived from the work of Hayden and Windsor [12], identified as directive, interactive, and collaborative, each suggesting a different level of creative liberty between the engaged practitioners.

(3) The social aspects of collaboration, along with the notions of allocating creative direction duties, privileges, and responsibilities, have been addressed in my previous paper [2].

(4) For a detailed description of the symbiotic framework on collaborative process, see chapter three of [3].

References

1. Kropotkin, P.: Mutual Aid: A Factor of Evolution. McClure Phillips & Co., New York (1902)
2. Moriaty, M.: Symbiosis: organisation and mutual exploitation in interdisciplinary collaboration, artistic research will eat itself. In: Proceedings of The 9th SAR International Conference on Artistic Research, University of Plymouth, UK, 11–13 Apr 2018. Cox, G., Drayson, H., Fatehrad, A., Gall, A., Hopes, L., Lewin, A., Prior, A. (eds.): Society for Artistic Research, pp. 81–96 (2018)
3. Moraitis, E. (Moriaty, M): Symbiotic synergies: adaptive framework for polydisciplinary collaboration in performance practice. Ph.D. thesis, School of Arts & Media, University of Salford, Manchester (2019)
4. Klosty, J.: Merce Cunningham. E.P. Dutton, New York (1975)
5. Uroskie, A.V.: from pictorial collage to intermedia assemblage. Animat. Interdiscip. J. **5–2**, 223–241 (2010)
6. Kirby, M.: Happenings: An Illustrated Anthology. R&R Books, Reno (1966)
7. Miller, L.E.: Cage, Cunningham, and Collaborators: The Odyssey of Variations V. The Musical Quarterly, Oxford University Press, vol. 85–3, pp. 545–567 (2001)
8. Douglas, A.E.: The Symbiotic Habit. Princeton University Press, New Jersey (2010)
9. Paracer, S., Ahmadjian, V.: Symbiosis: An Introduction to Biological Associations. Oxford University Press, New York (2000)
10. Sapp, J.: Evolution by Association: A History of Symbiosis. Oxford University Press, New York (1994)
11. John-Steiner, V.: Creative Collaboration. Oxford University Press, New York (2000)
12. Hayden, S., Windsor, L.: Collaboration and the composer: case studies from the end of the 20th century. **61–240**, 28–39. Cambridge University Press, Tempo (2007)
13. Cage, J., Kirby, M., Schechner, R.: An interview with John Cage. Tulane Drama Rev. **10–2**, 50–72 (1965)
14. Pressing, J.: Improvisations, methods and models. In: Sloboda, J. (ed.) Generative Processes in Music, Clarendon Press, New York, pp. 129–178 (1987)
15. Moriaty, M.: Symbiont zero: multimodal interactive performance, 19 Aug 2019. Accessed 20 Nov 2019 [Online]. https://manolimoriaty.com/symbiont-zero/

16. Leone, A.: StratoFyzika—THÆTA, 16 Dec 2016. Accessed 20 Nov 2019 [Online]. https://vimeo.com/195961322
17. Leone, A.: Personal interview, 19 Feb 2018
18. Glowacki, D.R., O'Connor, M., Calabró, G., Price, J., Tew, P., Mitchell, T., Hyde, J., Tew, D.P., Coughtrie, D.J., McIntosh-Smith, S.: A GPU-accelerated immersive audio-visual framework for interaction with molecular dynamics using consumer depth sensors. Faraday Discuss **169**, 63–87 (2014)
19. Royal Society of Chemistry: Atoms and molecules are not static by dance room Spectroscopy (dS), 3 June 2014 [Online]. https://www.youtube.com/watch?v=H_EJquvSBMQ. Accessed 20 Nov 2019
20. Donnarumma, M.: Corpus Nil, 22 Jan 2016 [Online]. Accessed 20 Nov 2019 [Online]. https://vimeo.com/152710490
21. Donnarumma, M.: Configuring corporeality: performing bodies, vibrations and new musical instruments, Ph.D. thesis, Department of Computing, Goldsmiths University of London, London (2016)

Chapter 9
Between Presence and Program: The Photographic Error as Counter Culture

Tracy Piper-Wright

Abstract Common photographic errors such as over or under exposure, blur, or inadvertent cropping are increasingly rare as technological developments in digital photography have sought to eradicate the error from practice and perception. Efficiencies such as camera automation and image preview are often designed to remove the 'unreliability' of the human element in order to produce accurate and consistent images. The error, occurring on the margins of practice and increasingly rare, provides a counterpoint to this prevailing image culture by revealing the interdependence of photographer and camera through unintended outcomes. This chapter explores the ideological assumptions entwined in the development of camera technologies, and how cultures of practice based on a hierarchy of control between camera and photographer arose. Through examples drawn from the research project *In Pursuit of Error*, the chapter demonstrates how the error disrupts this hierarchy by evidencing the shared subjective agency of camera and photographer. The methodological framework of Actor-Network Theory is used to interrogate the relationship between photographer and camera and to reveal them as equal 'actants' in the event of photographing. The embodied photographer's attitude of play, experimentation, and not-knowing is interdependent on the camera as a co-creator of unexpected image events which disrupt the conventions of photographic representation.

Keywords Photography · Error · Agency · Doubt · Actor-Network · Embodiment · Subjectivity · Time · Hierarchy of agency · Digitization · Virtuality · Actor-Network Theory · Transformative art · Alternative realities · Presence · Cultures of practice · Experimental photography

9.1 Introduction: Histories and Hierarchies

Alone of all the creative arts, photography is the most deeply enmeshed with the technologies of production. A photograph cannot be made without an instrument external to the photographer whereas one might argue the technologies of drawing

T. Piper-Wright (✉)
University of Chester, Chester, UK
e-mail: t.piperwright@chester.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_9

or painting can, on occasion, be replaced by the human hand and the right surface. The symbiosis between camera and photographer makes for a peculiar push and pull between the claims of the technical and the subjective, which have been the hallmark of writing about photography as, variously, an art, a craft and a science since the inception of the medium. The tension between an apparently objective and automatic picturing mechanism and the role of the photographer in the creation of the image dates back to the critics and practitioners of the late nineteenth century, and centers around a hierarchy of agency—who or what is finally responsible for the photograph?

The unavoidable connectedness between camera and photographer is not a fault of the practice, but rather an important distinction which must be recognized in any discussions about it. In the early twenty-first century the digitization of photography coincided with the connectivity offered by the Internet, producing the circumstances for limitless digital images to be created and subsequently shared and viewed in distributed networks. This rapid development created extra layers of technological distance between photographer and camera as points of tension emerged between the physicality of analog film and the 'virtuality' of the digital photograph [1, p. 97]. As digital cameras become increasingly abstruse and proliferate the question of the relationship between it and the photographer becomes one of knowledge as well as agency. If I cannot know what the camera is actually doing, how much control can I have? The "*black box*" [2, p. 27] of the digital camera lies so far outside the realms of ordinary understanding that photography has almost returned to the realm of the magical.

What made photography 'magical', in its earliest presentations, was its ability to capture and retain an image of the world with a precision hitherto impossible through the human hand alone [3]. While early discussions on the invention of photography refer to the photographic *process* rather than the camera itself; the technology of the camera as an anthropomorphized 'eye' was first proposed by Da Vinci in relation to the camera obscura [4] the earliest form of enclosed light projection from which cameras were developed. Thus, some assumptions about photography were set out at the early stage of its development: a monocular, perspectival viewpoint which mimics the focus of attention in human vision and a unique responsibility to reality which is the product of an "*unreasoning machine*" that produces "*an unerring record*" [5, p. 269].

The camera's 'eye' supersedes the frailties of the human eye through its objective stance and ability to transmit and reveal the world as it is, without interpretation or editing. The camera becomes a technology for asserting truth, and the images it produces are facts that can be used as evidence.

Leading from its perceived status as a truth-telling machine, the quest for simplified and accessible accuracy has been a dominant motivator in the technological development of the camera. The famous Kodak strap line which accompanied the launch of its camera in 1888 "*You push the button - we do the rest*" [6, p. 38] exemplified a desire to remove the possibility of error in the creation of a photograph by eliminating the more complicated or technical aspects both in camera design (the camera had a fixed focus lens and limited aperture/shutter speed controls) and in the loading and development of film (the whole camera was sent back to Kodak for processing, thence replenished and returned to the owner) [6].

The Kodak camera is evidence of the twin aims of technological progress which can be found in most subsequent camera development including digital. Firstly, there is the desire to ameliorate the complexity of the photographic process per se; the unknowable chemical/algorithmic functions which are performed in the making of the image. Secondly, the camera sets out to moderate the potential of a faulty, error-prone human element from entering the photographic equation. The photographer is reduced to being a button pusher, and no more. The twin aims of camera development: simplicity and error elimination can be seen in many of the innovations in camera technology in the twentieth century, such as cassette film and auto-focus, which continued into the twenty-first century digital revolution.

These reflections on the early history of photography show that the pursuit of accuracy has been at the forefront of the practice and perception of photography since the beginning. The linking of photography as a technical yet simplified image making method that requires the presence of a 'button pusher' but which devolves the image making to the camera, makes for a peculiar awkwardness in the relationship between human and camera: an oddly mismatched hierarchy in which the photographer is perceived as both necessary and extraneous to the photographic event.

Despite these advances, errors still crept into the practice of photography. Not every eventuality could be eliminated, and the material agency of the film and the chemical process contained many potential pitfalls for the photographer, which were often only revealed once the prints had returned from the developer. Unsatisfactory images could be discarded, but were often simply incorporated back into the wallet of photographs. The gap between the making and revealing of an error effected a nostalgic distance between event and object in which the significance of the image could override the obvious flaws in the depiction. In the analog era photographs were perceived as a finite resource, and an error might appear a charming reminder of a moment in time.

Digital photography took its cues from film photography in terms of camera design and it is therefore unsurprising that its subsequent development extended the simplicity/error-elimination methodology. However, digital photography offered a level of certainty that far exceeded what had been possible before. Due to the algorithmic nature of the sensor and digital processor cameras became computers, and the photographer became less and less the primary decision-maker [7]. Later developments such as image preview effectively capped the potential for error by making it possible to delete substandard images at source, narrowing the possible images that could emerge from any given shoot. In the digital era the opportunities for 'casual' error creation changed; no longer could a substandard image slip through the net and into the pile of prints. Each image could be vetted so that only the best were eventually presented in online spaces.

As our consumption of photography as digital images in networked environments increases the more our perception of photography reflects what we are presented with—invariably 'good' photographs. In this case a 'good' photograph does all that a photograph should: it shows things as they are, to the best of the camera's ability.

The technology of the camera, now most often embedded in a phone, can control lighting, saturation, and shadows to produce high quality images that feel ‘just like being there’. This quest for transparency, for a feeling that you are looking at or experiencing the ‘real thing’, has been the ultimate goal of consumer digital photography, with increased mega-pixels offering more and better rendering of the scene. The photograph becomes a window through which we observe the phenomenon depicted. This hyper-verisimilitude removes even the camera as the creator of the work, ostensibly rendered out of existence by the perfection of its image [7].

Concomitant with these advances is the increase in the quantity of images made available by digital technology. Not only do the best arrive on the Internet, but pretty much everything else, so that we wade through a sea of images at every turn. While photographs enter the network within a particular context they do not remain there in perpetuity, and can soon break free to circulate and appear in multiple sites and locations. The plurality and mobility of the digital photograph leads to a dissociation of the image from its context in time and place and a peculiar sense of authorlessness, where even the fact that we are looking at an image made by a camera pointed by a human can escape our perception.

The foregoing commentary sets out the context in which the research project *In Pursuit of Error* [8] (hereafter referred to as IPE) emerged and seeks to challenge. The project collects photographic errors from artists, photographers, and the general public in order to form an archive of the error in contemporary practice. Contributors are asked to include a statement that explains how their photograph occurred and why they feel it is an error. Through analysis of the images and narratives, the project reveals how artists value the accident as a point of discovery and development and engage in playing with and against the camera in the creation of ‘deliberate’ errors. The project aims to question some of the assumptions about representation and truth which beset photography as a practice, and to challenge the assumption that technological developments manifest objectively rather than because of cultural and ideological assumptions about what is correct or good. Thus the project attempts to destabilize the hierarchy that attaches to the relationship between camera and photographer (with one or the other ‘in control’ at any given time) in favor of exposing the horizontality of this relationship [9, p. 283]. The project uses the error to explore a revitalized concept of photography as an embodied, performative practice, in which the bodies of photographer *and* camera play a part.

9.2 Camera Acts and Human Acts

In order to consider how humans and cameras interact in the creation of a photograph, it is necessary to think through the processes that bring a photograph into being. Despite common assumptions about time in relation to photography—the split second ‘capture’—making a photograph has a number of stages, from the first desire to take a photo, to preparing or starting the camera, to focusing or selecting the composition through viewfinder or on screen and only then the taking of the photo. In this extended time period both camera and photographer perform a number of acts, the photographer her gestures, the camera ordered by the principles of its program. Within these parameters correct images are to be had; however, flouting the rules of either program or gesture tend to produce unexpected or unintended results.

It is useful to consider the practice of taking a photograph as operating on a continuum of control between agency and automatism. While one might assume that ‘agency’ pertains solely to the photographer and ‘automatism’ to the camera, in practice these roles are interchangeable [10]. Automatic gestures—holding the camera steady, or straight, or automatic programs such as auto-focus or aperture control create more or less expected results according to the scene presented. Agency plays its part in the decisions or mistakes of the photographer but the camera’s agency can also intrude on the photographer’s intentions, resulting in surprising and unexpected images.

The photographic errors submitted to IPE cover a range of accidental or unintended images and ‘deliberate’ errors in which a willful action has been made to achieve an unpredictable result. In many cases it is near impossible to identify from the resulting error image which party was the instigator, without the photographer’s identifying narrative in support (Fig. 9.1). While the visual distinction between the two types of errors is not necessarily apparent, they create a useful distinction which permits

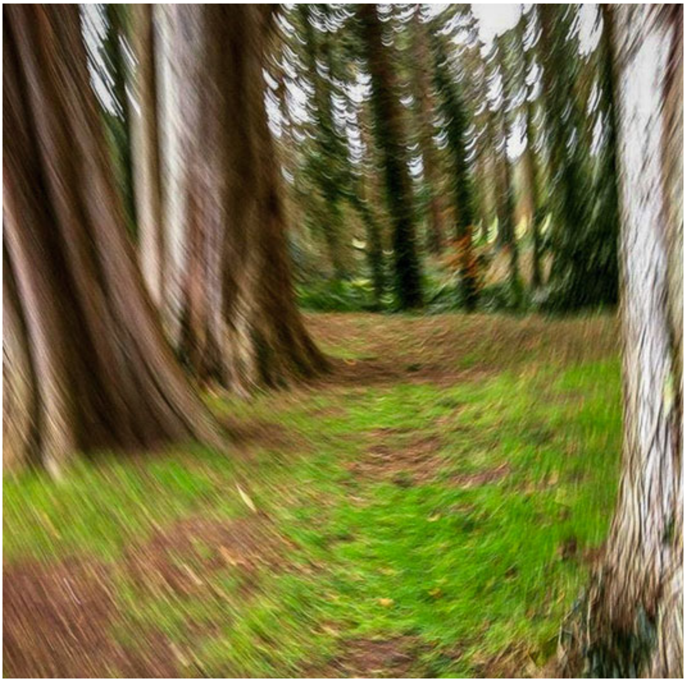

Fig. 9.1 Image copyright © Gail Griggs and reproduced by permission. Source: *In Pursuit of Error* [8]

a focus of attention on either actor in the event of photographing—the camera or the photographer. The narratives that accompany the contributions to IPE reveal the push and pull between the photographer's vision and the camera's vision, and where the presence of the camera as agent in the creation of the image is made apparent.

9.3 Agents and Networks

To consider the camera as an agent, or an accomplice, in the act of photographing is to reconsider the role of the technology and our relationship with it—as user, as master, or as collaborator. Actor-Network Theory (ANT) creates a framework through which to reconsider this relationship, based upon acknowledgement of the "*symmetry of humans and non-humans*" [10, p. 642] in networks. Networks are formed of social practices and technical processes as well as human and non-human 'actants' and vary in scale. A network could be as small as the photographer and her camera, or can be broadened out to consider the camera's developer and manufacturer, the photographer's educators and peers, and the social and cultural context of photography practice. ANT emerged from the sociology of science and technology as a means to critique assumptions about the development of technology in societies, pointing out relationships of power and questioning deterministic models of scientific development which present such development as rational and autonomous. ANT's non-hierarchical emphasis on 'actants' erodes distinctions between human and non-human actors and creates opportunities to consider how technology not only 'speaks back' to us through our interactions with it, but also how technology governs and en-frames our performance with it [11].

In the context of Actor-Network Theory the error sheds new light on the relationship between camera and photographer. Many of the accidental errors that are presented to IPE occur due to the mismatch between the photographer's intentions and the camera's program, or more strictly speaking, the settings that have been selected on the camera. Most modern cameras permit the pre-selection of aperture and shutter speed to account for the proximity of the subject and light conditions. Errors occur when the conditions fail to match the camera's settings, or vice versa (Fig. 9.2). In this case the situation being photographed becomes another actant in the network, a set of conditions which intrudes upon and affects the outcome.

In the surprise that is created by these unexpected images the photographer is made aware of their reduced role in the event of photographing, instead giving over the task of picturing to the camera. This mismatch between program and situation, 'translated' by the camera, presents a wholly new way of perceiving, a form of camera vision which reminds us of the subjectivity of perception per se. While gross mismatches between program and conditions create image-worlds far beyond our imagination, small collisions between settings and situation create spikes of maladjustment in the image through which the presence of the camera as an observing body can be detected. The accidental error unequivocally brings the camera's presence to the fore (Fig. 9.3). These images do not allow us to look 'through' or 'past' the photograph

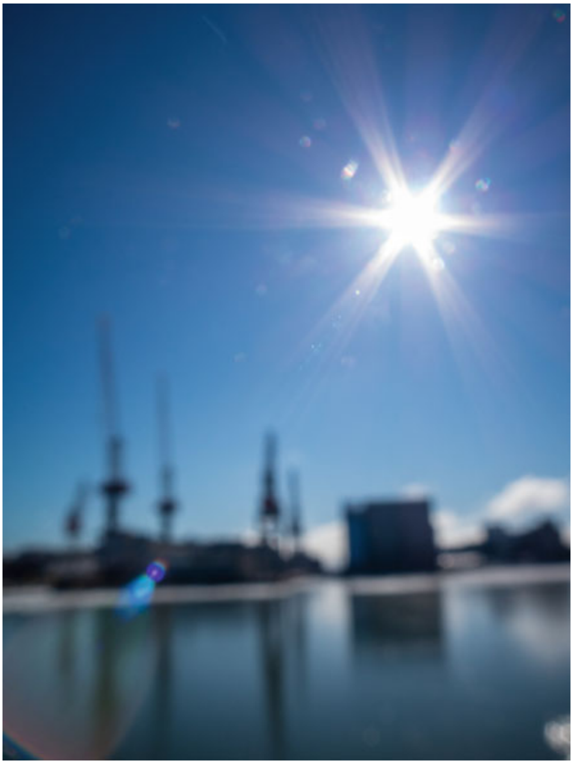

Fig. 9.2 Image copyright © Ian Wright and reproduced by permission. Source: *In Pursuit of Error* [8]

as medium, instead, through its faults, the 'photographicness' of the image is made glaringly apparent. The accident is therefore a valuable reminder of the technological mediation which the camera brings to the act of photography, a subjective vision which is easily overlooked in conventional photographs.

Photography's connection to the principles of objectivity and neutrality, which are socially and culturally grounded, have accustomed us to treat the camera as a perfect imaging-machine. The accident, revealing the fallibility of this conceit, reminds us that while automation exists, it is not a panacea which will offer unblemished facsimiles of the world every time. The accident demonstrates the camera's vision as subjectively driven rather than an objective fact and foregrounds the extent and limitations of the technology that lies behind that vision. These types of errors also reveal the role of the photographer in choosing the most appropriate functions to create an image, and thus the interdependence of camera and photographer in the event of photographing.

Not all accidents are the result of camera malfunction or wrong settings. Accidental images also arise through physical mishap (falling, shaking) or something inserting itself between the lens and the scene at the moment of capture. These intrusions into the photographic event evidence the wider field of actants in the Network of photographing. While the camera/photographer nexus would appear to be

Fig. 9.3 Image copyright © Catalina Codreanu and reproduced by permission. Source: *In Pursuit of Error* [8]

the sole locus of creation, the error reveals the multiple secondary elements: light, time, subject, background; the numerous observable and unobservable phenomena that can impinge on the image. The accidental error reveals the momentariness of the photograph, its situatedness in time and space and its fixed location and viewpoint. Conventional photography practices strive to present a scene which is as far as possible universal, a witness to an event rather than a participant, working at an observing distance which lends the scene a sense of objectivity and 'truth'. This photographic stance, as common in newspaper reportage as holiday snaps, relies on a detachment between the photographer/camera and the scene, either through pose or 'stilling' of the action ('smile!') or through remaining on the periphery. By contrast, the accidental error provides incontrovertible evidence of the embeddedness of the camera/photographer within the flow of space and time through which pours all that is normally left out of the photograph (Fig. 9.4). Through happenstance the error records these fleeting intrusions and rapid changes that make up our customary lived experience, fixing for a second the swirl of life that we are part of.

Accidental errors create opportunities to observe the camera at work in the creation of the image, in many cases an overlooked or taken for granted act. For Borda [12] the physical materiality of the camera is in danger of being left behind in an increasingly

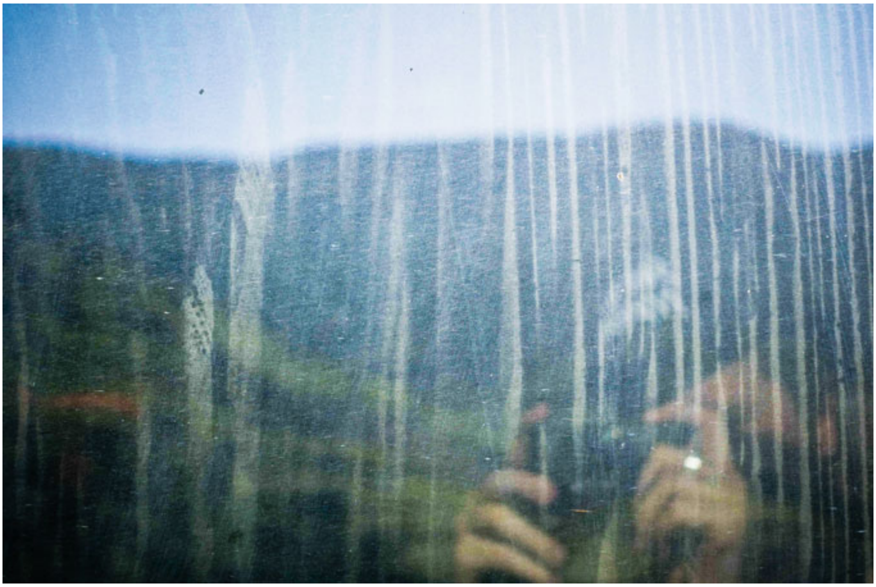

Fig. 9.4 Image copyright © Brett Chapman and reproduced by permission. Source: *In Pursuit of Error* [8]

digitized, automated picturing world which makes the camera "*a missing entity that we no longer perceive*." [12, p. 179]. The physicality of the camera has been greatly diminished by recent developments such as mirror-less technology which removes weight and mechanical action and in mobile phones which integrate the camera as a part of a hand-held computer. If the 'objectness' of the camera is somewhat at risk from these developments, the accidental error reasserts it as a form of what Jane Bennett would term 'thing power': the agency of material objects to act and impact other materials, thereby producing effects in the world [13]. The thing-power of the camera is writ large in the accidental error, where the photographer is left wondering what might have occurred, standing outside the making of the photograph, receiving the image as a *fait accompli*. For Bennett, acknowledging 'thing power' entails recognizing what she terms its 'out-side', that which we know to exist but can only indirectly perceive [13]. The camera exercises its 'thing power' through the hidden process of bringing the photograph into being. We know the theory but the actuality of the process is held in abeyance, because the chemistry or the program is closed to our perception [2]. This hiatus is where the camera exerts its agency and where for a few moments the balance of power between photographer and camera is tipped in the camera's favor. This gap in our knowledge should remind us that we are not necessarily masters of our technology, but rather informed collaborators, operating on a certain amount of knowledge and an element of trust.

9.4 From Tool to Plaything

The hiatus that occurs in the moment of translation from event to image is an aspect of all photography, correct images, and mistakes alike. This loss of control, however momentary, seeps into the practice of photography and informs the relationship between camera and photographer which transpires to be a balance between knowing and not-knowing, of control and loss of control. Thus, photographs could be organized on a continuum from those made with complete knowledge and command, and those produced as a result of a complete loss of control and ignorance. The error could be said to occupy the middle to latter part of the continuum and thus express not a simple binary distinction between 'correct' or 'faulty' images but rather an elongated space of practice in which minor to major mistakes or maladjustments, made by either party, impact upon the eventual photograph.

Control could be considered a cornerstone of camera development through technological enhancements in efficiency and ease of use. The vagaries of the photographic process are brought under control by innovations such as cassette film, the digital sensor or 'Auto' pre-sets. The control is purportedly for the photographer, who can now manage the process more readily, but in fact the control, particularly in relation to programmable functions on modern digital cameras, is situated firmly with the camera, or perhaps we should say the camera's manufacturer. Elements of control can also be exercised through a culture of photographic practice; the way in which one should hold the camera or operate the shutter was often of particular concern in manuals for new style cameras where the photographer's performance with the new device was as much under scrutiny as the camera. Flusser points out that both 'apparatuses' (as he terms cameras) *and* photographers are subject to the control of the Program: the systems which define and limit the practice of photography [2]. Flusser is rather negative about the possibility of photographers escaping the limitations of the Program but he does recognize the agency of the individual in testing or subverting the expectations of picturing. For Flusser, the increasing functional capabilities of the camera, its automation of the photographic process, have liberated the photographer from the 'work' of making pictures. Now there is nothing else to do but play [2, p. 29].

Playing with the camera to undermine expected or 'correct' image making can be seen in the 'deliberate' errors, or rather, photographic subversions submitted to IPE. These images are often accompanied by a narrative that suggests the photographer's moment of performance with the camera and their action in the moment that has brought the image into being. Subversions often involve the photographer's physical movement, running counter to their expected role of stillness and stability—a human tripod which facilitates the camera's task. These movements can be complemented by a knowing destabilization of the camera functions—extensions of shutter speed to slow down the camera's capturing eye, forced de-focusing to render the scene into amorphous blobs of color (Fig. 9.5).

These actions could be characterized as playing *against* the camera, forcing it to see in a very different way through manipulation of the controls. Whether

Fig. 9.5 Image copyright © Melis Cantürk and reproduced by permission. Source: *In Pursuit of Error* [8]

through movement or manipulation the subversion foregrounds the photographer as an embodied presence in the act of making photographs in a similar way that the accident reveals the camera's subjective viewpoint. The subversion interposes the photographer between the camera and the scene as much as if a stray thumb or forefinger were to appear in the frame—we are reminded that the camera is not simply alone and recording by itself as an objective observer. The subversion reminds us that there is a photographer who is pointing, choosing, moving or otherwise governing the activity that precedes the image.

These subversions become traces of performance in time, capturing a certain configuration of events that involve camera, photographer, and situation. One may well ask why photographers feel compelled to intervene in the process of photographing in this way. Certainly, the desire to do so is evident throughout the history of photography, notably expressed as a principle of the Provoke photography movement in Japan in the 1950s in their mantra of '*are bure boke*'—"*grainy, blurry, out of focus*" [14]. Practices which test the conventions of photography can be seen in the work of practitioners as diverse as Meatyard [15] and Barth [16] whose out of focus experiments suggest alternative ways of using the camera as a subjective and sensory mode of expression rather than an objective recording device. The deliberate error is therefore more than just play; it is an urgent reassertion of creativity in the act of photography, one that seems to be increasingly marginalized by technological advancement which attempts to drive the unreliability of the human presence further away from the photographic act.

Deliberate errors may also be motivated by a desire to *not* produce photographs. One of the main issues in photography theory has been the ‘reality effect’ of the photograph [17], that is to say that the photograph is not so much a created image as a recording, a document of what was in front of the lens at any given time. The reality effect is what lends photographs their ‘transparency’ [18], our tendency to look *through* photographs as material media to focus solely on what is depicted within the frame. The emphasis on transparency is what drives technological development, a quest to create a photograph which will be as real as being there, a pure and unadulterated ‘slice of time’. As technological development makes this more possible it is little wonder that photographers expand their thoughts into new territory and tend to explore the different forms of picture-making that the camera may afford.

Elements of Francois Laruelle’s thesis [19] can be brought to bear on the deliberate error in this regard. Laruelle attempts to disentangle photography from its grounding in doubling or copying by pointing out the philosophical distinction between the object in the world and its photographed representation [19]. Perceiving the object and its photographed form as the same is a fallacy that over-prioritizes the world and the objects in it, without considering the distinct ontology presented by the photographic image. For Laruelle claiming the non-identity of the photograph releases it from the dualities of the ‘reality effect’ and permits it to be a *related* but non-identical depiction of objects in the world. Set free in this way the photograph is no longer the poor handmaiden of reality but *another presentation of reality* which is distinct and unique to photography as a material practice [19, p. 55].

The potential of the photograph as a unique form of envisioning is suggested by Laruelle’s commentary, and speaks of the practical understanding of photography as a transformative art. While embedded in an examination of the photograph as a philosophical problem, Laruelle’s commentary expands photography from a simplified and primarily technological act toward an understanding of the central importance of the photographer/artist who, through the “*spontaneous philosophy*” of practice can reveal the “*very essence of photography*” [19, p. 85]. The photographers exploring the photographic subversion reveal the ambiguity at the heart of photography by making images that run counter to the principle of representation.

The creation of photographic subversions often centers upon an expansion of some kind: extended physical movement or elongated shutter times, which result in strange depictions of seemingly other-worldly phenomena—traces, trails, lines, and blurs which suggest but do not signify; the original scene lost behind a veil of color and movement (Fig. 9.6). These images present a divergent concept of photography which does not adhere to conventional understanding. They are often described as ‘painterly’, a direct response to the evidence of gesture and time that are inscribed on the image. They are in many respects, a form of ‘non-photography’ divested of the need to stand in for things in the world, instead presenting another reality which is lost to our normal human vision. For those who seek a deliberate error there is no need to make a photograph per se—we have machines that can do that for us. For the artist the liberation lies in the expanded capacity of the camera as a tool for seeing the world in radically revised ways.

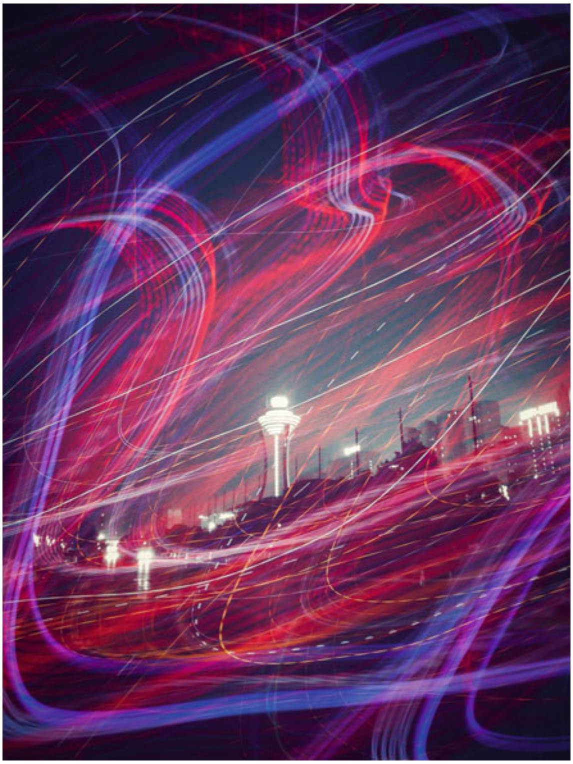

Fig. 9.6 Image copyright © Una Li and reproduced by permission. Source: *In Pursuit of Error* [8]

The satisfaction of the accident, and of being presented with the will of the material (or technology), is an intrinsic part of an artist's developmental method, their motivation to explore and progress. 'Not-knowing' drives practice forward [20].

In photography, the subversion contrives opportunities for not-knowing and to be surprised by unexpected outcomes. While a certain set of actions are put in motion it is not the case that the photographer can know how and to what extent they will affect the resulting image. The photographer may know that certain operations or actions are likely to produce one type of result, but she cannot predict the image outcome as when making a photograph in the conventional way. The subversion lies further toward the knowledge/control end of the continuum discussed at the start of this section, but it shares similarities with the accident in the gap that opens between intentions and outcome. This gap is made up of the present tense performance of photographing and the combination of photographer, camera, light, time, subject, and situation which coalesce in the resulting image. The error is an improvisation, always occurring in the immediate, unscripted moment and thus unknowable until that moment has passed.

For photographers who engage in the deliberate subversion of photographic protocol the results of their transgression offer a similar level of satisfaction to encountering an accident, and can perhaps offer new avenues to explore in practice. The possibility of a different type of photography is offered by the artists who tread this path.

9.5 Tinkering with Technology

The foregoing has shown how the error steps outside the conventions of photographic practice and reveals a more complex relationship between camera and photographer than that between an 'operator' and her 'apparatus'. Photographers often have personal relationships with their cameras, forming a kind of symbiosis between actants where one knows what a particular camera will do in a given situation. The photographer who engages in 'camera vision' connects to the photographic seeing that is a required element of making good pictures and yet as we have seen this can be disrupted by an unexpected event or knowingly cast aside. These apparent 'failures' could be seen as end points, or dead ends from which one must reverse or retreat, or they could be seen as opportunities presenting new phenomena which stimulate the imagination. Invariably the contributors to IPE couch their errors in this latter context, as intriguing surprises which stimulate their practice or their perception about what a photograph is or could be. The etymological root of 'error' lies in the notion of 'wandering', suggesting a deviation which is both intended and imbedded in not-knowing as a principle [21, p. 21]. To wander is to be open to the possibilities that arise in that act of wandering, be they positive or negative and might also imply a return to the conventional route at a later point. This conception of error encapsulates how photographers use the error in practice to lay claim to previously unexplored territory.

The territory occupied by the standards and procedures for 'correct' photography is vast and well developed. Since the very early inception of the medium, photographic practice has been intrinsically tied to rules on the right way to use the technology in order to produce good photographs. Some guidelines were initially necessitated by the complex and awkward materials and processes entailed in early photography, but rapid development of photographic substrates meant that processes soon became easier, quicker, and cheaper. Rules are not made by technology itself, but by the culture that surrounds and uses it. In the case of photography, the emphasis on progress and refinement exemplified through rapid technological development worked alongside a perceived need to regulate and define the limits of this emergent art form. Like all technologies, photography is deeply embedded in the social and political structures that helped formulate it as a popular and commercial entity and which continue to inform its development. In this network of influences, cultures of practice emerge.

The most pertinent distinction in the practice of photography is between the informed and the casual photographer, a distinction evident since the early days of the medium's history. The informed amateur photographer was an early adopter of new technology, in some cases contributing to the development of the medium through their experiments. Informed photographers created Photographic Societies where they could discuss and disseminate treatises on the art and science of photography, organizing its philosophical principles, its areas of concern, and its goals. The casual photographer emerged as the medium became simplified and democratized by the new easier to use substrates and cameras, culminating in the Kodak, which offered them a means to enter the realms of photography without the necessary skills and knowledge to create their pictures other than a willingness to point and shoot. The first fully-fledged 'movement' in photography, Pictorialism, emerged as a reaction to these new 'snapshooters' and to the automation and loss of human skill that the new developments suggested for the medium [22].

Thus the technological development of photography, driven by democratization and commerce, contributed to a fracturing of perceived elements of skill and knowledge that were in the guardianship of a cognoscenti. Kodak's invention forced the Pictorialists towards increasingly 'unphotographic' works—those that capitalized on the artist/photographer's hand to destabilize the verisimilitude of the image, turning it instead into proto-painting [22]. The casual photographers, freed from concern about the quality of their images by the fast and easy methods available to them, took more chances with their photos; and errors, mistakes, and mishaps became part of the photographic landscape [23]. As Hand points out, this entry of the banal mistake into the culture of photography practice challenged "*the dominant discursive and material legitimacy of photography, especially in terms of skill and expertise.*" [24, p. 104].

Arguably, this distinction between informed/casual photographers is still recognizable today. The camera clubs of Britain are filled with those who pride themselves on their technical skills and expertise while casual photographers take selfies on their mobile phones. Photography's intrinsic link with technology makes this distinction, and the value placed on technical know-how, continually pertinent today.

The distinction between an informed and a casual photographer therefore lies in the amount of control they are able or willing to exert over the technology of photographing, which includes the camera, recording medium, and image production. The informed photographer, through her expertise, exercises control over the technology, mastering its principles to produce 'correct' photographs. The casual photographer is a receiver of the technology and perhaps somewhat subservient to it in that its expertise appears to outstrip his own. With less emphasis on control needed or desired by the casual photographer, technological development for this market expands with handy, time-saving innovations which bring the 'ideal' photograph within easy reach.

Thus, two paths of activity are suggested by cultures of practice in photography in which the level of control over the events of photographing favor one or other actant. As has already been demonstrated, the error appears to undermine this dichotomy and suggests a third way of working with photographic technology which is akin to Sherry Turkle's concept of 'soft mastery' [25, p. 56]. This concept emerged from a study carried out by Turkle and Papert on student programming styles [26] which revealed differences between those who took a logical, top-down approach to a programming problem, and those who preferred to work in an iterative, exploratory way with the computer. The distinction between 'planners' and 'bricoleurs' was expressed in a willingness, or otherwise, to engage with the computer as more than just a 'tool' but as a collaborator in the process of developing the program, exploring the nuances of its unique language and exploiting novel solutions to problems. Observation of different programming styles revealed that two approaches were at work; on the one hand there was a level of engagement with the process of programming as a problem which unfolded in time, and on the other, an approach which sought to pre-visualize all the aspects of the program before commencing work. This distinction in approach revealed a difference in the quality of the relationship between programmer and computer, which could be characterized for the bricoleur as a dialog and for the planner as a 'monologue' [26, p. 136]. The notion of conversation entails responding to the other party and perhaps adapting the flow of the conversation in accordance with those responses, while a monologue implies a silent audience. When errors occurred in the programming process, planners and bricoleurs differed markedly with how they dealt with this, either as failure or as opportunity:

> For planners, mistakes are missteps; for bricoleurs they are the essence of a navigation by mid-course correction. For planners a program is an instrument for premeditated control; bricoleurs have goals, but set out realize them in the spirit of a collaborative venture with the machine [26, p. 136].

Turkle's concept of 'soft mastery' expresses a position of informed knowledge about the goal or the object to be realized, but an epistemologically different way of making the journey. Soft mastery relies on a form of negotiation with the materiality of the object in question, be it a computer or a camera, a programming language or abstract problem. Turkle adapts the concept of the bricoleur from Claude Levi-Strauss's descriptions of knowledge creation in primitive societies, what he terms a "*science of the concrete*" [26, p. 135]. To be concrete is to be present, tangible, handleable, not abstract and conceptual. This notion of the presence of objects as sets of things that can act and be acted upon is pertinent to a different way of understanding the camera, not as a tool to be mastered conceptually but as a thing to be worked with physically by testing it out and seeing what it will do.

This approach is readily witnessed in photographers who experiment with the camera and suggests a level of playfulness and willingness to 'see what happens' when using the technology. This kind of 'tinkering' with the parameters of photographing can be seen in many of the contributions to IPE. It's important to note that Turkle's concept of 'soft mastery' does not set out to simply reverse the dichotomy between logic and practice, control and experimentation, but to expose the hierarchy that would assume that logic and control were the only or best ways of engaging with technology. The type of knowledge created through negotiation, through *practice*, reveals alternative epistemologies that run counter to the status quo [26].

A good example of a bricoleur approach to photography can be found in the work of Julia Margaret Cameron. Cameron was an early pioneer of photography as an art form, creating striking portraits of friends and family in scenarios influenced by literature and painting. A particular feature of Cameron's photography is a deliberate softness of focus. In her extensive writings she notes how this particular feature of her work arose in practice, and led her to adopt it as a signature style:

> I believe…that my first successes in my out-of-focus pictures were a fluke. That is to say, that when focusing and coming to something which, to my eye, was very beautiful, I stopped there instead of screwing on the lens to the more definite focus which all other photographers insist upon [27, p. 77].

It is pertinent that while having complete command of the camera as a piece of technology, Cameron instead chose to pursue a deliberate 'mistake' or subversion of the accepted protocols for photographing in order to compose an image which was closer to her intentions. Cameron's informed but embodied interaction with the camera was deemed 'sloppy' and incompetent by those who had set themselves as gatekeepers for the craft, a regulatory status quo which set the rules by which photographs were to be made [28]. The fact that Cameron refers to them as her 'out of focus pictures' is perhaps a significant internalization of this criticism in a nascent world of cultures of practice which were being formed and entrenched.

What Cameron's early flouting of the 'rules' of photography suggests is a connection between photographer and camera in which the photographer becomes aware of the frailties and limitations of the technology, and the creative potential that these peripheries afford. This awareness stems from a willingness to get inside the camera in some way, to envisage its 'camera seeing' as a unique form of agency which has a contribution to make to the final image. In their study Turkle and Papert observe this type of investment into inanimate objects as a form of "*reasoning from within*" [26, p. 144] which is embodied rather than abstract. Reasoning from within requires a proximal relationship with the objects that we use, rather than a distance which views them as purely functional tools. To acknowledge the camera's presence in the making of a photograph is to acknowledge it as a collaborator and changes our relationship with it.

Entry to this new way of thinking about technology might be as simple as the first time we encounter something that has gone wrong. Bill Brown observes that we rarely notice the objects that surround us when they are working correctly. In this state they become invisible; we almost see past them, or through them. However, when something goes awry we are forced to reckon with the object as a different order of 'thing', an agent that has impacted on us in an unforeseen way. The breakdown or interruption in the flow of expected behavior changes our relationship with the object and redefines it [29].

Error, mistakes, tinkering, and subversion are therefore vital and important aspects of photography as a creative practice. They create gaps in the armor of accepted practice, chinks of light where other possibilities for photography can emerge and be explored. The epistemological pluralism espoused by Turkle and Papert [26] exposes a new way of relating to photographic technology; as an embodied, proximal relationship between two agents, two actors who negotiate in the creation of a photograph.

9.6 Conclusion: Being in Two Minds

The foregoing has suggested some alternative ways to consider the relationship between camera and photographer, and how cultures of practice emerge which reinforce oppositional hierarchies between users and their tools. The power of the accident or the subversion to undermine some of the dominant metaphors that adhere to photography—facsimile, accuracy, perfection—exposes a counter culture of photographic practice which has been explored and exploited by practitioners since the early days of the medium.

To adopt the embodied and proximal methodology of the bricoleur is to be open to a sense of discovery and unfolding in the creative process, a form of confident 'not-knowing' from which to begin.

Vilem Flusser observes that "*The act of photography is that of 'phenomenological doubt'*." [2 p. 38]. For Flusser doubt in photography is expressed through the potential multiple viewpoints enabled by the camera and the aspects of the photographic process which are invisible to us. Doubt is woven into the elements of the photographic event in which multiple actants converge at a moment in time and in the hiatus of control and decision-making that is characterized by the accident or the subversion.

The etymology of doubt in 'doubling' in the sense of having to choose between two things [30] offers another way of interpreting the not-knowing that we experience in the event of photographing. To doubt is to be in two minds or to assume two positions. The error exposes this doubling as it occurs in practice, as a dance between two epistemological positions: to know and not know, to be in control and to relinquish control, and as a dance between two actors: camera and photographer. To be in two minds is to enter a position which permits a relational flow between machine vision and the embodied photographer, between presence and program, in which the merging of both exceeds the power of either.

References

1. Deleuze, G.: Bergsonism. Translated by H. Tomlinson and B. Habberjam. Zone, New York (1988)
2. Flusser, V.: Towards a Philosophy of Photography. Translated by A. Mathews. Reaktion, London (2000)
3. Parker Willis, N., Porter, T.O. (eds.): The Pencil of Nature. A New Discovery. The Corsair. 1 No. 5 (Saturday April 13): 70–72. Reprinted in Photographic Theory: An Historical Anthology. In: Hershberger, A. (ed.) Wiley-Blackwell, Oxford, pp. 44–47 (2014)
4. Da Vinci, L. C.: The Function of the Eye. As Explained by the Camera Obscura in Photographic Theory: An Historical Anthology. In: Hershberger, A. (ed.) Wiley-Blackwell, Oxford, pp. 17–18 (2014)
5. Petchesky, R.P.: Fetal Images: The power of visual culture in the politics of reproduction. Fem. Stud. **13**(2), 263–292 (Summer, 1987)
6. Pritchard, M.: A History of Photography in 50 Cameras. Bloomsbury, London (2016)

7. Bate, D.: The digital condition of photography: cameras, computers and display. In: Lister, M. (ed.) The Photographic Image in Digital Culture, 2nd edn. Routledge, London, pp. 77–94 (2013)
8. Piper-Wright, T.: In Pursuit of Error [Online]. www.inpursuitoferror.co.uk
9. Frow, J.: A pebble, a camera, a man who turns into a telegraph pole. Crit. Inq. **28**(1), 270–285 (Autumn 2001)
10. Feenberg, A.: A critical theory of technology. In: Felt, U., Fouché, Clark, R., Miller, A., Smith-Doerr, L. (eds) The Handbook of Science and Technology Studies, 4th edn. MIT Press, Cambridge Mass, Cambridge, MA, pp. 635–663 (2017)
11. Latour, B.: On actor-network theory: a few clarifications. Soziale Welt Jahrg H **4**, 369–381 (1996)
12. Borda, S.G.: Locating the camera in a digital time. Photographies **11**(2–3), 177–192 (2018)
13. Bennett, J.: Vibrant Matter, A Political Ecology of Things. Duke University Press, Durham, NC (2010)
14. Chong, D.: Tokyo 1955–1970 A New Avant Garde. The Museum of Modern Art, New York (2012)
15. Meatyard, R.E.: Learning to see 'No-Focus' (2011) [Online]. https://www.americansuburbx.com/2013/01/ralph-eugene-meatyard-reframing-photography-theory-and-practice-excerpt-2011.html
16. Barth, U.: Artist's website [Online]. http://utabarth.net/work/untitled-1998-99/
17. Barthes, R.: In: Barthes Reader, A., Sontag, S. (ed.) The Photographic Message [1961]. Hill and Wang, New York, pp. 194–210 (1982)
18. Walton, K.: Transparent pictures: on the nature of photographic realism. Crit. Inq. **11**(2), 246–277 (1984)
19. Laruelle, F.: The Concept of Non-Photography. Translated by R. Mackay. Sequence Press, New York (2011)
20. Barthelme, D.: In: Herzinger, K. (ed) Not Knowing in Not Knowing: The Essays and Interviews of Donald Barthelme. Random House, New York (1997)
21. Nunes, M. (ed): Error: Glitch, Noise and Jam in New Media Cultures. Continuum Books, London (2011)
22. Warner Marien, M.: Photography: A Cultural History, 4th edn. Laurence King, London (2014)
23. Hirsch, R.: Seizing the Light: A History of Photography. McGraw-Hill, Toronto (2000)
24. Hand, M.: Ubiquitous Photography. Polity Press, Cambridge (2012)
25. Turkle, S.: Life on the Screen: Identity in the Age of the Internet. Simon & Schuster, New York (1995)
26. Turkle, S., Papert, S.: Epistemological pluralism: styles and voices within the computer culture. Signs **16**(1), 128–157 (1990)
27. Cameron, J.M.: Annals of My Glass House. First Published in Photo Beacon (Chicago) 2 (1890), pp. 157–160. In: Hershberger, A. (ed.) Photographic Theory: An Historical Anthology. Wiley-Blackwell, Oxford, pp. 76–79 (Reprinted) (2014)
28. Weaver, M.: Julia Margaret Cameron 1815–1879. Little Brown Company, Boston, MA (1984)
29. Brown, B.: Thing theory. Crit. Inq. **28**(1), 1–22 (Autumn, 2001)
30. Klein, E.: A Comprehensive Etymological Dictionary of the English Language. Elsevier, London (1969)

Chapter 10
Signs of Surveillance

Daniel Buzzo

Abstract This chapter discusses the challenges of working with complex digital information, visual images, meta-data, and temporal and geo-spatial information, as raw materials for artistic expression. In the chapter the reader will have an insight into the thought process and working practice, artistic and technical, of forming information into a recognizable body of work and processing both the content and the form of the work into an emotional, reflective experience. It not only discusses the challenges of working with external, commercial software frameworks and web services and the challenge of dealing with the brittleness of digital things but also the 'semantic affordance' offered by computer systems in working at a conceptual level with art materials. The 'Signs of Surveillance' project originated as a photographic observation and collation activity in early 2015 and has grown to a complex digital web and installation live visualization project. Since that time thousands of photographs of signs of surveillance and the warning signs, indicating an area or activity is being monitored by video-camera, have been captured in more than 15 countries, including Belgium, Canada, China, Denmark, France, Germany, Greece, Italy, Japan, Korea, Luxembourg, Netherlands, Portugal, Spain, Sweden and the UK. This chapter discusses the development of one aspect of this multi-part work, dealing directly with managing and manipulating a large body of digital data and working with complex visualization systems and online and offline digital distribution technology.

Keywords Digital art · Media art · Installation · Semantic affordance · Digital brittleness · Surveillance society · Derive · Geo-location · Web technologies · Visualization

10.1 Introduction

The pervasive nature of surveillance, as well as the normalization of the signs of it—both physical and metaphorical, is arresting when it is laid out how clearly intertwined this silent over-watch of endless surveillance cameras has become with our everyday

D. Buzzo (✉)
University of the West of England, Creative Technology Lab, Bristol, UK
e-mail: daniel.buzzo@uwe.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_10

lives. Across Europe and the wider globe, surveillance of the body public, of civic space, of every interaction in everyday society appears at some kind of saturation point.[1] In 2015, the then UK Information Commissioner, Tony Porter, himself a former counter-terrorism officer said:

> The lack of public awareness about the nature of surveillance troubles me

and as Matthew Thomas wrote in the Guardian newspaper, quoting Porter:

> [it] risks changing the "psyche of the community" by reducing individuals to trackable numbers in a database

This is despite strong evidence that the publicly stated goals of civic safety and crime prevention are not being fulfilled [25]. The 2005 UK Government Home Office Research, Development and Statistics Directorate concludes in its official report, 'Assessing the Impact of CCTV' [14] that:

> the CCTV schemes that have been assessed had little overall effect on crime levels […] CCTV is an ineffective tool if the aim is to reduce overall crime rates and make people feel safer. The CCTV systems installed in 14 areas mostly failed to reduce crime (with a single exception), mostly failed to allay public fear of crime (with three exceptions) and the vast majority of specific aims set for the various CCTV schemes were not achieved.

In 2004, Richard Thomas the then UK Government Information Commissioner warned [2]:

> My anxiety is that we don't sleepwalk into a surveillance society where much more information is collected about people, accessible to far more people shared across many more boundaries, than British society would feel comfortable with

Making a comparison to the collection of vast quantities of information on individual of Franco's fascist state and the eastern European communist regimes, he added in response to the question of whether there was a risk of Britain following this route,

> I think there is a danger. I don't think people have woken up to what lies behind this. It enables the government … to build up quite a comprehensive picture about many of your activities.

It is against this confusing and disturbing backdrop that this project asks a question of the surveillance colonization of the physical environment around us by building, visualizing and exploring an international database of signs of surveillance. These seemingly ubiquitous information/warning displays come in all shapes, sizes and designs, while often appearing helpful or informative is actually (in the UK at least) part of the legal obligation, largely unknown by the public and ignored by operators,

[1] In its 2013 report, The Picture Is Not Clear: How Many CCTV Surveillance Cameras Are There in the UK? [3] the British Security Industry Association (BSIA) suggested that camera numbers in the private sector could outnumber those used by public bodies by as much as 70 to 1. The BSIA survey covered the whole of the UK, not just London, and its maximum estimate suggested there was a CCTV camera for every 11 people in the country though it said the most likely figure was closer to one for every 14 people.

on any operator or installer of a CCTV surveillance camera. The Information Commissioners Office (ICO), the independent UK authority, explains in the guidance 'CCTV filming carried out by others: What can I expect?' [23]

> The CCTV operator must let people know they are using CCTV. Signs are the most usual way of doing this. The signs must be clearly visible and readable, and **should include the details of the organization operating the system** if not obvious. (emphasis added)
>
> CCTV should only be used in exceptional circumstances in areas where you normally expect privacy—such as in changing rooms or toilets, and should only be used to deal with very serious concerns. The operator should make extra effort to ensure that you are aware that cameras are in use.

As can be seen from the corpus of collected images in this project, this point that CCTV warning signs '*should include the details of the organization operating the system*' is one that is notable when operator information *is included* rather than when it is absent, such is the apparently casual attitude to the use of CCTV and any adherence to privacy or regulatory policy.

This growth of surveillance and reactions to it, rather than being a recent phenomenon, has been going on for nearly three decades. Several artists and projects have worked in this area; notable amongst them are recent projects such as 'Art and Surveillance' lead by Susan Cahill in Canada that collates artistic projects on surveillance [8] and older ones such as http://www.spotthecam.nl created in early 2000s by Maurice Wessling and Bits of Freedom[2] in conjunction with the Waag Society in Amsterdam, Netherlands[3] and the 'Surveillance Camera Theatre'[4] from the Surveillance Camera Players [24], an informal activist theatre troupe formed in 1996 in New York City between Bill Brown and Michael Carter. Carter, in his 1995 manifesto 'The Guerrilla Programming of Video Surveillance Equipment' [9], proclaims:

> It is important to remind oneself of the relationship between the eye of the media and that of the corporate police state – for they are both the guardian of the commodity, however nebulous and ephemeral that commodity may become. As a tactic designed to point out the paradox of a system that turns the lens on a public that has been taught to place more importance on images recorded by cameras than images seen by their own eyes, we propose *Guerilla Programming of Video Surveillance Equipment* (emphasis added).

As a photographic observational project, the existing corpus of images of 'signs of surveillance' comprises over 2000 digital photographs taken across the globe between 2015 and 2019. Each image contains date, time and geo-location meta-data allowing geographic mapping and search and retrieval in a variety of ways. The whole project has several elements:

- A compendium of the designs, locations and forms of the myriad of sign-types in the collection (see Fig. 10.1)
- A traditional digital photographic print exhibition

[2]https://www.bitsoffreedom.nl.

[3]https://waag.org.

[4]http://www.notbored.org/scp-how-to.html.

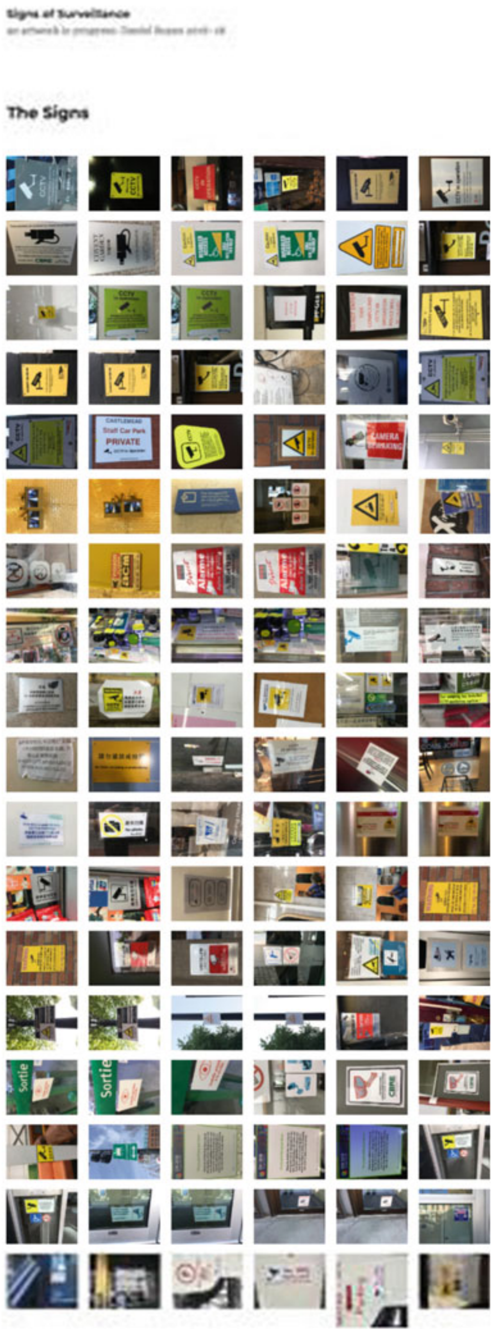

Fig. 10.1 Example of the variations and number of different sign shapes, designs and forms from numerous countries

- An interactive 3D geo-map-based visualization
- An online web-based searchable catalog that asks for public contribution to extend and complete the European map of Signs of Surveillance
- Training a machine learning system on the corpus of signs to enable automatic sign recognition.

This chapter deals with the development of element number three, the development of an interactive, dynamic 3D geo-map-based visualization of the photographic collection.

10.2 Process of Gathering Raw Images and Meta-Data

The process of gathering raw images for the collection of photographs of signs of surveillance began as a non-verbal act of noticing, in noticing the apparent overabundance of these signs in public spaces. After noticing came the wordless desire to evidence that noticing, to collate and compare, to contrast and reflect. to investigate if the feelings of noticing were borne out by actual evidence—in this instance the evidence being the collation of photographs recording the signs. This process of observation and recording as basic research, and raw material, is common to many artistic practices, and is a recurring theme I use to undertake non-verbal investigation of items of importance I see in the world around me. In some ways I use the camera as one would use a microphone to take field recordings for later study in the studio. In this work the gathering of images made the proliferation of these signs in public spaces abundantly clear (see Fig. 10.1); partly as the act of looking for them became habit, partly as my subconscious eye became trained to see these small icons, images and visual devices and the kind of places they would appear high up on walls of large buildings, low down on shop doorways, in the entrances and lobbies of offices and houses. The act of looking also revealed the signs in unexpected places, among piles of pastries in display cabinets, buried in hedges and flower beds in residential gardens, on the sides of cars, buses, trams and trains, and on vending machines and garden sheds.

10.2.1 Building Semantic Affordance with Artistic Raw Materials

In the process of gathering the photographs, extending the corpus of images from country to country as I traveled while engaged in work on other projects, a feel for the body of work began to emerge. The feeling of emergent, artistic, comprehension is the one that I recognize when undertaking works of almost any sort, from extended drawing studies of scenes (see Fig. 10.2) or objects to wrestling with the philosophical

Fig. 10.2 Example of extensive use of drawing for exploration and visualization, here showing early explorations of using image meta-data and tagging to map-tile backgrounds

aspects of how best to structure a system when incorporating dense computer code (such as the Volca project [6, 7] or the Time Machine [4, 5]).

This understanding is the developing of a cognitive, sensory and implicitly non-verbal relationship with the materials and ideas or objects under scrutiny. It is a feeling of what I call 'semantic affordance', in that one feels an innate ability to cognitively manipulate the essential conceptual elements embodied by whatever is the subject of scrutiny. This affordance gives a direct fluidity and competence that allows further examination and contemplation of the materials at hand at a conceptual and ontological level. This affordance or agency to manipulate the conceptual elements embodied by the material under study could be seen as the central activity in my artistic practice. It is through this level of deep non-verbal understanding of the manifold semantic concepts seen held within objects and materials that inform the aesthetic choices that are made when re-formulating materials in the preparation and creation of artistic outputs. As the artistic outputs are imagined, sketched, produced as maquettes and prototypes, a re-connection to the original non-verbal enquiry is sought. The process is a search to close the loop from initial observation, non-verbal comprehension, manipulation and synthesis of conceptual structures to a final embodiment of concepts as an intervention into the physical world. The answering of the initial question and the final scratching is a mental itch. In this sense the works are predominantly conceptually driven and operate at a physical level in the conceptual rather than technical or decorative world. As Shanken [21] raises in ‘Art in the Information Age: Technology and Conceptual Art’, although the divisions between conceptual art and technological art have generally been seen as in conflict, he explores the view that while the history of technological art has been seen as separated from that of conceptual art both were rooted in experimentation and re-interpretation and proposes a re-thinking of their status as separate and divorced from each other. He quotes Sol Lewitt’s 1967 essay ‘Paragraphs on Conceptual Art’ [16] where Lewitt describes conceptual art as a quasi-mechanical process:

> In conceptual art the idea of concept is the most important aspect of the work . . . [t]he idea becomes a machine that makes the art.

It is this very idea that drives my quest for these conceptual affordances in the work, which allows mental structures to be created from which the art creates itself. The arena of the technical in part is a desire to work unbounded by both convention and the patina of the physical that seem part and parcel of other mediums of expression. The ‘active’ nature of technology allows for embedding, encoding and subsequently animating these *‘conceptual machines to make art’* into the systems underlying the physical surface of the work.

10.2.2 Gathering Images and the Dérive

In this project the initial activity was a process of subconscious harvesting, conducted as an ongoing photographic dérive, a drift, though the world we inhabit with a watch for these signs of surveillance that had now become artistic items of interest. Guy Debord, French philosopher and author of ‘The Society of the Spectacle’ often associated with Situationist International,[5] describes the dérive as:

> a mode of experimental behavior linked to the conditions of urban society: a technique of rapid passage through varied ambiances [13]

Over the period beginning with the first photograph of the series, taking in Lisbon in June 2015, and lasting through 15 countries and more than four years over 2,000 images of signs of surveillance were recorded in dérive fashion.

10.3 Managing and Manipulating Large Digital Image Corpuses as Artistic Raw Material

Dealing with materials gathered using digital tools as the subject of artistic study has a number of opportunities and also challenges. Some of these are common to the practice of much artistic research and some unique to digital materials. Digital

---

[5] https://www.tate.org.uk/art/art-terms/s/situationist-international.

materials, while fluid, flexible, malleable, and almost instantaneously duplicable and transferable, are also at their core, inherently brittle. Their flexible, immaterial, nature and their ability to be versioned, trans-coded, summarized and edited means that any notion of an original is fleeting and slippery. Attempting to trace the origin, and original of a digital document, is like grasping at a ribbon blowing in the wind. Partly this is the nature of sampling the world with digital, that is, numerical processes. It is important to remember that the sampling process is fundamentally divorced from techniques of the analog recording realm.[6] The connection with the place and instant of creation is fleeting, and beyond the memory of the place and time that a button was pressed or a menu item clicked the digital object has no patina or evidence of its place or moment of creation.

10.3.1 Meta-Data and Artistic Data Management

All digital artifacts have meta-data, that is, there is data about the data. There is information about the information contained inside any digital document, be it sound file, image, text, video or software code. What is unusual is that in the digital realm this meta-data is built of the same substance as the mate´riale it describes. In the instance of this project each image was recorded with meta-data describing the image. There are basics facts associated with any digital files, for example, creation date, modification date, byte size of the file, name, filetype and the current location of a document in a specific computer system. There also, commonly, exists within image files additional data using the EXIF (EXchangeable Image File format) standard.[7] The EXIF data standard was originally introduced by The Japan Electronic Industries Development Association (JEIDA) in 1998 and is widely adopted as a standard to store extended information about digital photographs. This meta-data commonly includes information about the make and model of the apparatus or camera used for the original recording and extends to information about lenses, flash, aperture and shutter speed of the recorded image. The meta-data also includes contextual or circumstantial data including the date/time of the image capture and increasingly common with images taken with smart phones and the latest generation of hand-held cameras, the geographic meta-data, expressed as latitude, longitude and altitude. This EXIF data and specifically the associated geo-location data became of particular interest in the course of this project and is processed and manipulated heavily in the final artworks produced as part of the work (see Figs. 10.3 and 10.4).

[6] Sampling puts a mesh to the world and encodes numerically, explicitly sampling reality at positions on a pre-defined grid—the only parameters of this crude and bombastic approximation are the frequency and resolution of the grid and the depth of the data captured or sampled at each point. All information, texture and nuance between the sampling points of the grid are simply ignored or disposed of.

[7] https://www.exif.org.

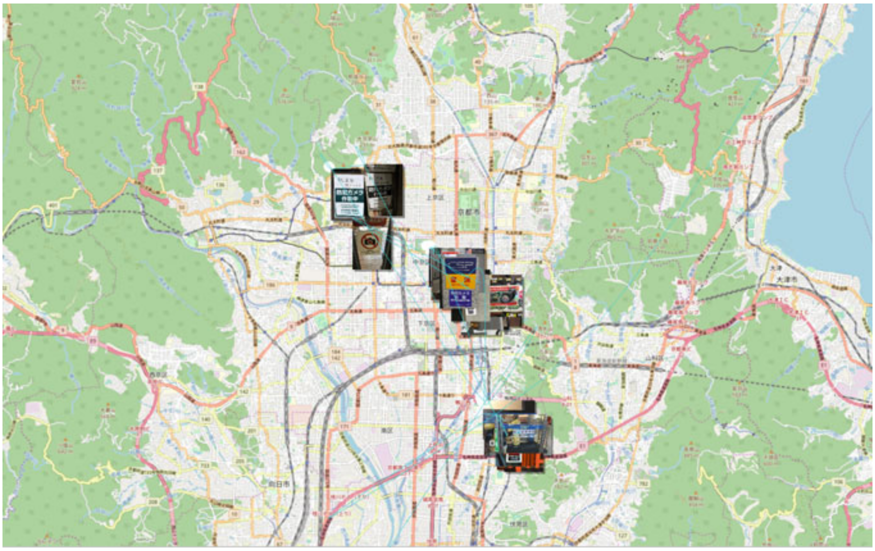

Fig. 10.3 Early map visualization using C++ and openFrameworks with spline paths generated following chronological order or recording of individual images. Here showing walks through Kyoto, Japan over a three day period in 2018

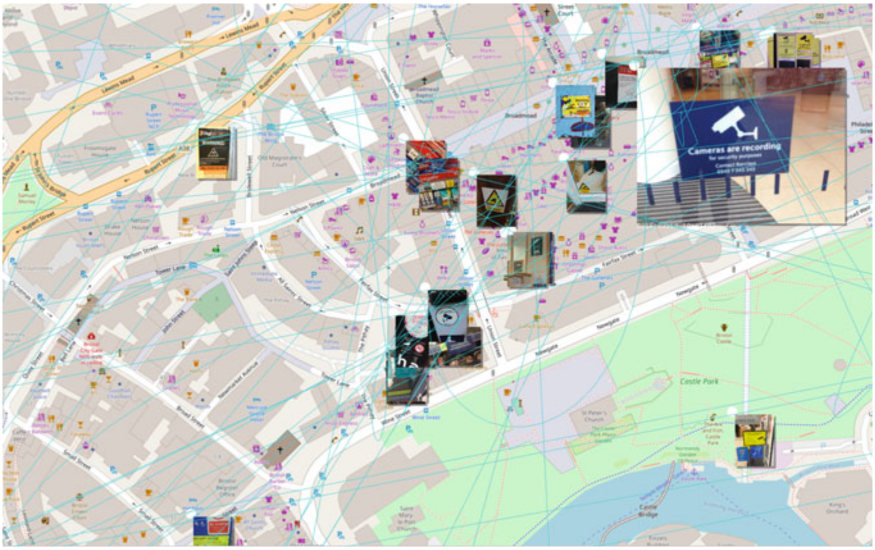

Fig. 10.4 Early map visualization using C++ and openFrameworks with spline paths generated following chronological order or recording of individual images. This version utilizes only geo-location and temporal data from each image

10.4 Developing Artworks Combining Hand-Coded and Industrial Digital Tools

Developing artworks utilizing technology, whether that be industrially mass-produced physical materials such as paint, canvas, glass-fiber, electronics or software involves a level of compromise and negotiation with the materials an artist chooses to engage with. Being restricted to colors manufactured by a supplier, being constrained by the retail costs of a device or being challenged by the features available in a software API are all within the same canon of challenges faced by artists working in many contemporary contexts. As an artist regularly working in depth with technology, and software specifically, this challenge of adapting, working with, fighting with and customizing industrial products is a regular occurrence. Part of the aesthetic of much technology orientated art is this engagement with, and subversion of, industrial products, situating them in new contexts and utilizing them in new and novel ways. Implicitly tied to this aspirational goal of both mastery and subversion comes a challenge within the practice of making art with technology, one that is endemic to all art but is amplified exponentially when engaging with software. This challenge is the negotiation, both in production and distribution of works, with the inherent brittleness of digital things.

10.4.1 On the Brittleness of Digital Things

As all physical things decay and change under what appears to be the effect of time,[8] so do digital ones, and this decay is seemingly at a rate inversely proportional to the power of digital material. Just as a digital image can be spread around the world and seen and manipulated by a billion people simultaneously it can also collapse, cease and disappear with equal speed. A server outage, a power failure, a change in the software application programming interface (API)[9] or even the simple act of

[8]One could begin a lengthy discussion in the nature of the perception of time, correlation and causality. Suffice to say that in most practical and functional aspects it would appear that as Stappers and Giarcardi point out in their work on designing for temporal context [22]:

> The most important thing designers should know is that there is no such single thing as time.

As Carl Sagan says "[Time] is profoundly resistant to simple definition." Discussing the nature of time, Sagan, in an interview during the making of NOVAs TV program 'Time Travel', goes on to note [20].

> Ever since St. Augustine, people have wrestled with this, and there are all sorts of things it isn't. It isn't a flow of something, because what does it flow past? We use time to measure flow. How could we use time to measure time?.

[9]In computer programming, an application programming interface (API) is a set of subroutine definitions, communication protocols, and tools for building software. In general terms, it is a set

applying a seemingly unrelated operating system update can bring digital artworks, not to their knees, but to a state of ceasing to be. Though digital files and lines of software code may still be intact, software art, like video art before it, is performative and temporal; it exists at the moment of viewing; it needs to be run, to execute, to function and to fulfill its promise as art. This base need of instantaneous creation, to generate itself at the moment of viewing by an observer, is the challenge, excitement and weakness at the heart of digital artworks. *Bit Rot*, [10, 15] or occasionally *Link Rot*,[10] is described by Coupland in his 2016 book of the same name [12] as:

> the way digital files of any sort spontaneously (and quickly) decompose

The most important thing designers should know is that there is no such single thing as time.

As Carl Sagan says "[Time] is profoundly resistant to simple definition." Discussing the nature of time, Sagan, in an interview during the making of NOVAs TV program 'Time Travel', goes on to note [20]:

> 'Ever since St. Augustine, people have wrestled with this, and there are all sorts of things it isn't. It isn't a flow of something, because what does it flow past? We use time to measure flow. How could we use time to measure time?'

and is 'a slang term' for hypertext links that are broken. Link rot is created when a web page is moved, taken down or re-organized. Clicking on a rotten link usually results in a 404 error, which includes a message that the page cannot be found. This 'digital decay' affects all computational systems and is in equal parts the ventral thrill and motivation and also an ever-present challenge in digital art making. As the internet pioneer Vinton Cerf observes [10]:

> There is something ultimately satisfying about keeping information in digital form… But this blissful outlook may not comport with the reality of digital information preservation and interpretation.

In the context of this artwork I am writing about—sat in seat 6c on a flight to Lisbon, tapping on a tablet computer (and now weeks later re-editing on a subway train under Hong Kong harbor)—hoping that what I write here will synchronize flawlessly with the master version for this document so I can continue on my laptop at home, or the desktop computer in my office or the myriad of other computers I have in my two studios—the challenge of working with industrial tools in the making of signs of surveillance has been great. Both in the practicality of the making of the

---

of clearly defined methods of communication among various components. A good API makes it easier to develop a computer program by providing all the building blocks, which are then put together by the programmer. An API may be for a web-based system, operating system, database system, computer hardware or software library. An API specification can take many forms, but often includes specifications for routines, data structures, object classes, variables or remote calls. POSIX, Windows API and ASPI are examples of different forms of APIs. Documentation for the API is usually provided to facilitate usage and implementation. (https://en.wikipedia.org/wiki/Applicationprogramminginterface).

[10] https://www.techopedia.com/definition/20414/link-rot.

work, designing, programming and forming it, and also in the conceptualization of it, the philosophical and aesthetic decisions underpin it structurally. This arena is the ill-defined and rarely talked about area where semantics and ontology meet engineering, where philosophy becomes embodied in systems and structures and ways of doing things. Just as William Gibson says [1] with incisive clarity:

> We can’t see our culture very well, because we see with it

Perhaps this sentiment is distilled to its essence in the Japanese anecdote that ‘to a hammer, everything looks like a nail’.

10.4.2 Aesthetics, Frameworks, APIs and Ontologies

When looking through the gathered body of work, mentally sitting among the thousands of photographs from around the world, and reflecting on the journey of collection and understanding, a non-verbal set of connections start to be made, there begins to form an ontological framework of what is and what is not, what does go and what does not when considering, comparing, organizing and arranging the material. Alongside the challenges in managing digital collections, of cataloguing, versioning, trans-coding, naming, renaming and duplicating and archiving, there is the selection of applicable tools to manipulate these non-physical collections of *things-that-may-be*.

In the development of the work the public exposure of the meta-data inside each image became increasingly important in relating an individual item in the collection to the whole. Beginning with a process of drawing, commonly with ink on paper, ideas of collating, relating and visualizing this relationship, between individual element and the whole, took shape. Sketching ideas in code, using the C++ toolkit, openFrameworks,[11] a sense of the dynamic in the material came to the fore. Initially the project was an observation and dérive exercise and at a certain stage it transformed into a discussion with the gathered material. As is of often the case in life drawing, one starts with mark making in reference to the subject being observed but at some point crosses into mark making in reference to the body of marks one has made on the paper or canvas. Adding to or subtracting from a growing object that begins to exist independently of that which is originally observed. This is the point where a piece of work develops its own life or emergent identity, one that is divorced from being a facsimile of the original scene.

After working with initial crude mappings of the geo-located images into 3D space using geometric primitives and texture mapping of a variety of representations of the earth’s surface a move to a more complex visualization was needed. To access high-resolution maps and images of the surface of the whole earth necessitated engaging with external data sources, initially continuing working writing code

[11] ‘OpenFrameworks is an open source C++ toolkit designed to assist the creative process by providing a simple and intuitive framework for experimentation’ (https://openframeworks.cc/about/).

in C++, the open-source online OpenStreetMap (OSM).[12] Geographical information system (GIS) database was accessed through its web-based API.[13] While this brought huge flexibility and access to a wealth of visual and meta-data about the earth it added a subtle but pivotal disjuncture in the work. Even though the code was still handwritten C++, compiled to run locally as an executable binary application on a specific machine, the work now had a brittle chain of failure built into it. The work now became reliant on an internet connection, reliant upon a connection of sufficient bandwidth to the outside world and at the other end of a chain of routers and connections. It was reliant upon the servers at OSM being available, and that the access restrictions and protocols of their API, and the data in their underlying database were available and had not been altered, patched, upgraded or had their license of use changed. What also began to happen is that the underlying ontology, the causal philosophy of the interrelation between elements, images, ideas and concepts that was embodied in the architecture of the software I was writing changed. The attitude and values in the project, the structure, classifications and ontology that was emerging, was codified in its most concrete form in the classes, methods, functions, loops, arrays, iterators and variables that scaffolded and guided the work to become at the moment of performance. By engaging with this external API, and the underlying philosophy, attitude, ontology and expectation encoded within it, it there began and evolving and protracted negotiation on how to navigate the external conceptual space without becoming overwhelmed hegemonistically[14] and becoming merely an extension of it. Illustrating what it could do, rather than a master of it demonstrating what I could do with it, sculpting it to my will and the will of the evolving work. This conundrum is somewhere between the Sapir-Worf hypothesis [17] on how language shapes thought and conceptions of one's reality and the ominous words of Friedrich Nietzsche when he said [18]:

> Whoever fights monsters should see to it that in the process he does not become a monster. And if you gaze long enough into an abyss, the abyss will gaze back into you.

This negotiation for control became a battle, metaphorically, for the ground under the project, and this external empire of protocols and ontologies and the emerging

[12]http://www.openstreetmap.org.

[13]Utilizing the openFrameworks add-on ofxMaps (https://github.com/bakercp/ofxMaps). ofxMaps creates an interface to OSM in the 'SlippyMap' style (https://wiki.openstreetmap.org/wiki/SlippyMap). It is written and maintained by Christopher Baker.

[14]The Encyclopedia Britannica describes Hegemony as the dominance of one group over another, often supported by legitimating norms and ideas. The term hegemony is today often used as shorthand to describe the relatively dominant position of a particular set of ideas and their associated tendency to become commonsensical and intuitive, thereby inhibiting the dissemination or even the articulation of alternative ideas. The associated term hegemon is used to identify the actor, group, class or state that exercises hegemonic power or that is responsible for the dissemination of hegemonic ideas. (https://www.britannica.com/topic/hegemony).

artwork—using C++ but communicating into a web-based world, using http transport[15] layers—began to shape, not only what was being said but a shift linguistically into the world of web technologies. That is not to say that the possibility to stay in the dialect I was writing in was not available, it was entirely, but the challenge would be to re-write for myself the additional tools, utilities, libraries and processes I was beginning to rely on to achieve the realization of my increasingly complex and specific pen and ink drawings of the project. Just as a decision to make your own paint becomes a significant part of the work so does the decision to make one's own digital tools.

As Richardson discussed in his 1998 article 'New Media, New Craft' [19] reflecting on what the status of new digital tools may be in an art context:

> Using programming to create a piece of art or design requires an abstraction of thinking, translating the idea of the final visual form into a structure required to create the work. A leap of understanding is required to translate a creative idea into a piece of code. Creative ideas and solutions are thus abstracted into structures and objects that are natural to the computer material. Such an understanding of material subsequently creates work that echoes the invisible structure of the code

Richardson goes on to add:

> The use of programming, as a way of manipulating and understanding the new material, also represents the means by which artists and designers are able to get closest to the virtual material. When they use programming to create a visual work, the underlying process and structure become of fundamental importance. The invisible structure of the work becomes as significant as the final outcome. The work experienced by the viewer is a visual translation of the underlying framework and mental engagement of the artist or designer with the material.

This challenge, between using available tools, and traveling further, faster and making everything from scratch for oneself, perhaps risking re-inventing the wheel having taken years to learn how to best make a wheel, is common to many artistic endeavors but never more so than in self-coding digital artworks. Richardson continues pointing out the difference that hand-crafted digital tools make in the conceptual understanding of any artwork:

> In direct contrast to the post-modern point-and-click, cut-and-paste approach to creating a piece of creative work, the use of programming requires that a framework is firmly established, around which the work is built.

Having made strategic choices and seen where the project wanted to go, and how it could be formed in a way that allowed it to talk for itself, investigations of middleware frameworks and software libraries began in earnest. Moving parts of the codebase into java script and using the browser as interpreter and platform wheel, rather than the byte code produced by CLANG or the GCC C++ compiler

[15] http, or hypertext transport protocol, is a computer protocol that is used to allow clients (commonly web browsers running on users computers to request and subsequently receive text, image, audio and video data from web servers).

allowed easy integration with online utilities I was already using, such as map-tiles[16] of satellite and geo-political imagery and reverse geo-coding.[17] This easy ability to communicate with remote functions, features and data comes with an additional cost beyond the loss of independence, self-reliance and overall stability (see Fig. 10.5).

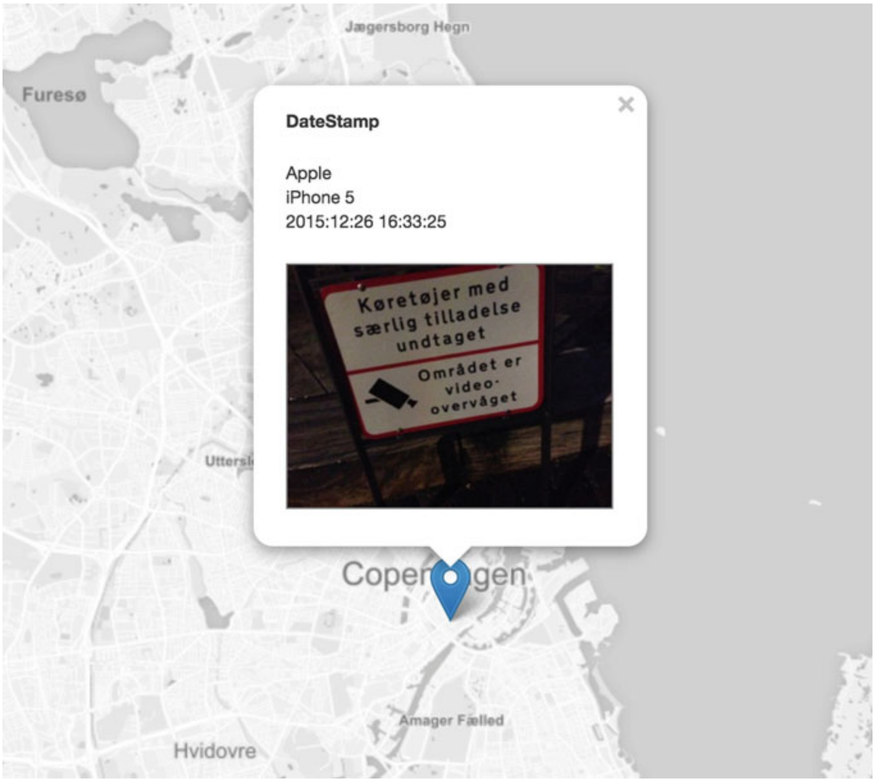

Fig. 10.5 Browser based version written in JavaScript using leaflet.js showing early tests with meta-data extraction and visualization

[16]Map-tiles are a way of breaking large GIS-orientated datasets such as maps into smaller fragments that can be called and used as needed, remedying the need to load large datasets as monolithic pieces. A calculation is made of the geo-location that is of interest, the scale that the map is to be viewed and the size of the viewing port (or in our instance, web browser window); a series of request are made; the map-tile server and the corresponding map fragments are returned as individual files and then tessellated in the viewer.

[17]Reverse geo-coding is the ability to take and specific geo-location, commonly expressed in latitude and longitude, and return a descriptive physical world location. For example, the a reverse GeoCode request for the location 52.356991666666666, 1.2931251573910854 is returned as Oostpoort 12, Waldenlaan, Winkelcentrum Oostpoort, Amsterdam, North Holland, Netherlands, 1093NH, Netherlands by the OpenStreetMap database functions that allowed the work to turn the GPS latitude and longitude data inside individual images into named localities with street town and country data.

In this instance it carried a commercial one. Although I was using a free developer account for one of the major mapping utility providers, the monthly usage limit was quickly reached for data requests. Due to license limitations on usage of the data that was provided, it was not legally possible to cache data between sessions of usage, nor store it in any long term or permanent way. This necessitated performing a reverse geo-code lookup for the locations of images each time the project was viewed or run, necessitating over 2000 calls to the remote API each time. Although the cost of an individual reverse geo-code request was only fractions of a cent per request, this added up to a cost of USD2 every time the work was viewed. The map-tile imagery requests came in addition to this cost. Looking at open-source alternatives became complex, while the service cost was free and the license terms far less restrictive in the data servers were not configured for heavy use, resulting in the servers banning the IP address of the requesting machine after the first few hundred geo-code requests. A strategy was developed to pre-request and cache the geo-code data and serve it from a self-hosted server by writing a script that requested the relevant information from the open-source server at a deliberately slow, throttled rate and writing the returned reverse lookup data to a local file in geoJSON format.[18]

This conformed with both the terms of use of the open-source server and also its license on use and retention of data. The second challenge was on how to deal with the mapping data being requested from the commercial provider. Open-source map data providers, understandably, were unable to supply maps data in the quantities the project needed and also separated the idea of individual users of the service from the creation of applications that would use the service. Unfortunately, there appear very few instances of a middle ground for artistic or non-profit uses of open-source services putting most artworks or projects that use third-party services or data firmly into this arena of being classed as commercial users and being charged accordingly.

One of the options available within the license terms for the core corpus of map image data—the smaller version being in the region of 65gb of image tiles—was to clone the data needed and set up and operate a web-based map data server specifically for the project. This added a layer of technical complexity and a certain amount of unnecessary redundancy but afforded a break from the reliance on commercial providers and also added the possibility of generating a machine-specific version that could run as a single instance of the project with all necessary data held locally. This would remove the requirement for an internet connection for a greater level of autonomy. This involves setting part of the host computer to operate as a web server

[18]GeoJSON is an implementation of JSON (JavaScript Object Notation) that encodes geographic information in text form as nested objects, typically containing a latitude and longitude geometry reference optionally followed by additional data. In our instance the data encoded includes details of the EXIF camera data relating to images and their recording location. An example of typical GeoJSON entry will look similar to the following: “geometry”: “type”: “Point”, “coordinates”: [4.927913888888889, 52.356991666666666, 1.2931251573910854], “type”: “Feature”, “properties”: “url”: “sign6.jpg”, “date”: “2018:04:30 10:07:09”, “orientation”: 6, “make”: “Apple”, “model”: “iPhone SE”, “size”: 23397, “type”: “image/jpeg”, “locality”: “Oostpoort 12, Waldenlaan, Winkelcentrum Oostpoort, Amsterdam, North Holland, Netherlands, 1093NH, Netherlands”).

and routing web calls from the work or application back to the locally running web server, sometimes called LocalHost.

With these two elements in hand, batch generated reverse geo-code data, locally held, and provisioning the projects own map data server, the forming, tuning and final choreography of this section the piece proceeded.

10.5 The Challenge of Live Vs Video of Activity or Interactivity of Exposing the Internal or Relying on the Surface

In developing live digital works there is a challenge of exposing and communicating where the work is. In the case of paint and photography and other flat visual arts, the work is commonly readily identified in the surface. When working with live digital processes this identification, location and exposition of the work—in this case meaning the artistic effort, intention or focus of attention—becomes obfuscated and requires specialist technical knowledge to gain insight into often hidden black-box processes. Some artists working with digital/technological processes take the route of exposing the mechanism of systems, disassembling computers into their working component and exhibiting them exploded on gallery floors, deliberately exposing the 'technology' to indicate complexity and 'liveness'. Another common route to provide this exposition to an audience is to make systems interactive or reactive to some aspect of the audience, making clear that something live and dynamic is occurring and perhaps leading the audience into consideration that which is beneath the surface, the 'deeper mechanic' inside a work or piece. With work that takes neither of these routes, work that is active but not interactive, that does not make its components part of the artwork display, the challenge is to help the audience understand that what they see is live and note rendered video recordings or pre-made files being re-played. And that each moment seen is created and becoming at that moment. It is being performed live, never to be repeated in that fact same way again.

10.5.1 Exposing the Internal or Relying on the Surface

This challenge of exposing the internal mechanism of projects and works and the delicate balance of the work end up being about the mechanism and the tools rather than the original intent is a complex one. In this work the multi-part nature of the outputs from the project allows a range of expression and nuance which in another work would not necessarily be available. With the installation version of Signs of Surveillance the clean collection nature of the photographic source material and the exposure and manipulation of the image meta-data is clue enough to the live/process nature behind the work. Alternative versions, such as the artists' book and the controllable web-based version address other elements of the project sufficiently.

10.5.2 The Final Work for Gallery Installation

The final instantiation of the work discussed in this article is designed for viewing in a gallery or installation context (see Fig. 10.6), and has been tuned, sculpted and shaped accordingly. In an installation context the audience is mixed, with a range of interests, awareness and contextual insight.

The audience, the viewer also has a range of available temporal modes within which to receive the work and the underlying themes and idea. Part of the work is paced and presented for a transitory audience with short attention and an availability of meaning in the surface of the work that is 'glanceable'. That will survive artistic scrutiny of a glance of a few seconds. At another level the work has a deeper pace and rhythm that is designed to survive deeper scrutiny and draw the viewer into a deeper dialog with and understanding of the work, allowing nuance and interpretation at the pace and depth the viewer is comfortable with. The work for gallery installation is active but unlike its open web-based counterpart (available publicly at http://signsofsurveillance.com) not explicitly *interactive* (see Fig. 10.7). To this end, it has a specific set of behaviors that it exhibits to engage the viewer and draw them through the corpus of work. When working through the meta-data accompanying the body of images, a certain irony was revealed, in that, if one followed the time-stamps of the collected images one could re-create, with a varying range of accuracy, the route that I had taken through neighborhoods, cities and countries around the world over the

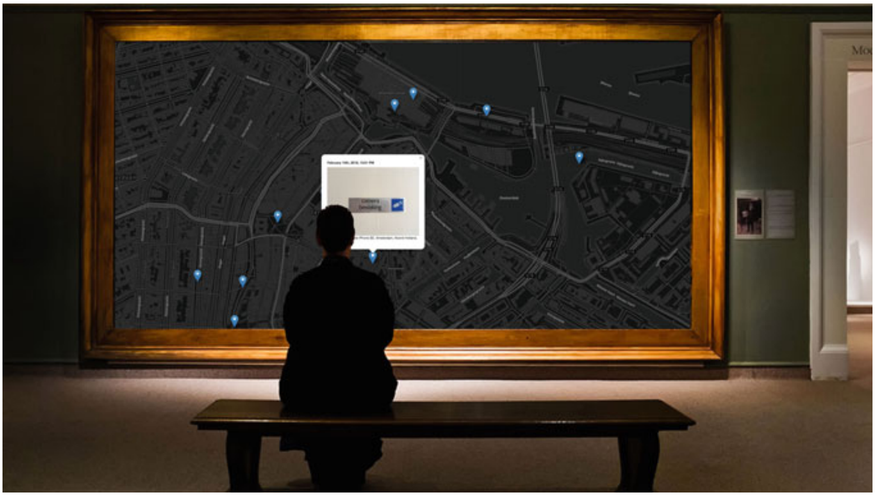

Fig. 10.6 Mockup of gallery installation of early globe version

Fig. 10.7 Final version showing custom map styling, with clustering, image meta-data and dynamic transitions along the 'walk-line' between images over the 5 year period of collection. This location, Ijmeer, Amsterdam, Netherlands

preceding five years. The time-stamp data combined with the geo-location of each image showed the points on the globe that I had stood at the press of every shutter and the capture of each photograph. Beginning to investigate these invisible lines, simple routines were written to create a single path through each geo-point. Using both Catmull-Rom[19] and Bézier[20] curves different paths were visualized showing the path between each captured image.

10.6 Conclusion

In this chapter I have attempted to expose and discuss some of the approaches and practices that I have evolved and adopted over the last 30+ years of working with digital technologies. My original thoughts were that working in conjunction with complex, highly sophisticated tools and systems which transformed the relationship from one of artist and tool into much more of an intimate discussion, a collaboration

---

[19] A Catmull–Rom spline, named for Edwin Catmull and Raphael Rom, is a special case of a cardinal spline. Catmull–Rom splines are frequently used to get smooth transitions between key points and are often used in animation and similar computer graphic works.

[20] Named after Pierre Bézier, a Bézier curve is a parametric curve used in computer graphics. Several points using Bézier curves can be combined to form a Bézier spline.

where one asked questions of the systems one engages in, navigating and negotiating the parameters and avenues in and through the conceptual structures, functions and processes inside the machine. From this comes the innate understanding of the systems and materials one is working with, what I have called semantic affordances. Sadly, this conceptual flexibility and strength that digital materials bring also brings multiple points of failure, usually with no graceful decline. A point of failure at any juncture in a digital artwork is usually a complete failure. This is what I mean when I talk of the brittleness of digital things. For this work, which extensively involved with the collection of a large body of individual items working in the digital gives great flexibility to collate, manipulate, transform and express. It also gives myriad opportunities for instantiation of a work in the physical world, and huge availability of choices of how to make an intervention into the mind of the viewer. At this instance, the challenge came in making gallery-orientated versions and web-based while using web technologies and remote data in both. The issue of reliance on, and of cost, when using external systems, such as map-tile data and geo-location services was a particular challenge but let to new and interesting areas setting up self-hosted and local versions of some of these external commercial data sources. This does, however, have its own drawbacks, and the writing discusses in some detail the philosophical, cultural and ultimately ontological struggle when engaging with external systems, APIs and data. Also that, they have their own political approach, their own ontologies and that can be a hegemonist force with the potential to overwhelm the internal ontology that an individual work of art generates for itself. This question of the internal complexity and dialog that goes on inside active digital works is the last point in this writing, investigating some of the challenges that are balanced when dealing with the decision of how much to expose the internal structures of a work to bring viewers deeper inside, drawing them below the surface of a work while not making the work purely about the internal structure. Thus, working to retain the original focus of the work but helping give insight into the live process at work at the moment of performance, particularly with works with any generative nature to them.

10.6.1 Final Reflection

The final version of this work, or at least the current version, is part of a body of pieces that are differing expressions of a formalized process of collecting and collating. This collecting began as a dérive of observation and photographic collecting around the world. Begun initially as a completely non-verbal process the project developed its own vocabulary and logic over the years of photographing, to the point where the material began to guide the form and the final work. Only then began the process of exploration in the studio, of applying technological processes to illustrate and instantiate the mood developing inside of the work. This process is common to much of my work and my day-to-day artistic activity: one that is an ongoing dialog I have with the world, of observing, looking, making, and underneath it all ultimately seeking sense-making.

The work, while not forcing a specific political point, is intimately political. It is intended as an exposure of pervasive surveillance of our physical world, to a scale that it continues to surprise me, even as I become inured to it. This journey we have chosen to take with surveillance technology, and the ability we have built to track, record and intrude into every aspect of the body public, and our individual bodies, private is operating at a scale that many would find unimaginable should they be able to see it clearly.

As Noam Chomsky, never one to use an alarming phrase when calm reasoned words will do, says [11]:

> there are two things to bear in mind, one is that the phenomenon (of surveillance) should not be at all surprising, the second is that the scale of it is surprising.

10.7 Epitaph for a Digital Artwork

I sit and write, longhand on paper with a pen, the epitaph at the closing of this chapter. The document and journey written covers six countries, countless hours and edits, full of insight and reflection. The final edits are yet to be done but what I can write now is the epitaph. Reading back through this writing, I find I have made a fuller, more complete explanation of my internal process, discussion and artistic activity than ever before in one place. At times on technical, philosophical and political, I trust the reader will forgive me streams of consciousness and occasional melodrama of the miniscule internal theatre that is the struggle of working with digital tools. This writing, alongside ongoing development, coding and versioning of the software, has given me space to reflect on process and practice with a fresh perspective. Thinking of the work, in progress for nearly half a decade, makes me reflect that most readers of this will never see it. That by the time this volume is typeset, proofed, approved, printed and distributed, the work may, in practical terms, cease to exist. Web domains I pay for will expire. Servers will be upgraded, patched, obsoleted and retired and I will go on to new projects, works, technology and software. In very real terms this chapter of ink-on-paper (or the undoubtedly shorter-lived pixels-on-screen) will outlast the work by a magnitude of scale. Sitting in Hong Kong in late June 2019, the mood is somber but resolved and the world seems fragile and tenuous. This work on Signs of Surveillance is a small postcard in a discussion of technological change, reflecting on the fundamental importance of the ephemerality of art, of the importance of its functionless-ness. On the innate lack of practicality that those versions and instantiations of it that require upkeep, maintenance and care to continue to exist are happily always consigned to memory. This is the epitaph to a work of art that will soon cease to be. That will fail by nature of its powerful but short-lived reach and the fickle brittleness of the substance of which it is formed and the un-real substrate on which it is built.

As Picasso, Paul Vale´ry or Da Vinci may have said[21]

> Art is never finished, it is only ever abandoned.

and the abandonment of digital works into a continually changing virtual world affords them a very short lifespan when left to fend for themselves.

References

1. Beeker Northam.: William Gibson, Interview (2015). https://medium.com/handbrain/william-gibson-57e75f87e525
2. Booth, J.: UK 'sleepwalking into Stasi state' (2004). https://www.theguardian.com/uk/2004/aug/16/britishidentity.freedomofinformation
3. British Security Industry Association.: The Picture is Not Clear: How many CCTV surveillance cameras in the UK. Technical Report 195, British Security Industry Association, Worcester, UK (2013). https://www.bsia.co.uk/publications/publications-search-results/195-the-picture-is-not-clear-how-many-cctv-surveillance-cameras-in-the-uk.aspx
4. Buzzo, D.: What do we know of time when all we can know for real is now? In: Reyes-Garcia, P., Chatel-Innocenti, E., Zreik, K. (eds.) Archiving and Questioning Immateriality: Proceedings of the 5th Computer Art Congress, pp. 438–443. Paris, France (2016)
5. Buzzo, D.: The time machine. In: Sena Caires, C., Cardosa, J., Lipovka, A., Bidarra, J., Pimentel, L. (eds.) Proceedings of the 8th International Conference on Digital Arts—ARTECH 2017, pp. 199–201. ACM Press, New York, New York, USA (2017). https://doi.org/10.1145/3106548.3106617.url, https://dl.acm.org/citation.cfm?id=3106548picked=proxCFID=822909194CFTOKEN=38540610, http://dl.acm.org/citation.cfm?doid=3106548.3106617
6. Buzzo, D.: The volca project: a multi-sensory camera for augmented reality. In: Conference on Human Factors in Computing Systems—Proceedings, CHI'18 Extended Abstracts. ACM, Montreal, Canada (2018). https://doi.org/10.1145/3170427.3177767. URL http://dx.doi.org/10.1145/3170427.3177767
7. Buzzo, D.: The Volca project: a sensory experiment in collaborative visualisation. In: Transimage 2018. The fifth International Conference on Transdisciplinary Imaging at the Intersections of Art, Science and Culture. Edinburgh Futures Institute. The University of Edinburgh, Edinburgh, UK (2018). transimage2018.net/
8. Cahill, S.: The art and surveillance project. http://www.artandsurveillance.com/about/
9. Carter, M.: Guerilla programming of video surveillance equipment (1995). http://www.notbored.org/gpvse.html
10. Cerf, V.G.: Avoiding "bit rot": Long-term preservation of digital information. Proc. IEEE (2011). https://doi.org/10.1109/jproc.2011.2124190
11. Chomsky, N.: "What is Anarchism?" Speech at MIT Wong Auditorium. 18 Nov 2013 (2013). https://www.youtube.com/watch?v=oB9rpSAp2U
12. Coupland, D.: Bit rot: Short Stories + Essays. William Heinemann, London (2016)
13. Debord, G.: Theory of the Dérive. Les Le'vres Nues #9. Les Le'vres Nues **9** (1956). http://en.wikipedia.org/wiki/Drive
14. Gill, M., Spriggs, A., Little, R., Spriggs, A., Allen, J., Argomaniz, J., Waples, S.: Assessing the impact of CCTV : the Hawkeye case study. Technical report: The home office. UK Government, London, UK (2005). https://webarchive.nationalarchives.gov.uk/20110218141419/, http://rds.homeoffice.gov.uk/rds/pdfs05/rdsolr1205.pdf
15. Hayes, B.: Bit Rot. Am. Sci. (1998). https://doi.org/10.1511/1998.5.410

[21] There is debate about the correct attribution to the quote, including paraphrasing W. H. Auden in Collected Poems 1965, "Poetry is never finished; it is only abandoned.".

16. Lewitt, S.: Paragraphs on conceptual art. In: Stiles, S. (ed.) Theories and Documents of Contemporary Art. University of California Press, Berkley (1996)
17. Lucy, J.A.: Sapir-whorf hypothesis. Int. Encycl. Soc. Behav. Sci. **20**, 903–906 (2015). https://doi.org/10.1016/B978-0-08-097086-8.52017-0
18. Nietzsche, F.: Nietzsche: beyond good and evil: prelude to a philosophy of the future (2002)
19. Richardson, A.: New Media, new craft? electronic art and animation calalogue, pp. 157–159 (1998)
20. Sagan, C.: Carl Sagan ponders time travel: interview with Carl Sagan (1999). http://www.pbs.org/wgbh/nova/physics/Sagan-Time-Travel.html
21. Shanken, E.a.: Art in the information age: technology and conceptual art. Leonardo **35**(4), 433–438 (2002). https://doi.org/10.1162/002409402760181259
22. Stappers, P.J., Giaccardi, E.: Time in the expanding user context of designing. In: Proceedings of the SIGCHI conference on Human factors in computing. ACM—Association for Computing Machinery (2013)
23. The Information Commissioners Office.: CCTV filming carried out by others. https://ico.org.uk/your-data-matters/cctv/
24. The Surveillance Camera Players.: Surveillance camera players:10-Year Report (2006). http://www.notbored.org/10-year-report.html
25. Weaver, M.: UK public must wake up to risks of CCTV, says surveillance commissioner. The Guardian (2015). http://www.theguardian.com/world/2015/jan/06/tony-porter-surveillance-commissioner-risk-cctv-public-transparent

Part IV
Audio Visual Installations to Generate Collective Human Responses

Chapter 11
Coral Voices

Marlena Novak and Jay Alan Yim

Abstract Marlena Novak (visual artist) and Jay Alan Yim (composer/sound artist), under the collaborative name localStyle, have been making work that addresses environmental and socio-political concerns through the use of a wide range of media since 2000, particularly utilizing technological tools in their creative practice. Deep interest in understanding the contemporary conditions of non-humans and humans is informed by their engagement with publications and texts, attending, participating in, and hosting talks, panels, and screenings, and meeting with specialists and scientists regarding the topics of their research. *Choral* is a twelve-minute audiovisual installation commissioned by 150 Media Stream for a sculpturally unique LED panel display. This chapter describes the genesis of the project, from its inception as an artistic response to news reports of widespread coral bleaching events complicated by climate change, through a concerted phase to properly ground the project in scientific research, followed by an overview of the methodologies and resources used to realize the project, and including a discussion of the technical and conceptual challenges posed by working on a very large scale display medium in a public venue.

Keywords Mutualistic · Symbiotic · Coral reef ecosystem · Climate change · Global warming · Ocean acidification · Anthropocene crisis · Endangered species · Bleaching · Non-humans · Habitat loss · Environmental distress · Cultural processing · Shedd Aquarium · 3D animation · Reef-building coral · Scleractinian · localStyle · Electronic choir · Forty voice motet · Thomas Tallis · Polyphonic · Recomposition · Ambient · EDM · Sound design · Tetrapod

---

M. Novak
Department of Film Video, New Media and Animation, The School of the Art Institute of Chicago (SAIC), Chicago, USA
e-mail: mnovak1@saic.edu

J. A. Yim (✉)
Composition and Music Technology, Bienen School of Music, Northwestern University, Evanston, USA
e-mail: jaymar@northwestern.edu

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_11

11.1 Introduction: Corals Are in Crisis

Many coral species cannot adapt quickly enough to warming ocean temperatures and increasing acidification, threatening reefs worldwide and creating the potential for a catastrophic loss. The habitat created by coral reefs makes them fundamental to the sustainable diversity of ocean fauna, and to all living things—including humans—that rely upon this part of the earth's ecology.

Our audiovisual installation regards coral reefs as the 'voice' of the Anthropocene, hence the title *Choral*. Reefs play a foundational role in providing habitat for a quarter of all marine species and these ecosystems are in crisis. Although they face challenges from multiple directions, we are approaching our piece from an optimistic perspective. Techniques for fostering recovery and regeneration are already under development: a dedicated part of the scientific community is determined to find ways to make these methods scalable, and this is cause for hope.

Through our creative work, we endeavor to join this collective effort by contributing to a larger-scale human response. Although scientific research informs our fundamental approach to the visual appearance of various coral species, the way corals behave in the work reflects our shared imagination through speculative underwater world-building—rather than emulating a literal documentary. We were invited in Spring 2017 by the curator for 150 Media Stream [1], Yuge Zhou [2], to make a moving image artwork for 150's unique wave-shaped 89 vertical panel LED-screen lobby display. This custom-designed technology allows for working at a large scale—the Media Stream display measures 6.5 by 47 m—while the nature of this venue in the heart of downtown Chicago allows for a larger audience to encounter and consider this topic. Our response, *Choral*, is a computer-generated 3D animation with electronic sound that addresses our inquiry focused on the ecosystem of coral reefs (Fig. 11.1).

11.2 Initial Research Phase

Having attended Ars Electronica for five years, three Documentas, several Venice Biennales, as well as having participated in the STRP Festival, the National Art Museum of China's TransLife Triennial, the Taipei Digital Art Festival, and encountering a wide range of art installations incorporating sound, moving image resources, or combinations of the two, in addition to maintaining a collaborative praxis as artists, both of us are professors who have taught numerous classes since 2003 that involve new media and installations. We take our responsibilities to stay well informed seriously as it is integral to our pedagogical activities. The following essay may best be understood as intentionally circumscribed in its scope, since a more expansive survey of digital installations as a genre would exceed our remit.

As artists we have been fortunate to have a range of public platforms available to reach a diverse audience. The concern for what we, as a species, have done to

Fig. 11.1 *Choral* at 150 N Riverside Plaza, Chicago Illinois, USA. *Photo* Michael Salisbury [3], image copyright ©Michael Salisbury and reproduced by permission

the planet is reflected in our work as individual pieces are used as opportunities to probe deeper into these topics while assessing the effectiveness of different modes of expression on audience engagement. Given our history of collaborating on projects—*pr!ck* (2006–08) [4], *scale* (2009–10) [5], *Bird* (2011–14) [6] —that involved aspects of what two physicist colleagues have termed "*cultural processing*" [7], we felt it necessary to delve into more informed research beyond our initial encounters with journalistic reports dating from 2014 regarding the catastrophic events that coral reefs were suffering around the planet. Determined to gain a better grasp of the situation, we first undertook a program of self-education through a variety of documentary films and videos, paralleled by perusing a selection of more recent scientific papers.

In the course of learning more about the multiple causes and disastrous consequences of coral bleaching and death, we encountered the research program of two Chicago-based scientists, Luisa Marcelino (Research Assistant Professor of Civil and Environmental Engineering, Northwestern University) [8] and Timothy Swain (Postdoctoral Fellow, Northwestern University and the Field Museum) [9], whose published articles were a source of inspiration to us, and who agreed to meet us in person. Prior to our March 2018 meeting, we viewed a WTTW television segment where both were interviewed and we were struck by Dr. Swain's observation, "*The coral reef ecosystem may be the first ecosystem lost to climate change*" [10]. Though the topic was initially grim, our discussion with Marcelino and Swain was informative and productive. An afternoon conversation with these scientists absolutely validated our concerns regarding the critical condition of the global ecosystem of the reef and our commitment to developing the project for 150 Media Stream. We learned that the Marcelino Research Group's work at Northwestern points to coral polyps as architects, wherein the fractal properties of their skeletons redistribute light as a photosynthetic resource within the colony. Further study of this phenomenon suggests a relationship between faster-growing species and increased vulnerability to bleaching.

At the end of our meeting, Prof. Marcelino offered to curate a number of critical papers for us to study and Dr. Swain invited us to join him at an upcoming visit to Chicago's Shedd Aquarium to observe some of the coral works that he was engaged with in their laboratory. Having a chance to see these animals close-up and in-person brought a more immediate level of appreciation of their charismatic qualities. It was moving to see how tiny these creatures were while playing such a large role in marine ecosystem sustainability and by extension human economic dependency on that very ecosystem. As Rebecca Albright says:

> Although reefs cover just 0.1 percent of the ocean floor, they support nearly 25 percent of all marine species, including fisheries that feed millions of people worldwide. They also provide natural breakwaters that protect coastal communities by reducing wave energy by up to 97 percent and wave height by up to 84 percent. And they generate vast tourism revenue. If we lose reefs, we jeopardize the livelihoods of 500 million people and more than $30 billion annually in goods and services [11].

Many people benefit unknowingly from the coral reef habitat; numerous articles refer to the reefs as the "*rainforests of the sea*" [12] or "*the medicine cabinets of the 21st century*" [13], from whence a number of anticancer, antiviral, and pain management drugs are being explored, as well as bone graft material. During our behind-the-scenes encounter at the Shedd Aquarium, one of the staff members remarked that although they had valuable and instructive coral displays, they felt they weren't reaching enough of a diverse public to get their message across, and Swain replied: "*That's what Marlena and Jay do*, *as artists*". Consequently, we realized *Choral* could play a role beyond expressing our personal commitment to Anthropocene issues; it might also have the potential to raise public awareness and connect that awareness to the marine biology community that is actively working on solutions to the problems. Helping this community become more visible might ultimately translate into the public policy decisions we collectively need to be enacted for corals to be saved. One of the papers Marcelino referred us to was "*Coral Reefs in the Anthropocene*" [14]. Among the noteworthy points found:

> "[…] research has revealed provocative complexities in the expanding knowledge base about corals and their ecosystems, thus stimulating our imaginations regarding alternate ways to envision the future of reefs" and "Increasingly, coral reef scientists and managers encounter previously unseen configurations of species" [14]

According to Terry Hughes, the reality is that:

> reef ecosystems are more dynamic and patchier, as well as increasingly different to anything that people have encountered before. Embracing this paradigm shift will necessitate a transformation in the governance and management of these high-diversity ecosystems [14].

There won't be any single answer to these problems; solutions to fostering sustainability for corals in the future could build upon a wide range of methods developed by Marcelino's group as well as many other scientists working in the field. Some of these include the creation of a meta-level tool to correlate bleaching data from all previous coral studies into a coherent worldwide index [15] and identifying species better adapted to survive. We learned from Albright's article that:

> Mary Hagedorn of the Smithsonian Conservation Biology Institute has established the first genome repository for endangered coral species. [...] Her team has developed a freezing system for sperm that can be applied to a wide range of coral species. To date, the team has successfully banked 16 species from around the world (2 percent of the earth's estimated 800 species) [11].

Our optimism increased when we learned about the work of the late Dr. Ruth Gates at the Hawaii Institute of Marine Biology and her collaboration with Madeleine van Oppen of the Australian Institute of Marine Science to develop next-generation super-corals. Their labs are working on selective breeding and epigenetic tuning to tolerate warmer sea temperatures, and selective breeding of the symbiotic zooxanthellae and the bacteria that comprise the microbiome of coral polyps to breed more robust colonies. SECORE International is working on both increasing genetic diversity and fostering the odds in favor of coral larvae surviving past their initial vulnerability to being eaten by other marine creatures; when they are big enough to be outplanted, these new generations of young corals can help repopulate damaged reefs. One of the best designs for an economically scalable substrate for baby corals to grow upon is a grapefruit-sized concrete tetrapod, textured so that the larvae can readily attach themselves and start their reef-building. These tetrapods are featured in one sequence of *Choral* as a symbolic representation of the collective efforts of humans to channel their ingenuity toward finding a solution to the bleaching and reef degradation crisis. (One of our contacts at the Shedd Aquarium, Mark Schick is a collaborator with SECORE in the tetrapod project.) Other, more speculative approaches under development include deploying groups of underwater robots that would re-cement broken coral fragments to the deep-sea cold-water reefs they came from, aiding re-growth.

Having first-hand discussions with scientists who are dedicated to identifying and addressing the complex issues that promote coral bleaching was encouraging. These experiences bolstered our decision to create an audiovisual artwork that engendered hope and fostered public engagement rather than despair and cynicism. A meeting with Hobson [16] who is a researcher at NORC was also valuable to our project; drawing on personal experiences from research projects undertaken when she was based in Australia, Hobson told us that "*a noisy reef is a healthy reef*" which inspired us to investigate this aspect and subsequently became a factor in shaping the conceptual approach to sound design and soundtrack orchestration in *Choral*.

11.3 Project Development, Phase Two

A steady intake of information fostered the necessary processes of refinement and metamorphosis, guiding the project's vector away from didacticism toward a more poetic direction. A project of this scale compelled us to undertake two different, though complementary research tracks. The scientific data obviously had to be assimilated and understood to inform our conceptualization of the project, but we also needed to comprehend what kinds of hardware, software, and personnel resources were needed to realize our vision, and to develop a budget and a team that could feasibly support that goal. With the scientific side in full swing by the onset of winter 2017, we accepted an invitation to participate in the Species/Biodiversity Loss panel of the conference Why Do Animal Studies?: The Turn to the Quasi-, Post-, Anti-, Non-, Para- [17] in April 2018, with our presentation "Choral, a work in progress". At minimum, it was a chance to get expert feedback from scholars whose critical thinking and writing on non-human others and Anthropocene-centric issues had been impactful on our own mode of inquiry and efforts. As is common in these types of conferences, it was also a remarkable opportunity to be immersed in the multidisciplinary confluence of scholarly and artistic projects that comprise the field.

One of the strengths of how localStyle's collaborative approach has deepened since its founding in 2000 is the way we are able to pursue independent development tracks in our working methods based on our individual skill sets and areas of expertise, while maintaining a constant conceptually driven dialogue that revolves around the central thrust of any specific project. Inspired by the hospitality of corals to create habitats for other creatures, Novak began modeling, texturing, and animating individual corals—devoting time to both individual colonies from various species as well as to detailed hexacoral polyps—and to assemble a synthesized version of their biome utilizing 3D software tools (Autodesk Maya, Arnold Renderer, Pixologic zBrush) on a Mac Pro workstation. In the conference, her slides incorporated digitally created images that symbolically represented coral bleaching and the degradation of the ecosystem (Figs. 11.2 and 11.3). Based on audience feedback, this imagery turned out to be effective for attendees in the academic context of various presentations zeroing in on challenges that ranged from justice, law, and ethics to postcolonialism to disruption on a variety of planetary scales. These preliminary images thus played a crucial role in our conceptual development of *Choral*, even though we ultimately decided to tactically focus the installation's mode of address toward one that emphasized the

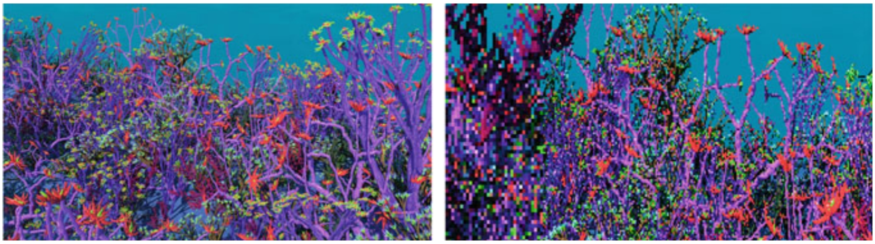

Fig. 11.2 *Study for Choral: Reef Ecosystem Degradation.* 3D image: Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

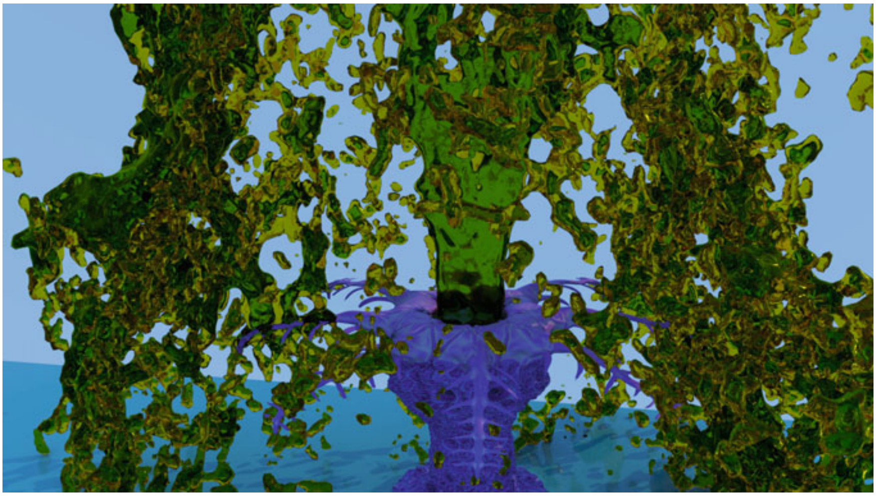

Fig. 11.3 *Study for Choral: Zooxanthellae expulsion.* 3D image: Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission.

hopeful side of human efforts to rescue coral. As with any environmental or climate-related issue, the presence of the political dimension is never far from the surface, and the operational question arises as to how people can be motivated to engage and empathize with a topic so as to enable policy-making to occur in positive ways.

Shortly after meeting with the Northwestern University scientists, the project implementation side of *Choral* began to accelerate. The organization that developed for the installation at 150 N Riverside Plaza placed Novak as co-producer, director, project manager, lead 3D visual artist (concept, modeling, texturing, and animation), and motion graphics conceptual developer; Yim was the co-producer and composer/sound designer as well as being involved with the 3D and motion graphics conceptual development. Clearly a work of this scope would have much to gain from having project assistants; they would benefit from the experience, contribute to the work in a multitude of ways, and be credited for their roles in a high-profile project.

In Spring and Fall 2018, Novak assembled a group of young artists who had formerly studied with her at the School of the Art Institute of Chicago. At an early stage, she compiled a collection of references as an encapsulated database to share with team members. These comprised science-based pieces of journalism in print, web browser, and video formats, organized into three main groups:

(1) how corals live,
(2) reasons for humans to care about corals, and
(3) factors threatening their existence.

The first group of references concerned coral taxonomy, structure, anatomy, habitat, behavior, etcetera. It was important for everyone on board to assimilate some of the basic information about these animals: coral polyps have a symbiotic relationship with photosynthetic dinoflagellates; their survival depends on these algae that provide between 90 and 98% of their nourishment; these zooxanthellae live under the epidermis of each polyp; the polyp's epidermis is coated with bacteria; and these three organisms appear to benefit one another. Especially pertinent were key points provided by the Coral Reef Alliance:

> Coral reefs are often referred to as the medicine chests of the sea. A number of creatures found on reefs produce chemical compounds that have been isolated for human applications—and many more are yet to be discovered. Scientists have developed treatments for cardiovascular diseases, ulcers, leukemia, lymphoma, and skin cancer, all from chemicals in reef plants and animals. Other compounds reduce inflammation, kill viruses, and relax muscles. The beautiful and fragile creatures of our coral reefs have the potential to make even greater contributions to our lives by providing new cures for life-threatening diseases. More than half of all new cancer drug research focuses on marine organisms. In addition, coral's unique skeletal structure has been used to make our most advanced forms of bone-grafting materials [18].

In addition to the stresses of temperature-induced bleaching and ocean acidification weakening their skeletal structures, other factors (many of which are under direct human control) combine to threaten coral's existence: in the natural competition between coral and seaweed, warmer water combined with fertilizer run-off gives seaweed and other macro-algae the advantage; overfishing of species that ordinarily keep seaweed in check by feeding on it exacerbates the stress; governmental policies that revoke environmental protections for existing marine national monuments result in more pollution from industrial exploitation such as mining and oil development; even tourism can be a factor as products like many sunscreens are toxic when introduced to the water. (The most recent evidence points to these products also being toxic to humans.)

As work progressed, we held group screenings of selected documentaries to harmonize our perspectives. Joining localStyle in preproduction concept development were Sally Jo [19] and Malu Ayers [20], and project intern Shinuo Snow Xu [21]. As team assignments solidified, Ayers and Xu worked as 3D artists (modeling, texturing, lighting, animation); Max Crider [22] built and animated 3D rigs for polyp and coral animation in the close-up scenes. Nathaniel Gillette [23] joined us in the Fall as a 3D and 2D artist and became motion graphics coordinator. Also in the Fall, Mak Hepler-Gonzalez [24] joined the *Choral* team as assistant producer, rendering manager and 3D artist involved in all aspects of 3D production, along with post-production, conceptual, and technical development; he contributed several advanced 3D techniques for compositional layout, rendering, and animation that would serve the project until its completion (Fig. 11.4).

11.4 Workflow

Due to having an artist's residency abroad during some of this period, we set up a shared online project folder and a blog to stay involved with each other's progress;

Fig. 11.4 *Choral* team members working at Unspecified Research Lab (top to bottom: Gillette, Novak, Hepler-Gonzalez, Ayers, Xu) *Photo* Jay Alan Yim, image copyright ©J. A. Yim 2019 and reproduced by permission

we also scheduled regular Skype meetings while away. Once back in Chicago, studio sessions resumed. Our working method evolved to include collaboration on many levels: in some cases, a single artist modeled, textured, lit, and animated their models; at other times, they would hand off models they made for another team member to texture, while another artist did the lighting and another executed the animation. If one of us developed a new material that would be suitable for others to use, or a lighting-set, or an animation technique that would be effective for each other's models, we shared these 3D elements. For the most part, our roles were fluid, unlike production hierarchies where a single person works on modeling and another solely engages with texturing, and so forth. Except for one artist who was only involved with much of the rigging, we exchanged and reversed the majority of our roles. This created a special sense of team effort and connection to the final piece. When one of our valued members relocated to another part of the country, we continued to work together via retrieval and development of their uploaded files. *Choral* would not exist in its current state if not for the synergy of this solid collaboration.

We were fortunate to receive supplementary grant funding from the Illinois Arts Council and a Faculty Enrichment Grant (SAIC) that supported aspects of the project; several new computers were necessary to address the rendering time needed for the unusually high resolution of each frame of animation. In addition to the previously mentioned software programs (Maya, Arnold, zBrush), Allegorithmic Substance Painter was used for texturing and Adobe After Effects was used for compositing. Over the course of the project, two custom-configured PC workstations were acquired by Unspecified Research Lab, which is localStyle's studio facility. Sound design/scoring took place on two Mac workstations. Throughout the project, as many as eight laptops were used in conjunction with the desktop machines. Work continued in a mixed Mac/Windows environment, tailored to take advantage of the capabilities of each platform (Fig. 11.5).

Fortunately, we had designed our studio space to be flexible in usage, which allowed a number of artists to work together comfortably and in close proximity to the kitchen and seating areas where we could take breaks as necessary. We regularly provided lunches and dinners, and team members ate together depending on the work periods (Fig. 11.6). Sharing home-cooked meals, often from items grown in our garden, built a closer sense of community; several times an artist from the team would also contribute cookies or bread they had baked. Group meal conversations sometimes addressed recent project achievements or trouble-shooting concerns, but mainly it was a time to focus on positive topics.

Fig. 11.5 *Choral* team members working at Unspecified Research Lab (left to right: Yim, Ayers, Hepler-Gonzalez, Gillette, Crider). *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

Fig. 11.6 *Choral* team members enjoying a lunch break (clockwise from upper right: Yim, Gillette, Xu, Hepler-Gonzalez, Ayers). *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

11.5 Compositional Design and Technical Challenges

There were a number of design challenges unique to this project. One of them entailed the sheer physical size of the video display; with the tallest panels standing at nearly 22 feet and the full array spanning 153 feet in width, we needed to make the visual elements narratively coherent even though it is impossible to stand back far enough in the lobby to see all of the LED blades simultaneously from the center. It is quite a different experience to visually compose a scene with digital models being made, textured, and animated on 28-in. computer screens having 3840 × 2160 resolution; we could assess the design in its entirety. Though we are fortunate to have a 4.9 m (diagonal) projection screen in-house at URL, that is still dwarfed by the size of the tallest blades (6.54 × 0.225 m) at 150 Media Stream. The physical scale impacted team decisions regarding formal qualities such as repetition, proximity, motion, and pacing, requiring care as to where visual elements would be located to create the most dynamic mise-en-scène. Strategically, the array's width helped direct the temporal proportions of different passages in *Choral*, as the situation compelled the viewer to move actively through the space to take in as many CGI corals as possible.

The second major factor in the design was working with the negative space that is an integral component of the display: we had to be conscious of this site-specific parameter to ensure that animated elements retained maximal legibility as they negotiated the voids between panels. Though it was quite useful to have a TIFF mask composited as a layer to preview image sequences on our computers, we appreciated the difference it made to see and hear the draft versions of *Choral* in situ. In a sense, it was visually somewhat like working with a reverse zoetrope in that the alternating slits and opacities worked together to create an interrupted continuity.

LED display resolution was a corollary aspect of the size factor: 150 Media Stream's total pixel count was 15360 × 2160, the equivalent of four 4K screens arranged in a horizontal panoramic view. Rendering moving image sequences at high resolutions is intensive in terms of both time and computational resources. We had non-exclusive access to a multiblade render farm, and non-exclusive access to several banks of computers, in addition to the machines at URL. Emily Kuehn [25]—who is an exceptionally resourceful staff colleague at SAIC—provided crucial support and assistance in addressing the unique and precise Maya template for the 89 screens (which measure a variety of heights and widths), and optimizing the render sequencing setup for the 16K display.

The acoustics of the building conditioned the approach taken to orchestrating the electronic soundtrack and equalizing the mix: the presence of many hard, reflective surfaces—stone, glass, metal—and the height of the atrium effectively disperses much of the audio signal and makes it nonlocalizable. Architectural design at 150 N Riverside Plaza produces acoustic results that are comparable in some significant ways with the reverberant spaces often associated with the performance of large choral works. This made the decision to base the soundtrack on Thomas Tallis' forty voice motet [26] an apposite one, both for these acoustic characteristics and because the eight-channel audio system corresponded to the polychoral division of voices in his score into eight separate vocal quintets. Additional motivations for choosing this point of departure will be discussed below.

11.6 Choral Animation Summary

The introduction begins with waves on a dark sea (where the ocean is a digital simulation). In the tradition of an origin myth, we see friendly bioluminescent polyps ascend to take their places amidst a field of stars in a night sky filled with simulated constellations (Fig. 11.7).

Stylized bubbles rise against the water to become stars; many are replaced by the astral polyps. As the polyps wink out, the celestial field metamorphoses into a digital wire frame that descends to form the contours of a seabed, gradually evolving into more solid terrain (Fig. 11.8).

As an aqueous curtain rises, a richly populated reef full of many species of coral is revealed, and the virtual camera pans at a deliberate pace across the ocean floor (Fig. 11.9).

Being digitally modeled, our reef places all of the corals front and center to emphasize their importance to the community of fish, other creatures, and marine plants that

Fig. 11.7 Polyps rising. *Photo* Michael Salisbury, image copyright ©Michael Salisbury and reproduced by permission

Fig. 11.8 Celestial polyps Photo credit: Michael Salisbury, image copyright ©Michael Salisbury and reproduced by permission

Fig. 11.9 Seabed revealed. *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

would comprise and inhabit this ecosystem in nature. Throughout our 3D animation, the corals are singing when visible (Fig. 11.10).

The digital camera zooms in and slowly circles around several of the more charismatic colonies on this imaginary reef. Despite most coral polyps being individually very small animals, in the aggregate, they play an outsized role in the formation of reef ecosystems, which is our motivation for modeling them in detail for these close-up views (Figs. 11.11 and 11.12).

The intended goal of these two sequences is to engage audience members with the awe-inspiring beauty of coral: to reconnect them to personal memories of experiencing coral in the sea or other environments. Hearing viewers remark, "*We should go back to the Shedd Aquarium*" after seeing our piece in the lobby of 150 N Riverside underscored the importance of making this kind of contact since Chicago's Shedd Aquarium has very good coral exhibitions with detailed information regarding the stresses on coral ecosystems and how those risks will impact our lives if corals are allowed to perish.

The following passage features many computer-generated tetrapods with growing baby corals descending through the water (Figs. 11.13 and 11.14). These represent the small concrete forms that researchers have designed to serve as ideal substrates for newly attached larvae to grow upon. Outplanting tetrapods is one of several complementary solutions currently under development and the Shedd is involved in promoting this approach. As artists, we had hoped that an engaged public would be curious to know more about what the tetrapods are and how they relate to coral reefs; during the test screenings, we have been pleased that this sequence has sparked people's interest and initiated conversation.

Fig. 11.10 Coral reef *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

Next, the scene crossfades from objective potential to the metaphysical, as the corals in *Choral* dance and demonstrate choreographic prowess and graceful coordination. They use their bioluminescent qualities in place of costumes. The dance aspires to usher in their miraculous spawning event (Figs. 11.15 and 11.16).

Finally, the magical moment arrives that happens once per year when coral colonies spawn in synchronization with other colonies of the same species: eggs and sperm are released by the millions to join in the water and produce new coral larvae. For those species whose preference is to incubate their larvae inside the bodies of their polyps, the mother polyps shelter their eggs and are fertilized by sperm from male polyps; when the time comes, the larvae emerge from the mouths of their mothers. Regardless of the method, the new corals and gametes rise in the water column toward the starry sky, swimming up to the surface as they are attracted to light, and eventually falling back to the seabed where they will begin new colonies. Symbolizing the cycle of regeneration, our animation is formulated to seamlessly loop from the spawning sequence back to the ocean scene at the beginning (Figs. 11.17 and 11.18).

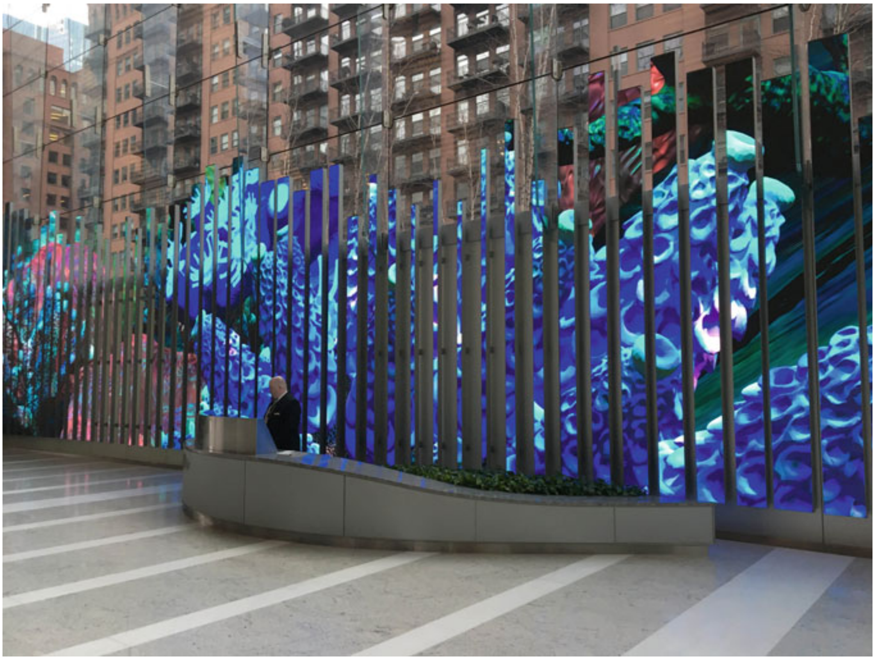

Fig. 11.11 Coral close-up view. *Photo* Jay Alan Yim, image copyright ©J. A. Yim 2019 and reproduced by permission

11.7 Sound Design and Electronic Score Summary

A healthy reef is in reality a noisy place, thus, our narrative begins with a rhythmicized evocation of that percussive sound world, gradually superseded by more sustained and contemplative textures. When the seabed materializes and we see the reef replete with coral colonies of many kinds, we hear the polyps singing polyphonically; it is left to the viewer whether one chooses to interpret this as metaphor or fantasy: that corals are the voice of the Anthropocene.

These non-human choristers are constantly present in the sound design of *Choral* until the final gamete sequence fades back into the ocean scene of the opening frames. Conceptually, the soundtrack began as a recomposition project, taking one of the most celebrated choral works in the early music repertoire, Thomas Tallis' 1570s motet for forty voices "*Spem in alium*", and applying an idiosyncratic version of *musica ficta* [27] so pervasively as to relocate the harmonic world of the motet to that of the present day. (At this point, it may be worth noting that this author first encountered the Tallis score as an undergraduate composition student in 1977. It was immediately elevated to my personal list of desert-island discs, and from the time of initially becoming a professor of composition, has for decades since then been recommended as a study score to my own students. It is truly a marvel of counterpoint and spatialisation, arguably superior—particularly in terms of melodic

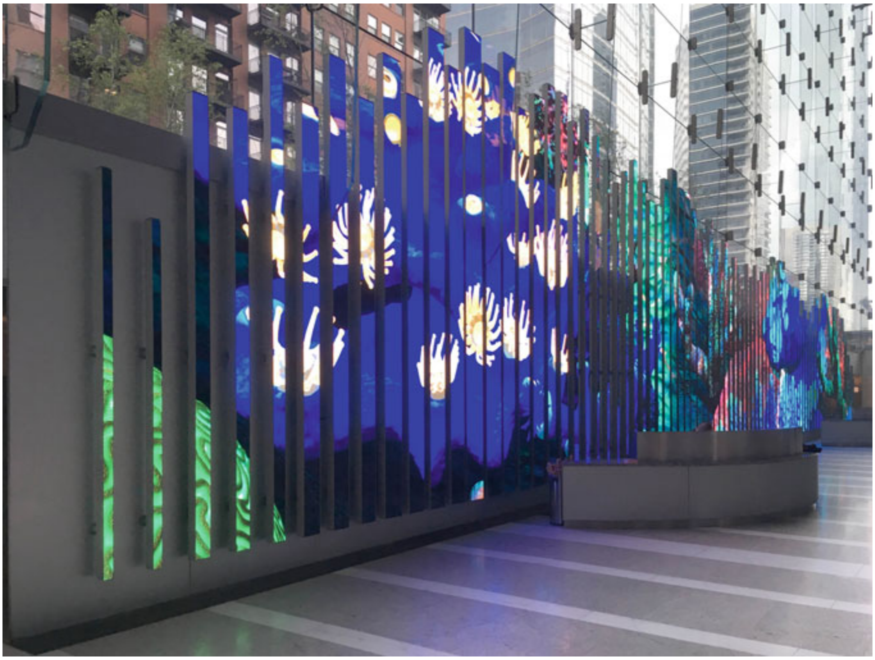

Fig. 11.12 Active polyp close-up. *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

independence—to Alessandro Striggio's [28] own forty voice motet, "*Ecce beatam lucem*", which is typically seen as the precursor to and inspiration for the Tallis.) The timbral world of the music is similarly updated to incorporate otherworldly vocal sounds with electronic textures far removed from the sensibilities of the Renaissance. In the spirit of technical inversion, all of the percussive sounds are triggered by the rhythms of Tallis' motet, whereas the smooth resonances that create the impression of being in the ocean have been fashioned from underwater hydrophone recordings of reefs, which are full of clicking sounds with short attack and decay times.

A variety of software tools contributed to the workflow: Finale for MIDI score input and recomposition in a staff notation environment (due to my classical compositional training, staff notation offers more effective control over counterpoint and harmony than the piano roll display in Live); Ableton Live as a MIDI track host for softsynth instrument playback and recording (including Native Instruments' Absynth 5); Sound Forge for time compression and as a plugin host for DSP and sound design (transforming the hydrophone recordings, shaping samples for the descending sounds in the tetrapod scene, spectral blurring of the vocal textures); Audacity for timestretching; and ProTools for overall track assembly, synchronization with video, and mixing. In the plugin department, Eventide's Blackhole reverb and Unfiltered Audio's BYOME were invaluable.

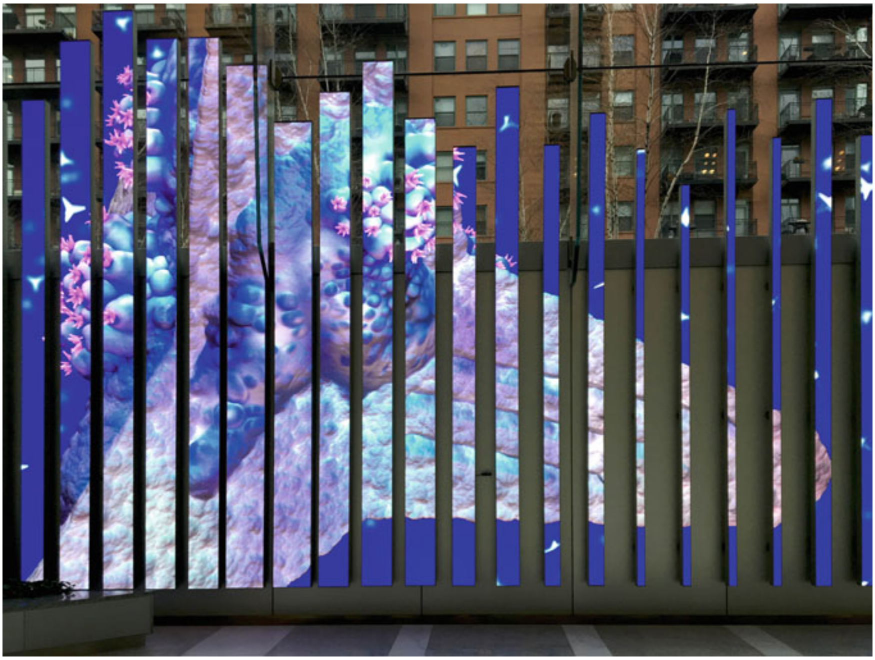

Fig. 11.13 Tetrapod with growing coral close-up. *Photo* Jay Alan Yim, image copyright ©J. A. Yim 2019 and reproduced by permission

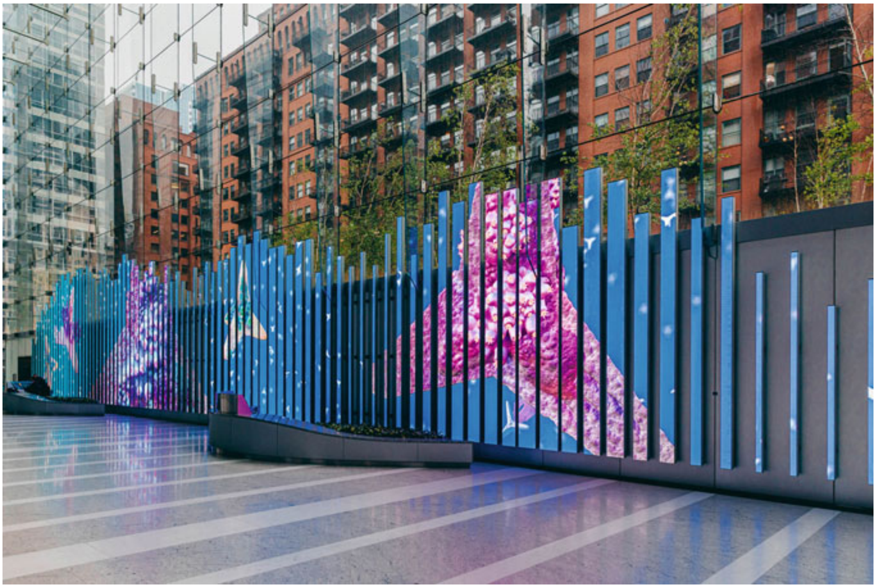

Fig. 11.14 Tetrapods descending to ocean floor. *Photo* Michael Salisbury, image copyright ©Michael Salisbury and reproduced by permission

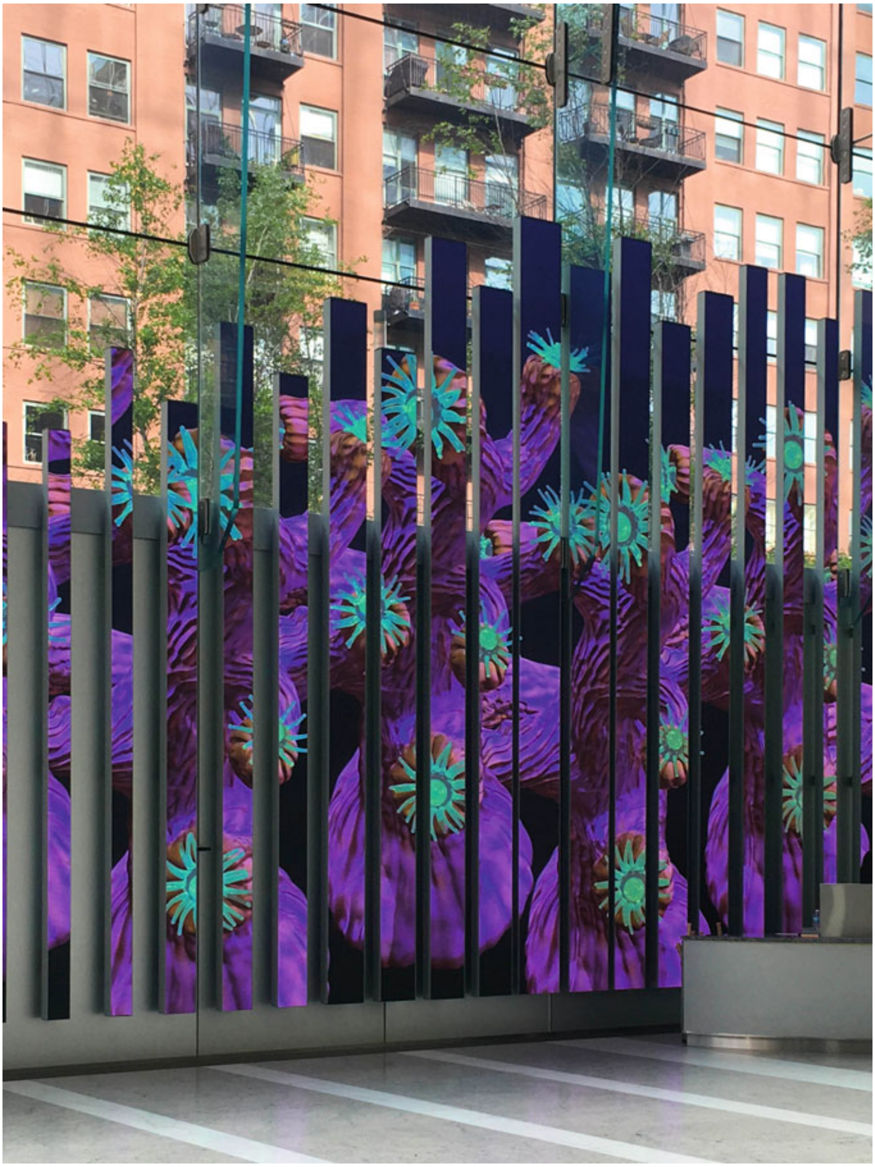

Fig. 11.15 Dance sequence close-up. *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

Fig. 11.16 Dance sequence, long view. *Photo* Jay Alan Yim, image copyright ©J. A. Yim 2019 and reproduced by permission

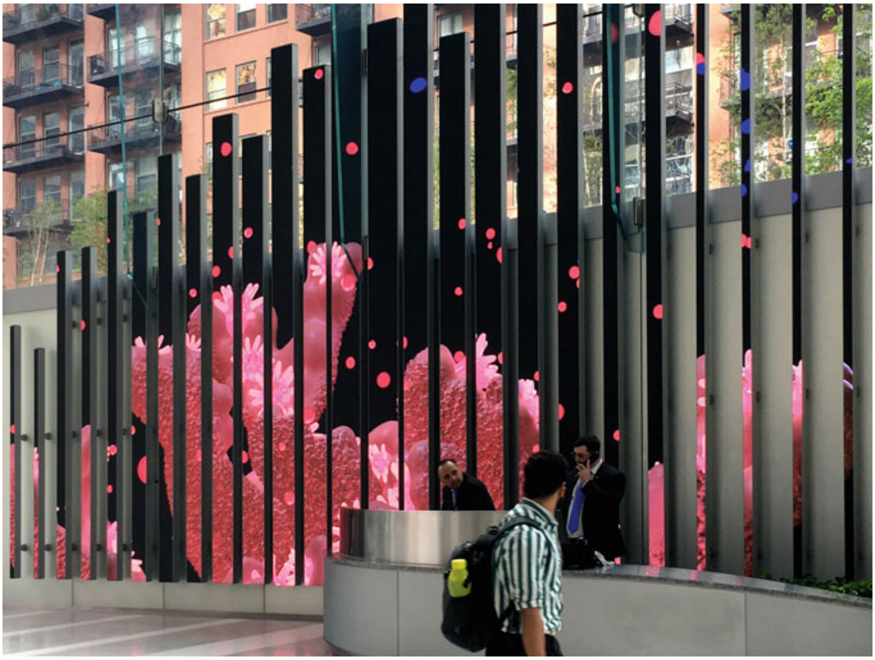

Fig. 11.17 Spawning coral sequence close-up. *Photo* Marlena Novak, image copyright ©M. Novak 2019 and reproduced by permission

Fig. 11.18 Spawning coral sequence long view. *Photo* Jay Alan Yim, image copyright ©J. A. Yim 2019 and reproduced by permission

The first (and most intensive) step was undertaking recomposition of Tallis' motet in Finale. Working in score view gave me the greatest degree of control as chromatic modifications—with increasing deviations—were made to the original score. Garritan Orchestra samples were used to record the basic choral textures, but these were modified substantially in Sound Forge with granular spectral tools and other audio processors. The MIDI data from the Finale file was exported to Live for further development. In Live, the combined MIDI data for all forty voices of the complete motet were used as a single clip to trigger a variety of softsynth instruments; each was recorded and rendered as an 8.5 minute audio track. These tracks were synchronized to the same start time in ProTools because the scoring strategy was somewhat unconventional: (1) to have the recomposed motet play uninterruptedly from beginning to end, thus ensuring continuity, while (2) the electronic orchestration changed for each animation sequence in order to best support the scene, via automation curves when making the final mix. MIDI data was processed using some of the commonly available utilities found in most modern DAWs: automation of pitch bend data made the microtonal retuning of the harmonic series arpeggios in the final scene easily achievable and straightforward, and a moderately complex deployment of an arpeggiator function in the techno-prog scene was used to create the swirling melodic arabesques.

11.8 Conclusions

Exploring this topic through the use of computer-generated motion graphics and 3D software has created an opportunity for us, along with our artist team members, to look very closely at these remarkable animals in order to observe their attributes as best as possible. But it didn't stop at digital mimicry; using these tools compelled a type of looking that resulted in awestruck wonder at the complexity and beauty of coral's functions. The privilege of having this enormous, custom-designed ultra-high resolution LED display to present our project in a public space allows a wide audience of diverse means and pursuits to engage with this subject. We hope that some portion of the viewers will be motivated to consider what role they may themselves play in fostering the sustainability of coral reefs, as scientists in the field have made it clear that we must act now without hesitation to save this ecosystem from extinction.

References

1. 150 Media Stream: [Online]. https://150mediastream.com/. Accessed 7 June 2019
2. Zhou, Y.: [Online]. http://yugezhou.com/. Accessed 7 June 2019
3. Salisbury, M.: "Michael Salisbury" [Online]. https://msalisbu.com. Accessed 7 June 2019
4. Pr!ck: [Online]. https://vimeo.com/116508599. Accessed 7 June 2019
5. Scale: [Online]. https://vimeo.com/19933816. Accessed 7 June 2019
6. Bird: [Online]. https://vimeo.com/45934636. Accessed 7 June 2019
7. Schaffer, K., Lemos, B.G.: Obliterating thingness: an introduction to the "What" and the "So What" of quantum physics (2019) [Online]. https://doi.org/10.1007/s10699-019-09608-5
8. Marcelino, L., Marcelino Group:. [Online]. http://www.civil.northwestern.edu/EHE/Marcelinogroup/. Accessed 7 June 2019
9. Swain, T.: Halmos College of Natural Sciences and Oceanography Faculty and Staff Profiles [Online]. https://works.bepress.com/timothy-swain/about/. Accessed 6 March 2020
10. PBS: Chicago tonight [Online]. http://www.pbs.org/video/chicago-tonight-local-scientists-institutions-fight-save-coral-reefs/. Accessed 7 June 2019
11. Albright, R.: Sci. Am. Jan 2018 [Online]. https://doi.org/10.1038/scientificamerican0118-42. Accessed 7 June 2019
12. Marine Conservation: [Online]. https://marine-conservation.org/what-we-do/program-areas/coral-conservation/coral-reefs/. Accessed 7 June 2019
13. NOAA Ocean Service: [Online]. https://oceanservice.noaa.gov/facts/coral_medicine.html. Accessed 1 June 2019
14. Hughes, T., et al.: Coral reefs in the Anthropocene (2017) [Online]. https://doi.org/10.1038/nature22901. Accessed 7 June 2019
15. Swain, T., et al.: Coral bleaching response index: a new tool to standardize and compare susceptibility to thermal bleaching (2016) [Online]. https://doi.org/10.1111/gcb.13276
16. Hobson, K.: [Online]. http://www.norc.org/Experts/Pages/kate-hobson.aspx. Accessed 7 June 2019
17. Why Do Animal Studies: [Online]. https://www.whydoanimalstudies.com/. Accessed 7 June 2019
18. Why Care About Reefs: [Online]. https://coral.org/coral-reefs-101/why-care-about-reefs/medicine/. Accessed 7 June 2019
19. Jo, H.: "HeeJun Jo" [Online]. https://www.heejunjo.com/. Accessed 7 June 2019
20. Ayers, M.: "Malu Ayers" [Online]. https://www.maluayers.com. Accessed 7 June 2019

21. Xu, S.: “Snow Xu” [Online]. https://snowxushinuo.com. Accessed 7 June 2019
22. Crider, M.: “Max Crider” [Online]. https://www.maxcrider.com. Accessed 7 June 2019
23. Gillette, N.: “Nathaniel Gillette” [Online]. https://www.nathanielgillette.com. Accessed 7 June 2019
24. Hepler-Gonzalez, M.: “Mak Hepler-Gonzalez” [Online]. https://makhepler-gonzalez.com. Accessed 7 June 2019
25. https://www.emilyemily.me/
26. Spem in alium: [Online]. https://en.wikipedia.org/wiki/Spem_in_alium. Accessed 7 June 2019
27. Musica ficta: [Online]. https://en.wikipedia.org/wiki/Musica_ficta. Accessed 7 June 2019
28. Alessandro Striggio: [Online]. https://en.wikipedia.org/wiki/Alessandro_Striggio. Accessed 19 Sept 2019

Chapter 12
Cyberdreams: Visualizing Music in Extended Reality

Jonathan Weinel

Abstract From the visual music films of the twentieth century to the Video Jockey (VJ) performances seen at the latest electronic dance music festivals, there is an extensive body of artistic work that seeks to visualize sound and music. The form that these visualizations take has been shaped significantly by the capabilities of available technologies; thus, we have seen a transition from paint to film; from hand-drawn animations to motion-graphics; and from analog to digital projection systems. In the twenty-first century, visualizations of music are now possible with extended reality (XR) technologies such as virtual reality (VR), augmented/mixed reality (AR/MR), and related forms of multi-projection environment such as full-dome. However, the successful design of visual music and VJ performances using XR technologies requires us to consider the compositional approaches that can be used by artists and designers. To investigate this area, this chapter will begin with an analysis of existing work that visualizes music using XR technologies. This will allow us to consider the spectrum of existing design approaches, and provide a commentary on the possibilities and limitations of the respective technologies. Following this, the chapter will provide an in-depth discussion of Weinel's practice-led research, which extends from work exhibited at the *Carbon Meets Silicon* exhibitions held at Wrexham Glyndŵr University (2015, 2017), and includes AR paintings, VJ performances, and a VR application: *Cyberdream VR*. Through the discussion of these works, the chapter will demonstrate possible compositional principles for visualizing music across media ranging from paint to XR, enabling the realization of work that reinforces the conceptual meanings associated with music.

Keywords Music visualization · Visual music · VJing · Virtual reality · Augmented reality · Extended reality · Electronic dance music

J. Weinel (✉)
London South Bank University, London, UK
e-mail: weinelj@lsbu.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_12

12.1 Introduction

In 2019 the Coachella music festival featured an "interactive augmented reality (AR) stage," in which audiences could use a mobile application [1] to enhance the experience through various fantastical contents, which appeared superimposed on the Sahara venue when viewed through a camera [2–4]. When viewed through the app, audiences could see "space objects like planets, asteroids, and stars" [5] within the performance space, providing digital visual content that complements the audience experience of music. This is just one example of extended reality (XR) technologies being brought into live performance spaces for electronic dance music. XR is an umbrella term that encompasses augmented/mixed-reality (AR/MR), virtual reality (VR), and more broadly, other associated technologies such as multi-projection 360-projection environments and fulldomes, all of which are increasingly being used to complement or visualize music at electronic dance music events, by VJs and digital artists.

The use of these technologies points toward a future in which public performance spaces for music are enhanced through immersive XR content. Music performance spaces are already immersive—sounds, lighting, and communal experiences of dance can all contribute toward generating powerful social experiences that are emotive and meaningful [6]. Yet, while sound can fully engulf the audience as a spatial, aural experience, visual accompaniments too can go further in surrounding and immersing the audience. Through the use of XR, we can begin to conceive music performances where eventually a mesh of synthetic 3D graphics engulfs the performance space, creating hallucinatory computer graphics that visualize the music [7]. Yet, these technologies also generate a variety of new issues that must be considered through research.

The main purpose of this chapter, then, is to explore how audio-visual experiences of music can be designed in XR. Specifically, I will discuss compositional approaches that can be used to design these experiences. I will argue for an approach in which designs in XR can provide visualizations of music that go beyond basic audio reactivity, embodying similar forms of symbolism as those present in the music, and enhance the audience experience by reinforcing meaningful resonances with the music. Towards this aim, first I will review some examples of XR music visualizations and VJ performances, in order to evidence present activity in this field. Following this, I will then turn to consider my own practice-led research creating artistic works such as AR paintings, VJ performances, and a VR application: *Cyberdream VR*. The exploration of these artifacts, performances, and software applications will demonstrate compositional approaches for realizing music visualizations that cross boundaries from analog media such as paint, into the digital; and from digital projections into immersive forms of XR. Through the course of this chapter, I therefore aim to illuminate possible approaches and open new conversations about visualizing music in XR.

12.2 The Current State of the Art

Visual music is an established art-form with considerable history dating back over a hundred years to the early color organs; works by artists such as Kandinsky; and later the films of artists such as Len Lye, Oskar Fischinger, John Whitney, and others [8]. The essential priority of visual music and related forms such as the psychedelic light show [9] is the representation of sound and music through complementary visual media. From the 1980s to present, the rapid expansion and democratized home availability of computer and video technologies saw a significant growth in the related forms of music visualizations, music video, and VJ performance [10]. Of course, there are many possible journeys through this expansive area of work, and it is beyond the scope of this chapter to provide an extended history. As explored in a recent panel discussion that the author participated in at London South Bank University [11], some VJs connect their work with visual music, yet inspiration may also come from the wider sphere of music culture, motion graphics, film, and video. For our purposes here, it will be sufficient to acknowledge that music visualization is a rich and varied field, but also one that has been shaped significantly by new digital technologies over the past century. It therefore comes as no surprise that XR technologies are gradually being assimilated into the panoply of tools used for visualizing music, yet with this, they generate specific new affordances and concerns, which we will now discuss through a selection of examples.

12.2.1 Multi-projection VJ Performances

VJ performance typically involves an individual mixing live video as a complement to electronic dance music performances, in an approximately equivalent manner to the DJ [12]. In recent decades, VJ performance has developed to use multiple projections, and video mapping techniques, which allow video to be projected on custom, irregular surfaces. At electronic dance music festivals such as *Mo:Dem* (Croatia, 2017), elaborate sculptures provide the stage design, on to which the VJ projects video-mapped visuals. Besides the main stage, smaller projection screens are also mounted in the trees (Fig. 12.1), and complement other aspects of the festival decor such as ultra-violet canopies. Here the VJ projections are audio-reactive, responding to the beat, but the designs also reflect otherworldly, alien or shamanic symbolism, which complements the psychedelic themes of the music (as discussed in [13]).

Along similar lines, *Burning Man* (USA, 2016) was one of many recent festivals to feature a fulldome theatre. Here, the fulldome provided an ad hoc movie theatre, which the audience could enter to view 360° films such as *Samskara* [14], which provides a cinematic experience based on the concept of a psychedelic journey analogous to an LSD experience. The film incorporates electronic music and relates to the overall psychedelic theme and ethos of the festival. Elsewhere, video-mapped domes have also been used for VJ performances; for instance, United VJs provide

Fig. 12.1 Psychedelic decor with VJ projections among the treetops at *Mo:Dem* festival, Croatia, 28 July 2017. *Photo credit* J. Weinel

performances [15] and workshops [16] specifically addressing techniques for VJing in fulldomes.

Besides fulldome, other custom multi-projection setups are often used. For instance, the *Resolution* [17] series of events in London has utilized various projection configurations to provided extended immersive visuals. For instance, the series presented Sim Hutchins, whose performances revisit 1990s rave nostalgia through combinations of electronic music and projected visuals, on a 270° projection system in the G05 venue [18]. Meanwhile, another event at G05 featured music by Bobby Tank with a VJ performance by L'Aubaine (Fig. 12.2, [19]), who performed on a 360° projection system.

12.2.2 Augmented Reality Companion Apps

Mobile apps are often used to provide companion experiences at music events, for instance *Notting Hill Carnival mApp* [20] provides useful features such as a map of sound systems for Notting Hill Carnival. The Coachella app fundamentally fulfills a similar function, providing digital marketing and informative features; however, it also goes further with the incorporation of a 'Coachella Camera' with AR features. This provides AR features similar to the popular app *Snapcat*, allowing the user to take selfies and photographs with AR enhancements. However, for our purposes here,

Fig. 12.2 L'Aubaine performing visuals on a 6-screen projector setup at Bobby Tank *Oxygen EP* release event, by Not Like That, G05, London, 2 February 2019. *Photo credit* Laurie Bender (L'Aubaine)

more interesting is the capability for real-time (synchronous) experiences of location-specific AR content, such as the space-themed 3D imagery described in the opening of this chapter, which could be seen at the Sahara stage when viewed through the app. Here the space-theme reinforces the identity of the Coachella festival, suggesting a fun, exotic festival experience that seductively indicates escape from the everyday.

Elsewhere, AR is also being used to complement or visualize music in other ways. The *Kybalion* album by Øresund Space Collective includes a mobile application created with artist Batuhan Bintaş. The application can be activated by viewing the illustrations of the album artwork through a mobile device, bringing to life the artwork through AR/MR and VR computer graphics. Here the app allows the audience "to not only listen to the songs but also to learn about the Hermetic teachings of Thoth by interacting with the album artwork" [21]. In this regard it extends the conceptual universe suggested by the space rock music, effectively allowing the audience to enter the imaginative virtual world that the music describes. Bintaş sees the work as revitalizing the album cover as an artifact to be enjoyed alongside the music, and in this regard it could be understood as complementary to the vinyl revival [22]. However, this piece can also be considered as a 'cyberdelic' (a portmanteau of 'cyberculture' and 'psychedelics') experience, using a term that was popularized in the 1990s by Timothy Leary [23], and is now used by The Cyberdelics Society [24, 25], of which Bintaş is an affiliate. *Kybalion* fits with the idea of cyberdelics because it utilizes the illusory capabilities of the technology to produce a digital art experience that is analogous to psychedelic hallucinations.

12.2.3 Music Visualizations for Mixed Reality Headsets

Although we have noted the Coachella AR app as an example of XR aimed at the dancefloor, mobile phones may be poorly suited as a means of enhancing immersion in the live experience of music; indeed their use at concerts has proven contentious for audiences [26–28]. An alternative approach could be to use MR devices such as the Microsoft HoloLens or Magic Leap, which allow the viewer to wear a holographic headset that superimposes 3D content over the surrounding natural environment. Elsewhere, MR headsets have been used to enhance digital arts exhibitions, by bringing animated visualizations to life. For example, the recent exhibition: *Leonardo da Vinci and Perpetual Motion: Visualising Impossible Machines* [29] used tablet devices and a HoloLens to provide AR/MR 3D holograms, to visualize Leonardo da Vinci's perpetual motion sketches as 3D computer graphics animations in the gallery setting.

This area remains relatively unexplored for music visualization, but there is some early work, such as *Synesthesia,* a HoloLens app that provides an MR music visualization experience based on the generation of audio-reactive graphics [30]. It is possible that technologies such as these could be brought into live music events. However, the obvious current limitation is that the devices are too expensive to be widely used in the music festival environment. Significantly, the viewing angle of these devices is also relatively small [31], which combined with cumbersome headsets would be likely to have a significant impact on immersion during a live music event. At the present time, MR music visualization would therefore be unsuited to the music festival environment, though certainly we could see visualizations of music in smaller scale settings such as gallery installations. As the technology improves and decreases in cost, it may be more feasible to organize larger scale events where audiences use MR glasses to view live visualizations of music. Alternatively, technologies such as the Holo-Gauze [32] provide possibilities for projecting Pepper's ghost holograms on invisible reflective materials, which can be viewed by audiences without headset. A similar approach using Pepper's ghost holograms has been utilized in visual music performances by Carl Emil Carlsen for his work with Silicum [33], and it is possible that future technologies using approaches such as these may provide other ways to introduce MR into the dancefloor context.

12.2.4 Music Visualizations in Virtual Reality

VR is also gradually being incorporated at music festivals. For example, Psych-Fi [34] provides immersive experiences at music festivals such as *Boomtown Fair* and *Sci-Fi London* film festival. At the 2016 edition of the *Liverpool International Festival of Psychedelia*, their app *Dioynsia* was included in the PZYK Gallery, a multisensory arts installation designed to complement the festival experience [35]. *Dioynsia* provides a short journey into a hallucinatory landscape in VR, thereby realizing the idea of a psychedelic trip through synthetic computer graphics and sound [36].

Elsewhere, L'Aubaine has also created work that translates the aesthetics of her VJ performances into 360° narrative piece, *360 Life #1,* which explores "introspection versus outrospection and the boundary between reality and surreality" [37]. Works of this type can be situated in the gallery context, but are also sometimes featured at VJ events; for instance, Fathomable's *Gnosis* [38] is a cyberpunk VR experience created by VJ Rybyk, which was featured at VJ London's AV Depot event [39]. There are also various other commercial VR experiences of music, which are relevant to consider in this section. For example, *Fantasynth* [40] is a short VR experience which provides a journey through a landscape of audio-reactive graphics, while *The Wave VR* [41, 42] and *Amplify VR* [43] are other music platforms that aim to provide music video or virtual concert experiences in VR. There are also various other bespoke music-related VR music experiences, such as *Fabulous wonder.land VR* [44], a VR experience based on *wonder.land*, a National Theatre musical created by Damon Albarn, Moira Buffini, and Rufus Norris.

12.2.5 Discussion

This section has outlined a selection of examples where XR technologies have been used to visualize music. It is significant to note that similar XR technologies underpin many of these productions, since 360° production software and video game engines such as Unity can be used to adapt XR experiences across multiple platforms. Thus, in some cases, where a work is designed for VR, it can be realized for other formats such as AR/MR or fulldome projection. The fluidity between these platforms is one reason why it is pragmatic for our discussion here to look at the bigger picture regarding the use of XR for visualizing music. Yet in considering various types of XR, we also find that these technologies afford different forms of audience experience. In some cases, multi-projection environments may be used to provide VJ experiences in the electronic dance music context, extending the lightshow. Yet in festival environments, XR technologies such as AR/MR and VR are finding new contexts, such as their use to provide 'side-shows' that audience members may experience between the main acts.

It is perhaps worthwhile to consider how XR technologies may impact on dance-floor immersion. Dancefloor immersion is often characterized as arising from the experience of losing oneself in communal experiences of dance and music [45]. Yet Rietveld [46] argues that electronic dance music culture has undergone a shift from dimly lit nightclubs and warehouse parties, toward visual spectacle, which can be associated with the power structures of consumer capitalism. In her argument, elaborate stage designs enhance the visual and redirect the gaze of dancers away from each other, toward all-powerful 'superstar DJs'. For Rietveld then, enhancing the visual spectacle of events may lead to a negative effect on collective experiences of dance-floor immersion. From this perspective, XR clearly carries a risk. When we consider examples such as the Coachella app, audiences are encouraged to direct their gaze to a mobile device, shifting activity away from the dancefloor toward social media interaction and the narcissistic taking of ‘selfies’. The negative impact of mobile phones on dancefloor immersion is already recognized in popular music press—for instance, a recent article in DJ Mag [47] even calls for a ban on mobile phones on the dancefloor, referring to academic research by Henkel [48] that suggests a ‘photo-taking-impairment’ effect on memory, underscoring the idea that such activities may reduce the presence and immersion of individuals in real-world contexts.

However, XR may also be capable of immersing the participant in other virtual spaces that are distinct from the dancefloor [49]. Where VR ‘side shows’ are provided at festivals, these may provide virtual spaces that relate to the themes and symbolic meaning of the event as a whole. In St. John’s [50] discussion, festivals and raves provide liminal spaces of physical and social activity that are removed from the everyday. While the dancefloor experience may be of critical importance for these events, activity in these spaces is diffuse and encompasses multisensory experiences in which aspects such as clothing, costumes, and conversation are also significant. Here, XR may be complementary, since condensed experiences of digital content away from the dancefloor may stimulate conversation, reinforcing the meaning and immersion into the event as a whole.

12.3 Case Study: Projects Visualizing Music in Extended Reality

Having outlined various examples related to the visualization of Music in XR, I will now turn to consider my own practice-led research in this area, which includes work across the areas of AR painting, VJ performance and a VR application: *Cyberdream VR*. Notably, some earlier iterations of this work were presented and discussed in the *Carbon Meets Silicon* exhibitions at Wrexham Glyndŵr University (2015, 2017). Beginning with a brief outline of earlier artistic works, in this section I will provide a personal journey through my creative practice, in order to demonstrate how the work visualizes music in different ways across a variety of media, eventually moving into XR territories. In doing so, I aim to illuminate some possible compositional strategies for visualizing music in XR.

12.3.1 Background

My background is in electronic music and visual arts, and was significantly developed through my Ph.D. [51], completed at the Keele University music studios. Here my work focused on the composition of electroacoustic music based on altered states of consciousness. In summary, this work seeks to design music that is analogous to the form and structure of psychedelic hallucinations, through corresponding sonic materials and structures. This resulted in a series of compositions that were released on the *Entoptic Phenomena in Audio* 12" vinyl [52]; software tools that were used to realize these compositions; and an audiovisual composition entitled *Tiny Jungle* [53, 54]. These works organize sounds, and (for audiovisual works) visual materials, in order to construct experiences analogous to hallucinatory journeys [55].

I later extended these ideas through further audiovisual compositions: *Mezcal Animations* [56], *Cenote Zaci* [57] and *Cenote Sagrado* [58] are three fixed-media visual music films that seek to provide synaesthetic experiences of electronic music and abstract visuals, based on the concept of altered states of consciousness. These were widely performed at international festivals for electronic music and visual music, such as the *International Computer Music Conference* [59], *Seeing Sound* [60, 61] and others, and were included in *Technoshamanic Visions from the Underworld* [62], a loop of collected audiovisual works presented at the first *Carbon Meets Silicon* exhibition. Notably, these works use the technique of 'direct animation', where 8 mm film is hand-painted, projected and digitized, and then combined with other materials such as stop-motion animation and computer graphics. Around this time at Wrexham Glyndŵr University, I also created *Quake Delirium* [63, 64], a video game modification that seeks to represent a hallucinatory state in the form of an interactive video game; and *Psych Dome*, an interactive installation for mobile fulldome, in which participants wear an EEG headset that captures brainwaves, which are used to affect parameters of an audio-visualization based on the visual patterns of hallucination seen during altered states of consciousness [65].

12.3.2 Augmented Reality Paintings

While working at Aalborg University in Denmark, I created several new paintings, which explored similar ideas to my earlier work [66]. For example, *Vortex* (2017) is based on the concept of visual patterns of hallucination, providing a funnel image related to Klüver's [67] 'form constants' (honeycomb, cobweb, funnel, and spiral forms seen during hallucinations). Alongside this work, I also began working with the creative coding environment Processing, designing motion graphics sketches related to altered states, while also drawing influence from demoscene art [68] and the related VJ mixes [69]. I began experimenting with mixing video live to music using the VJ software VDMX, combining direct animation with materials created in Processing and footage made using other techniques such as stop-motion animation. This resulted in *Technoshamanic Visions from the Underworld II* [70], a pre-recorded video loop created by mixing video live to music by the Japanese psychedelic rock band Hibushibire, which was presented at the *Carbon Meets Silicon II* exhibition at Wrexham Glyndŵr University. The exhibition also featured *Vortex* and several of my other paintings, which are essentially companion pieces that test similar visual ideas as those I explore in the videos.

Continuing to explore both painting and audiovisual composition in parallel, I created a series of works that interpret music through synaesthetic, psychedelic forms of visual art. Technically these works explore the use of flow techniques, airbrushing, and digitally cut stencils. They incorporate other aesthetic influences from music via the artwork of L.A. punk bands such as Excel [71], Suicidal Tendencies [72], and hip-hop music via the artist Rammellzee [73]. For example *Trip at the Brain* (2017) interprets a Suicidal Tendencies song of the same name as a pen sketch, which is converted into a digitally cut stencil and rendered in airbrush. *31 Seconds* (2017) incorporates airbrushed lettering, referencing a sample from the jungle track Origin Unknown 'Valley of Shadows' [74], and uses acrylic flow techniques and patterns that reference the designs of rave collective Spiral Tribe. *Bug Powder Dust* (2017) references the Bomb the Bass featuring Justin Warfield song 'Bug Powder Dust' [75], which is based on the William S. Burroughs novel *The Naked Lunch* [76]. For the latter piece, the painting uses airbrushed skeleton stencils reminiscent of Burroughs's 'shotgun paintings', to provide a form of visual quotation (or 'sampling', to use a music production metaphor) [77].

In many cases these paintings were created alongside the VJ work and vice versa, and develop similar aesthetic ideas and symbolism across these forms. I began carrying out some initial experiments that integrate these practices, by video-mapping my VJ content on to the paintings, thereby providing visual art with moving elements. Later, I created a series of three paintings that link the practices of painting and VJing by incorporating printed stills from my VJ work as collage elements: *Enter Soundcat* (2017), *Soundcat S-101* (2017), and *Soundcat 2000* (2017). These paintings were later developed through the use of an AR app, which brings the still images to life as VJ animations when the application is viewed through the mobile application, thereby reinserting the moving image elements into the paintings [78]. The AR paintings provide symbolic interpretations of sound and music, utilizing XR to link the physical media of paint with computer-generated motion graphics.

12.3.3 VJ Performances

My exploration of VJ performance began with improvizational jamming, in which video loops created with direct-animation, stop-motion animation, and computer graphics techniques were mixed live to various kinds of music including psychedelic rock and electronic dance music DJ mixes. This allowed me to experiment with different combinations of sounds and images. I eventually formulated this work into a live DJ/VJ performance under the alias Soundcat [79], which consisted of a DJ set utilizing various breakbeat music from the 1990s breakbeat rave era and beyond (e.g., [80]). In 2018 this was performed at as part of audiovisual concerts for VJ London at New River Studios, London (Fig. 12.3, [81]), and at a concert held at Tŷ Pawb arts centre as part of the ACM Audio Mostly in Wrexham [82].

The visual materials for the Soundcat performance are based on my previous explorations of psychedelia, while also drawing on graphics inspired by 1990s VJ

Fig. 12.3 Soundcat DJ/VJ performance at VJ London, New River Studios, July 2018. *Photo credit* Laurie Bender (L'Aubaine)

mixes and demo-scene graphics [83–85]. I incorporate 3D tunnel effects and geometric animations; 3D scenes reminiscent of the 'cyberdelic' science-fiction landscapes seen on fliers for mega-raves such as Fantazia or Dreamscape; dancing 3D figures; scrolling patterns referencing acid house culture through smiley faces; detournéments of the London Underground and Intel Inside logos; and other Discordian [86] or absurdist imagery. Branching out into the area of 'video music' (in which video samples or loops are used to create music, as exemplified by artists such as Addictive TV, Coldcut or Eclectic Method), one section remixes video trailers from the Planet of the Apes films to match the samples used in a track by Unkle ('Ape Shall Never Kill Ape' [87]). During this period I also became interested in vaporwave (Tanner [88]), an Internet music subculture which provides a surrealistic or hyperreal interpretation of 1990s computer graphics and techno-utopian culture, and some sections incorporate symbolic references to these forms through the use of computer software user interfaces and related symbols or designs.

Using these materials, I created original music videos for all of the tracks that I wanted to include in the VJ mix. These videos were mixed live in VDMX using audio-reactive effects, layering, and synchronized looping techniques, all of which were manipulated in real time using a MIDI controller (a Korg NanoKontrol). For some sections, I used an Akai MPC Studio to rhythmically trigger video clips live in synchronization with the music by improvising with the percussion pads. For a section based on Equinox 'Acid Rain V.I.P. (Breakage Final Chapter Mix)' [89], I used the tracker music sequencer Renoise to program a MIDI sequence in synchronization with the drum track, which was then used to trigger closely synchronized 3D graphics within VDMX. For each song, I created a different VJ mix, which was performed live in the studio, and recorded using a Blackmagic HyperDeck Shuttle. In some cases, further video overdubs were carried out in order to provide additional layering of visuals. This process resulted in a collection of original music videos for each music track, which could then be used to create the final DJ/VJ mixes.

The final live performances were created using the DJ software Serato Scratch, the MixEmergency video plugin, an Akai AMX mixer, and the Akai MPC Studio. This allowed the music videos to be mixed in the same way a DJ mix would usually be created, where changes to pitch can be made to synchronize the beat and blend between music tracks. Visually, further composites were created as the tracks are blended, which could also be further manipulated with effects in MixEmergency (for example, linking EQ adjustments to color contrast). In addition, I used the percussion pads of the Akai MPC Studio to trigger 'one shot' audiovisual materials, which were layered as composites with the video mix. The resulting DJ/VJ mix has some limitations in that various aspects of the visuals are pre-recorded, however, by carrying out intensive work beforehand (both in artistic and computational terms), the approach allows for a highly varied and efficient end result. This approach also prioritizes the mixing of audio and the overall structure of the DJ mix as the focus of effort during live performances, which is an appropriate strategy for solo performances where the music takes priority, and visuals are complementary.

12.3.4 Cyberdream VR

Cyberdream VR is a recent project that extends many of the approaches discussed in electronic music, painting and VJing into XR using VR. The project is based on the concept of a hallucinatory journey through the broken techno-utopias of cyberspace, providing a surrealistic world of psychedelic rave visuals and vaporwave music. *Cyberdream VR* was created for Samsung GearVR, was adapted for a VR cardboard version, and has been shown at various events including *Cyberdelic Incubator Melbourne* [90], *Sci-Fi London festival* [91] and *MIND: Past, Present + Future/Cyberdelics/Remote Viewing* [92].

The experience provides a short 'fly-through' (approximately 5 min long), consisting of a series of scenes. The menu screen is based on the flier for the *Fantazia NYE 1991–1992* rave event, presenting a surrealistic virtual landscape with a large face suspended over it. Upon entering *Cyberdream VR,* the viewer flies across a chequerboard bridge surrounded by statues of strange creatures, entering a fractal structure based on the Sierpinski triangle (Fig. 12.4). Next, we travel over a vast infinity pool with broken manikin heads floating in it. Following this, the viewer is suspended in a large room with airbrushed walls, which were created by digitally scanning paintings made with a real airbrush. In this room, an animated effect creates vortex patterns based on visual patterns of hallucination. In the next sequence we fly through a virtual sky bombarded with pop-up windows; a pastiche of the John

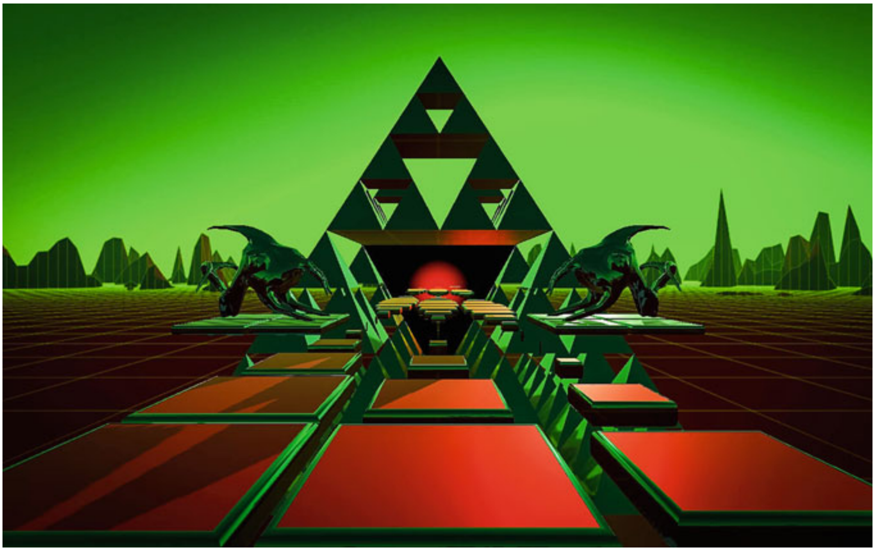

Fig. 12.4 Still image from *Cyberdream VR*. *Image* J. Weinel (2019)

Carpenter movie *They Live* [93], the spam adverts are revealed as signals of capitalist control. The next scene depicts a virtual chequerboard island on which Atari ST cursors (pixel art rendered as 3D graphics) bounce manically or lie derelict among Grecian statues suggestive of techno-utopianism (also a vaporwave trope, see [94, 95]). After this, the next two rooms consist of cycling waves of brightly-colored cubes with oscillating color patterns and sizes. These are based on the classic 'plasmas' of demoscene videos [96], which generate fluid animations using oscillating patterns—here the technique is translated into 3D, giving an impression of being inside the pixels of a computer monitor, while also subtly referencing the design of the Windows '95 logo. Following this, the viewer enters another airbrushed room (again, created using digitized hand-painted art), in which spherical objects move in Lissajous figures. The final scene consists of a dark, chaotic room with bouncing stroboscopic arrows, and the text "the future is lost, crash the system, back to the tribes." This message is a comment on the loss of the techno-utopian futures once imagined by cyberculture [97, 98], while calling for a dissolution and ecstatic recombination of these digital structures. The comment 'back to the tribes' also playfully hints at the idea of 'technoshamanism' (the use of technologies to access shamanic forms of experience, see [99]) and references free-party rave culture (e.g., Spiral Tribe).

The soundtrack for *Cyberdream VR* includes short pieces of acid house, hardcore rave, and vaporwave music. Just as the scenes of the project are essentially artistic sketches, these pieces of music are audio sketches. Thematically both the visuals and audio are related to, and reinforce the overall concept of the piece. Rave music suggests the futuristic aspects of hardcore techno [100], while the vaporwave clips use a plunderphonic approach (music made from existing audio recordings, see [101]) by slowing down imperfect loops of corporate library music intended to enhance productivity in the workplace. In this regard, the piece sonically mirrors the visuals through combinations of symbolic elements from psychedelic rave cyberculture and corporate computer culture. The overall result aims to elicit a broken, hallucinatory vision of the techno-utopianism of cyberculture, revealing the artificial or hyperreality of these visions, while also hinting at the ecstatic possibility in the dissolution of these structures. Described another way, the piece takes Douglas Rushkoff's [102] concept of the Internet as a hallucination, and attempts to visualize that hallucination as a synaesthetic XR experience that allows the viewer to enter into the virtual worlds suggested by rave culture and vaporwave music.

12.3.5 Discussion

The work I have outlined in this subsection spans over a decade of creative practice creating work related to the concept of altered states of consciousness. In different ways, these works represent hallucinations, and synaesthetic experiences of sound and music through combinations of sound and visual art. One of the distinguishing features of this work is that it prioritizes the visualization of music by focusing on the symbols and conceptual meanings that are suggested by music, rather than the physical properties of acoustic soundwaves through audio-reactivity (though some parts of the work do also include audio-reactive or closely synchronized elements). In this regard, the work follows Danneberg's view that music visualisers based primarily on audio reactivity may be relatively uninteresting, because they render only simplistic, readily apparent features of sound. Instead, he argues that composers should "make connections between deep compositional structure and images" [103]. With my own work, I interpret this 'deep structure' at a conceptual, symbolic level, where the visualization becomes a means to unlock the imaginary spatial environments and visual associations suggested by the music. While these symbolic visualizations can be realized with static visual art, animated visuals provide a way for these to be realized as time-based audiovisual media. XR technologies then provide a way to extend this idea further still, by providing spatial portals into these synaesthetic virtual worlds.

12.4 Conclusions

The first half of this chapter explored various examples where XR technologies are being used to visualize music. Through this discussion, we saw how XR provides new possibilities for constructing immersive visual experiences that complement music. These may extend the idea of the concert lightshow, or provide complementary 'side' experiences that reinforce the cultural meaning of these events. The latter half of the chapter then discussed my own practice-led research, creating AR paintings, VJ performances, and a VR experience related to music and altered states of consciousness. These works broadly seek to elicit synaesthetic experiences of sound and music through various forms of visualization. Through the exploration of these works, I have demonstrated some possible approaches for visualizing music using XR, and I also hope to have shown that XR technologies need not be approached as novelty gadgets—but rather as means through which to extend fundamental artistic concepts for visualizing music. The approach that I have emphasized here is one in which XR visualizations do not lean heavily on audio-reactivity, but rather seek to access deeper symbolic meanings, in order to manifest the imaginative worlds suggested by music as synaesthetic immersive 3D spaces. The unique potential of XR is to go through the portals into music that visual music paintings, films, and VJing have so tantalizingly provided in the past. Now, it is possible for the listener to enter into the music as an audiovisual space, and feel as if they are inside the visual worlds suggested by music, or for the visual forms of music to spill out into the concert hall or living room. Whether these technologies are used to visualize the psychedelic music, rave music, and vaporwave discussed here, or other genres, the potential is to radically transform the way we experience music.

References

1. Coachella: Coachella 2019 [mobile application for iOS and Android] (2019). Information available online: https://www.coachella.com/mobile/. Accessed 21 April 2019
2. Dellinger, A.J.: Coachella built an AR experience for festival-goers, Engadget, 12 April 2019. Online: https://www.engadget.com/2019/04/12/coachella-cameras-augmented-reality-sahara-tent. Accessed 21 April 2019
3. Emrich, T.: Augmented Reality Coachella Experience (2019) [YouTube video]. Online: https://youtu.be/kY1Mr0b_I4Y. Accessed 21 April 2019
4. Melnick, K.: Coachella Debuts Its First Interactive AR Stage, VR Scout, 14 April 2019. Online: https://vrscout.com/news/coachella-ar-interactive-stage/. Accessed 21 April 2019
5. Roettgers, J.: Coachella Goes AR With Immersive Stage Experience, Variety, 12 April 2019. Online: https://variety.com/2019/digital/news/coachella-ar-experience-1203188058/. Accessed 21 April 2019
6. Weinel, J.: Inner Sound: Altered States of Consciousness in Electronic Music and Audio-Visual Media. Oxford University Press, New York (2018)
7. Weinel, J.: Augmented unreality: synesthetic artworks and audio-visual hallucinations. In: Grimshaw, M., Walther-Hansen, M., Knakkergaard, M. (eds.) The Oxford Handbook of Sound & Imagination. Oxford University Press, New York (2019)
8. Brougher, K., Mattis, O.: Visual Music: Synaesthesia in Art and Music Since 1900. Thames & Hudson, London (2005)
9. Weinel, J.: Improvising with Light: Nova Express Psychedelic Lightshow, OUPBlog, 14 December 2018. Online: https://blog.oup.com/2018/12/nova-express-psychedelic-light-show/. Accessed 21 April 2019
10. Weinel, J.: Synesthetic overdrive. In: Weinel, J. (ed.) Inner Sound: Altered States of Consciousness in Electronic Music and Audio-Visual Media, pp. 115–134. Oxford University Press, New York (2018)
11. Rietveld, H.C., Allen, C.T., Bender, L., Pilkington, M., Weinel, J.: VJ Panel: Immersive Visual Music, 15 May 2019. London South Bank University, London (2019)
12. Faulkner, M.: VJ: Audio-Visual Art and Vj Culture. Laurence King Publishing, London (2006)
13. St. John, G.: Global Tribe. Equinox, London (2012)

14. Android Jones and 360art (2015–2016) Samskara [fulldome film]
15. VJSpetto: This is Fulldome VJ—United VJs [YouTube] (2013). Online: https://youtu.be/dl3b5PBl87o. Accessed 26 May 2019
16. United VJs: VJ University (2019). Online: http://vjuniversity.com.br/. Accessed 26 May 2019
17. Resolution: Resolution Events London [Facebook event page] (2019). Online: https://www.facebook.com/resolutioneventslondon/. Accessed 26 May 2019
18. 4:3: Sim Hutchins: 'Druk Pak'|4:3 Music Video [YouTube] (2019). Online: https://youtu.be/FtckhsaB5RA. Accessed 26 May 2019
19. L'Aubaine: L'Aubaine—Live visuals and videos in immersive environments [Vimeo video] (2019). Online: https://vimeo.com/326374325. Accessed 26 May 2019
20. Nicomon: Notting Hill Carnival mApp: the official Carnival app (2018). Information available online: https://www.notting-hill-carnival-mapp.com/. Accessed 21 April 2019
21. Bintaş, B.: Øresund Space Collective—Kybalion: A Cyber-Dimensional Way to Experience Music. EVA London (Electronic Visualisation and the Arts) 2019, 8–11 July 2019, British Computer Society, London (2019)
22. Moore, J.: Back in the groove: How vinyl rose from its sickbed to capture the eyes and ears of millennials, The Independent, 21 September 2017 (2017). Online: https://www.independent.co.uk/news/long_reads/vinyl-demand-lps-record-store-day-a7952911.html. Accessed 21 April 2019
23. Leary, T.: Chaos & Cyber Culture. Ronin, Berkeley (1994)
24. The Cyberdelic Society: The Cyberdelics Incubator (2019). Online: https://www.cyberdelicsociety.com/cyberdelics-incubator. Accessed 21 April 2019
25. Valentish, J.: Acid test: how psychedelic virtual reality can help end society's mass bad trip, The Guardian, 26 March 2019 (2019). Online: https://www.theguardian.com/technology/2019/mar/26/acid-test-how-psychedelic-virtual-reality-can-end-societys-mass-bad-trip. Accessed 21 April 2019
26. Beaumont-Thomas, B.: Phones at gigs can be annoying—but they must never be banned, The Guardian, 3 December 2018 (2018). Online: https://www.theguardian.com/music/2018/dec/03/phones-at-gigs-annoying-research-must-never-be-banned. Accessed 21 April 2019
27. Jenkins, S.: Should phones be banned at gigs? BBC News, 28 January 2018 (2018). Online: https://www.bbc.co.uk/news/entertainment-arts-42851434. Accessed 21 April 2019
28. Thorpe, V.: Kendrick Lamar joins stars trying to keep concerts special, The Guardian, 10 February 2018 (2018). Online: https://www.theguardian.com/music/2018/feb/10/kendrick-lamar-bans-phones-photographers-from-concerts. Accessed 21 April 2019
29. Birkbeck: New Exhibition Explores Leonardo da Vinci's Impossible Machines (2019). Online: http://www.bbk.ac.uk/news/new-exhibition-explores-leonardo-da-vinci2019s-impossible-machines. Accessed 27 May 2019
30. Odom, J.: Synesthesia Adds Trippy Sound Visualization to the HoloLens, Next Reality, 14 February 2017 (2017). Online: https://hololens.reality.news/news/have-you-seen-this-synesthesia-adds-trippy-sound-visualization-hololens-0176215/. Accessed 21 April 2019
31. Heaney, D.: HoloLens 2's Field of View Revealed, UploadVR.com, 25 February 2019 (2019). Online https://uploadvr.com/hololens-2-field-of-view/. Accessed 21 April 2019
32. Holotronica: Holo-Gauze—Holotronica (2019). Online: https://stuartwarrenhill.com/holo-gauze/. Accessed 27 May 2019
33. Carlsen, C.E.: Silicum 04: Audiovisual Performance (2018). Online: http://cec.dk/works/silicium-04/. Accessed 26 May 2019
34. Psych-Fi: PsychFi | Turn On, Boot Up, Trip Out—#HackThePlanet (2019). Online: https://www.psychfi.com/. Accessed 27 May 2019
35. Liverpool Psych Fest: PZYK 2020 (2016). Online: http://www.liverpoolpsychfest.com/2016/08/pzyk-vr/. Accessed 26 May 2019
36. Dinehart, S.E.: Dionysia: A Cyberdelic Experience VR Demo Video [YouTube video] (2017). Online: https://youtu.be/94ehDHthw7k. Accessed 21 April 2019
37. L'Aubaine: 360 Life #1 [Vimeo video] (2018). Online: https://vimeo.com/313546173. Accessed 21 April 2019

38. Fathomable: Gnosis [virtual reality experience] (2018). Available on Steam: https://www.oculus.com/experiences/rift/1242416849112952/. Information available online: http://gnosisthegame.com/. Accessed 21 April 2019
39. VJ London: AV Depot #2 Interactive Labyrinth (2016). Information available online: http://vjlondon.com/home/events/event/av-depot-2. Accessed 21 April 2019
40. Fantasynth: Fantasynth [virtual reality experience, multiple platforms] (2017). Information available online: http://fantasynth.com/. Accessed 21 April 2019
41. WaveVR: The Wave VR (2018). Online: http://thewavevr.com/. Accessed 21 April 2019
42. Deahl, D.: Inside Imogen Heap's Cutting-Edge VR Concert. The Verge, 23 August 2018 (2018). Online: https://www.theverge.com/2018/8/23/17769166/imogen-heap-concert-oculus-vr-headset-thewavevr. Accessed 26 May 2019
43. Mbryonic: Amplify VR (2018). Online: https://mbryonic.com/portfolio/amplify-vr/ (Accessed 21 April 2019)
44. Productions: Fabulous wonder.land VR (2019). Online: https://59productions.co.uk/project/fabulous-wonder-land-vr/. Accessed 26 May 2019
45. Hutson, S.R.: Technoshamanism: spiritual healing in the rave subculture. Popul. Music Soc. **23**(1), 53–77 (1999)
46. Rietveld, H.C.: Journey to the light? Immersion, spectacle and mediation. In: Attias, B.A., Gavanas, A., Rietveld, H.C. (eds.) DJ Culture in the Mix: Power, Technology, and Social Change in Electronic Dance Music. Bloomsbury Academic, New York (2013)
47. Shortlidge, C.: Is it Time for a Total Ban on Phones on the Dancefloor? DJ Mag, 17 April 2019 (2019). Online: https://djmag.com/content/it-time-total-ban-phones-dancefloor. Accessed 26 May 2019
48. Henkel, L.A.: Point-and-shoot memories: the influence of taking photos on memory for a museum tour. Psychol. Sci. **25**(2), 396–402 (2014)
49. Rietveld, H.C., Weinel, J.: Extended Dancefloor: Visualing Dancefloor Immersion in XR, Play/Pause Symposium—Immersion|Dissonance, University of Birmingham, 22 May 2019
50. St. John, G.: Technomad: Global Raving Countercultures. Equinox, London (2009)
51. Weinel, J.: Altered states of consciousness as an adaptive principle for composing electroacoustic music [Ph.D. thesis]. Online: http://www.jonweinel.com/media/ASC_Commentary_38.pdf. Accessed 26 May 2019
52. Weinel, J.: Entoptic Phenomena in Audio [12" vinyl]. Hardcore Jewellery (2014)
53. Weinel, J.: Tiny Jungle [visual music film] (2011). Online: https://youtu.be/i3kK9PG2XkU. Accessed 26 May 2019
54. Weinel, J.: Tiny Jungle: psychedelic techniques in audio-visual composition. In: Proceedings of the International Computer Music Conference 2011, University of Huddersfield (2011). Online: http://hdl.handle.net/2027/spo.bbp2372.2011.066. Accessed 26 May 2019
55. Weinel, J.: Entoptic phenomena in audio: categories of psychedelic electroacoustic composition. Contemp. Music Rev. **25**(2), 202–223 (2016)
56. Weinel: Mezcal Animations [visual music film] (2013). Online: https://youtu.be/E6Rd201F8QA. Accessed 26 May 2019
57. Weinel: Cenote Zaci [visual music film] (2014). Online: https://youtu.be/x4UGq1LlyYU. Accessed 26 May 2019
58. Weinel: Cenote Sagrado [visual music film] (2014). Online: https://youtu.be/q8XrEagszt8. Accessed 26 May 2019
59. ICMC-SMC: Music Programme (2014). Online: http://www.icmc14-smc14.net/program/conference-program/music_program.html. Accessed 27 May 2019
60. Seeing Sound: 2013 Movies (2019). Online: https://www.seeingsound.co.uk/seeing-sound-2013/2013-movies/. Accessed 27 May 2019
61. Seeing Sound: 2016 Screenings (2019). Online: https://www.seeingsound.co.uk/2016-screenings/. Accessed 27 May 2019
62. Weinel, J.: Technoshamanic Visions from the Underworld [artist statement]. ITA(15) Carbon Meets Silicon Exhibition Catalogue, Oriel Sycharth Gallery, 8–11 September 2015. Wrexham Glyndŵr University, North Wales, pp. 36–37 (2015). Online: http://glyndwrpix.co.uk/carbonaugust2/mobile/index.html. Accessed 26 May 2019

63. Weinel, J.: Quake delirium: remixing psychedelic video games. Sonic Ideas/Ideas Sónicas **3**(2), 22–29 (2011)
64. Weinel, J., Cunningham, S., Roberts, N., Griffiths, D., Roberts, S.: Quake delirium EEG: a pilot study regarding biofeedback-driven visual effects in a computer game. In: IEEE Proceedings of the Sixth International Conference on Internet Technologies and Applications 2015, Glyndŵr University, North Wales (2015). https://doi.org/10.1109/itecha.2015.7317420
65. Weinel, J., Cunningham, S., Roberts, N., Roberts, S., Griffiths, D.: EEG as a controller for psychedelic visual music in an immersive dome environment. Sonic Ideas/Ideas Sónicas **7**(14), 85–91 (2015)
66. Weinel, J.: Finding 'the weird' in psychedelic art, OUPblog, 18 January 2018 (2018). Online: https://blog.oup.com/2018/01/finding-weird-psychedelic-art/. Accessed 26 May 2019
67. Klüver, H.: Mescal and Mechanisms of Hallucinations. University of Chicago Press, Chicago (1971)
68. Polgár, T.: Freax: A Brief History of the Computer Demoscene. CSW-Verlag, Winnenden (2005)
69. Weinel, J.: How Atari and Amiga computers shaped the design of rave culture, OUPBlog, 5 April 2018 (2018). Online: https://blog.oup.com/2018/04/atari-amiga-computers-design-rave-culture/. Accessed 21 April 2019
70. Weinel, J.: Technoshamanic visions from the Underworld II. In: IEEE Proceedings of the Seventh International Conference on Internet Technologies and Applications 2017, Wrexham Glyndŵr University, North Wales, pp. 345–346 (2017)
71. Ross, S., Clements, D.: Excel 1979–1992. Paper Work NYC, New York (2018)
72. Clayton, R.: Welcome to Venice RXCX. Gingo Press/KYI, Los Angeles (2018)
73. Laz Inc.: Rammellzee: A Roll of the Dice [exhibition], 2nd October–8th December 2018 (2018). https://www.lazinc.com/exhibitions/1394/. Accessed 12 March 2019
74. Origin Unknown: Valley of Shadows [12" vinyl]. Ram Records (1993)
75. Bomb the Bass featuring Justin Warfield. *Bug Powder Dust* [12" vinyl]. 4th & Broadway (1994)
76. Burroughs, W.S. (1959) The Naked Lunch. Reprint, Fourth Estate, London 2010
77. Riflermaker: Dead Aim: The Unseen Art of William S. Burroughs. Riflemaker, London (2005)
78. Soundcat VJ: Augmented Reality Paintings by Soundcat VJ [YouTube] (2019). Online: https://youtu.be/TzIb0-mt10w. Accessed 26 May 2019
79. Soundcat VJ: Soundcat [Facebook page] (2019). https://www.facebook.com/SoundcatArt/. Accessed 26 May 2019
80. Soundcat VJ: Soundcat—Breakbeat DJ/VJ Set [YouTube video] (2018). Online: https://youtu.be/xuJP4asCr44. Accessed 26 May 2019
81. VJ London: July VJ Meet-Up and Showcase, 12 July 2018, New River Studios, London (2018). Information available online: http://vjlondon.com/home/events/event/july-2018-vj-meet-up-showcase/. Accessed 26 May 2019
82. Audio Mostly: Soundcat—Breakbeat DJ/VJ Set Exploring Psychedelia, 12 September 2018, ACM Audio Mostly 2018: A Journey Into Sound [evening concert], Tŷ Pawb, Wrexham, North Wales (2018). Information available online: https://audiomostly.com/2018/conference-programme/. Accessed 27 May 2019
83. Dr. Devious and the Wiseman: Dance in Cyberspace [VHS]. Parade Video (1992)
84. Hex: Global Chaos [VHS]. Ninja Tune (1993)
85. Frost, M., Irwin, C., Jamieson, D., Simpson, P.: Future Shock. Prism Leisure Video (1993)
86. Koke, J., Pearcy, D., Hartsock, N.: Principia Discordia. Steve Jackson Games, Austin (1994)
87. Unkle: Ape Shall Never Kill Ape [12" vinyl]. Toy's Factory (1998)
88. Tanner, G.: Babbling Corpse: Vaporwave and the Commodification of Ghosts. Zero Books, Alresford (2016)
89. Equinox: Acid Rain V.I.P. Planet Mu (2006)
90. The Cyberdelic Society: Cyberdelics Incubator Melbourne [Facebook event page] (2019). Online: https://secure.latest.facebook.com/events/293967014606877/. Accessed 27 May 2019

91. Sci-Fi London: VR Experiences [festival programme] (2019). Online: https://sci-fi-london.com/2019/04/06/vr-experiences/. Accessed 26 May 2019
92. The Explorers Club/The Cyberdelic Society: MIND: Past, Present + Future/Cyberdelics/Remote Viewing [Facebook event page] (2019). Online: https://sci-fi-london.com/2019/04/06/vr-experiences/. Accessed 26 May 2019
93. Carpenter, J. (director): They Live. Universal Pictures (1988)
94. Chandler, S.: Escaping Reality: The Iconography of Vaporwave (2016). https://daily.bandcamp.com/2016/09/16/vaporwave-iconography-column/. Accessed 12 March 2019
95. Chandler, S. (2016) Genre As Method: The Vaporwave Family Tree, From Eccojams to Hardvapour. https://daily.bandcamp.com/2016/11/21/vaporwave -genres-list/ (retrieved 12 March 2019)
96. Vandevenne, L.: Lode's Computer Graphics Tutorial—Plasma (2004). https://lodev.org/cgtutor/plasma.html. Accessed 12 March 2019
97. Turner, F.: From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism. University of Chicago Press, Chicago (2006)
98. Bennetsen, H.: From Counterculture to Cyberculture: The Legacy of the Whole Earth Catalog [Youtube video] (2011). https://youtu.be/B5kQYWLtW3Y. Accessed 12 March 2019
99. Weinel, J.: Inner Sound: Altered States of Consciousness in Electronic Music and Audio-Visual Media, pp. 90–93. Oxford University Press, New York (2018)
100. Fisher, M.: Ghosts of My Life: Writings on Depression, Hauntology and Lost Futures. Zero Books, Alresford (2014)
101. Oswald, J.: Bettered by the borrower: the ethics of musical debt. In: Cox, C., Warner, D. (eds.) Audio Culture: Readings in Modern Music. Continuum, New York (2004)
102. Rushkoff, D.: The Internet Is Acid, and America Is Having a Bad Trip, Medium, 4 September 2018 (2018). Online: https://medium.com/team-human/the-internet-is-acid-and-america-is-having-a-bad-trip-fa0864c3ef1e. Accessed 26 May 2019
103. Dannenberg, R.B.: Interactive visual music: a personal perspective. Comput. Music J. **29**(4), 28 (2005)

Chapter 13
Augmenting Virtual Spaces: Affective Feedback in Computer Games

Stuart Cunningham, John Henry, and Jonathan Weinel

Abstract Computer games can be considered a form of art insomuch as they are critiqued, revered and collected for their aesthetics in addition to their ludic qualities. Perhaps most significantly, computer games incite a plethora of emotional responses in their players as a deliberate and defining mechanism. However, unlike other forms of traditional media and art, another key feature of games is their intrinsic interactivity, reliance upon technology and non-linearity. These traits make them particularly noteworthy if one wishes to consider how art forms might respond and adapt to their audience's emotions. The field of affective computing has been developing for several decades and many of its applications have been in the analysis and modelling of emotional responses to forms of media, such as music and film. In gaming, recent developments have led to an increasing number of consumer-grade biofeedback devices which are available on the market, some of which are explicitly sold as 'gaming controllers', giving rise to greater opportunity for affective feedback to be incorporated. In this chapter, a review is provided of the affective gaming field. Specifically, it is proposed that these developments give rise to interesting opportunities whereby virtual environments can be augmented with player affective and contextual information. An overview is provided of affective computing fundamentals and their manifestation in developments relating specifically to games. The chapter considers the impact this biometric information has upon games players, in terms of their experience of the game and the social connections between competitors. A number of associated practical and technological challenges are highlighted along with areas for future research and development activities. It is hoped that by exploring these developments in gaming that the longer established forms of art and media might be inspired to further embrace the possibilities offered by utilising affective feedback.

S. Cunningham (✉) · J. Henry
Centre for Advanced Computational Science (CfACS), Manchester Metropolitan University, Manchester, UK
e-mail: s.cunningham@mmu.ac.uk

J. Henry
e-mail: john.henry@mmu.ac.uk

J. Weinel
London South Bank University, London, UK
e-mail: weinelj@lsbu.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_13

Keywords Affective computing · Affective feedback · Computer and video games · Emotion · Game design · Interactive media · Social gaming · User experience

13.1 Introduction

The ability to engage with an audience on an emotional level is one of the defining traits of many forms of art and media. The Cambridge English Dictionary defines art as "*the making of objects, images, music, etc. that are beautiful or that express feelings*" [1]. This supports the notion that the author of such works is able to express emotion, be it their own or that of others, through a variety of mechanisms. One might also take the view that the audience members, whilst being able to perceive the emotion of the author, will also have their own response to the stimulus, which may be consistent with the author's emotional intent or not. Historically, this emotional communication has been a largely one-directional affair: the author creates a piece of work with its emotional intent and disseminates it in some way, the audience experiences the art and has their emotional response to it, and this sequence may repeat itself. However, there is traditionally no recourse for the emotional response of the audience to feedback to the author beyond the writing of reviews, critiques, blogs and other forms of response.

We propose that computer games can be considered a form of contemporary art, much in the same way as video, film, animation and interactive audio-visual installations are now viewed. Certainly, games combine the requisite forms of media cited by the dictionary definition: images and music that are visually pleasing. Games are also recognised for their ability to engage an audience and provoke emotional responses in their audience. Gee [2] advocates that the interpretation of their aesthetics and the story aspects of games qualify them as art. Further, we note that games are critiqued, reviewed, discussed and are points of cultural reference. Smuts [3] shares this perspective, although notably recognises that not every computer game may qualify for the label as being recognised as art. One characteristic that makes games particularly compelling as an art form is the rate of change and development with which the media evolves and its facility to integrate easily with other technological developments, both hardware and software based. Therefore, as a form of interactive art, games are uniquely poised to trailblaze and be the proving ground of new ideas and initiative, which may later be adopted by the wider artistic community in all forms of practice. Melissinos [4] states that "*…games are also the only form of media that allows for personalizing the artistic experience while still retaining the authority of the artist,*" making the distinction that narrative and content of the work can be tailored to the individual(s) playing. It is on these bases that we consider games as being a platform to develop work that affords interactivity, in terms of audience affect and immersion within the game. Further, we propose that this can lead to develop and enhance a sense of community and connection between human players in a game environment, who are remote to another.

Many years have now passed since Rosalind Picard produced the seminal work that helped to define the field of *Affective Computing* and its associated challenges, opportunities and potential risks [5]. Key to the domain are the three types of affective technology Picard outlines where computers are able to: recognise; represent and have emotions. Whilst the former of these is of greatest concern in this chapter, the second element of representation of emotion should not be neglected. The field itself has developed, at least on the front of academic and some industrial research, over this time period. However, its mainstream applications in the hands of the audience are still relatively few and far between with exceptions such as the formation of spin-out company *Affectiva*[1] from Picard's MIT Media Lab. Perhaps this is unsurprising, as we have seen the widespread adoption of other paradigm-shifting art and entertainment technologies, such as virtual reality (VR), take a long time to reach the mainstream and gain acceptance from publishers and audiences alike.

A common underpinning element of affective computing is the reliance upon various sensors and mechanisms for the provision of biofeedback; the mechanisms by which aspects of bodily function and response can be identified and manipulated [6]. Whilst not an essential aspect of all affective computing systems, the use of such technologies is an intuitive method that provides indicators of affective state and responses to stimuli, often with the ability to operate in real-time. There are distinct advantages of using such sensors. For example, subjects, in our case games players, do not need to actively focus on providing feedback as they would with self-report mechanisms, rather data can be collected passively and without distracting attention from the medium itself. Additionally, sensors are able to provide objective measurements, whilst asking for self-reports or other information may introduce bias on the part of the subject. Whilst medical grade equipment is desirable in high-resolution research scenarios, at a consumer level there are a range of technologies, some of which can provide viable affective data [7–10] and be easily integrated or added to gaming devices and apparatus.

We propose that affective gaming is a natural extension of the affective computing field. Such an extension offers game developers, the opportunity to detect, respond to and provoke emotions in players. Computer games, like many forms of art, media and entertainment, offer their players the opportunity to be emotionally stimulated and involved [11, 12]. One of the key features that separates games from other forms of media-based entertainment is its broad non-linearity and its deep and varied levels of interactivity. As such, affective gaming affords the possibility to create gaming experiences that can not only provoke and influence their players' emotional responses, but that player emotions can also be used as an input to the game itself, allowing it to respond to the player and provide a customised experience. This process is generally referred to as *affective feedback* [13]. One clear example would be a game that increases its level of difficulty to increase tension in the player, if it were to detect that the current level of difficulty is not sparking the intended response.

The ways in which end users interact with technology is maturing and traditional mechanisms of button pressing, joystick moving and mouse clicking have been

[1] https://www.affectiva.com/.

ubiquitous and effective. However, these technologies have become a legacy, partly down to reluctance in the market to engage with alternate methods of input, such as motion detection, speech and other modes of interaction. We suggest that, in the coming years, the time will be right to examine both active and passive methods of interaction with games and other digital media. There are multiple possibilities to create experiences that are powerful, intelligent, customisable, adaptive, socially enabling and responsive to their users. These developments represent exciting opportunities to create innovative entertainment and artistic works that enhance and evolve the user experience.

13.2 Affect, Immersion and Engagement

In *Inner Sound*: *Altered States of Consciousness in Electronic Music and Audio-Visual Media* [14], Weinel proposes a conceptual model that considers the 'affective properties' of sound and audio-visual media as a central feature. Here affective properties are considered as related to the properties of valence and arousal described in Russell's [15] circumplex model of affect. In games, sound and music may help to elicit an emotional response from the player. Following Gabriellson and Lindstrom's [16] meta-study of music and emotion, typical features such as percussive sections of music may be associated with high arousal, while sparser rhythmic sections may relate to low arousal. Major modes may relate to positive valence, while minor modes may suggest negative valence. While these are general correspondences that may not apply in all cases, such typical associations can still be used by games designers to reinforce the affective experience of games. We commonly see this through action sequences that are scored with up-tempo music, or failure or melancholy sections in game narratives that are reinforced with corresponding music. For Weinel, such features help to provide an affective experience that is framed by representational properties, and the overall experience provides a heightened state of multimodal awareness that may encompass forms of experiential knowledge.

Of course, in the gaming context, affective states do not only relate to music. Cajella's [17] work on 'player involvement' breaks down immersion in video games into the categories of kinaesthetic, spatial, shared, narrative, affective and ludic forms of player involvement. While this model takes the affective experience as a distinct component, it is surely a form of involvement that must emerge from all of the others. For instance, kinaesthetic involvement describes engagement through control of a game character, while spatial involvement relates to the virtual environments provided by games. When a player controls an avatar that leaps through the levels of a game, they are engaging kinaesthetically and spatially, but the feeling of excitement that may develop from this also leads to affective involvement. Similarly, for players who enjoy the shared involvement of multiplayer combat games, an added sense of arousal comes from knowing that their own success or failure has a bearing on the emotions of their human competitors. For games that develop complex narratives, as with films, designers may aim to tell a story that has an emotional resonance with the player. Lastly, ludic involvement also generates arousal, as players attempt to evade losing lives or reaching a ‘game over’ state, which inevitably is disappointing. Hence, we can see that in fact, all types of involvement feed into the affective involvement of the player. Sound and music are by no means the only way through which affect can be generated in interactive games, but these are often used to help reinforce and heighten the affective experience of the player.

13.3 Social Presence and Connection

Weinel’s [14] work on altered states of consciousness also draws some further connections between the affective properties of media and social or shared experiences. This emerges through Rouget’s [18] seminal work on music and trance in various ritual contexts such as those found in shamanic cultures. Rouget draws a distinction between high-energy states such as trance, which could be understood as extreme states of high arousal, and meditative states of contemplation (referred to in the original text as ‘ecstasy’), which conversely may be thought of as low arousal in form. Rouget explores a variety of ritual contexts in which these states may be used in cultures across the globe, and comments on how music can be involved in structuring and producing these states. Yet interesting, high-energy states such as trance are also distinguished as social, involving loud noises, movement and other techniques of sensory overload such as the spraying of liquids; while meditative states are characterised as occurring in darkness, solitude and related to a reduction, narrowing or focusing of the senses.

There has been little work done on considering video games as altered states of consciousness, but clearly this is a popular form of media that perhaps is valued by audiences for its capability to induce a sense of (secular) trance. Is it not possible that as teenagers play popular games such as *Fornite* [19], the heightened state of excitement they experience, which draws them out of the everyday and into the virtual, is in fact something we might call a state of trance? Various interactive aspects of the media conspire to produce a highly aroused, social experience, in which they are immersed into imaginative virtual worlds of play. In these terms, it seems that there is no shortage of high-arousal action games that aim to produce something we might call a sense of trance. But what then, of more tranquil or meditative states? In fact, there are also various games that specifically aim to induce states of meditation, such as *Guided Meditation VR* [20]. This title is essentially the VR equivalent of a guided meditation experience, which provides tranquil virtual locations with an instructive audio narrative. More broadly, other single-player games may seek to provide tranquil, solitary experiences. For instance, *ABZÛ* [21] is a mysterious underwater exploration game that de-emphasises ludic involvement in favour of kinaesthetic, spatial and narrative involvement, as the player navigates mostly peaceful ocean environments with a relaxing soundtrack. Certainly, games such as this could be understood as offering experiences that are characterised as meditative in form.

13.4 Augmenting Virtual Environments

The field of Augmented Reality (AR) has developed significantly in recent years. From the perspective of a user or consumer, it seeks to combine information from the real world with information not visible in that environment using the standard array of human senses [22]. Potentially, this additional information may be drawn from imperceptible information that exists in that space or by including extra information from another place: real or virtual. Thus far, the majority of AR systems have sought to overlay a user's everyday environment with additional information. For example, an AR navigation application might overlay information about a car that is being looked at, such as year of manufacture, engine size and so on. Alternately, a real worldview might be overlaid with the user's schedule for the day. There have been several commercial attempts at developing AR systems of this kind, perhaps most notably the *Google Glass*[2] hardware project, as well as an array of smartphone apps developed commercially or as research projects.

However, less common is the ability to apply the same principles to augment a Virtual Reality (VR) space with information from the real world. For example, a virtual tour of a building to be constructed might be presented by replicating the current weather being experienced in the real world by the user. Notable consumer devices that explore these possibilities are Sony's *PlayStation Camera* [23] and Microsoft's *Kinect for Xbox One* [24]. These platforms have seen video games being developed that insert, or respond to, a live camera feed image of the player in a game environment, giving them the ability to interact by gesture with the game, hence augmenting the VR environment. This builds upon the more established practice of integrating audio, specifically player speech utterances, into game environments, made popular in online multiplayer gaming. It is this latter variation of augmentation that exemplifies some of our concerns in this chapter.

Our motivation particularly stems from the recognition that playing games in virtual or online environments has many differences from their real-world equivalents. For instance, there is a reduced ability to interact with fellow team members and opponents. For example, there is a distinct absence of interaction through facial expressions, gesture, posture and general body language. Even with the presence of speech utterances and emoticons, it is challenging to determine accurate emotional responses and exert forms of emotional intelligence, to determine if other players may be angry, sad, scared, exhilarated and so on. As recognised by Picard [5] in relation to other forms of electronic communication, such as email, this detracts from the entertainment and immersion within the game and also from the ability for players to successfully interact with one another. To address this, we propose that these differences lead to opportunities to improve players' sense of immersion within a virtual environment and their social experience with other players in that environment. However, the drive for increased immersion and realism in games and virtual worlds leads to causes for concern regarding the health issues associated [25] and

[2] https://developers.google.com/glass/.

thus any experimental approach must be mindful of the ethical issues surrounding such work.

The use of standard biofeedback is fairly commonplace, whereby real-time representations of the underlying signals in question are presented to a person connected to some form of sensor. Perhaps the most familiar manifestation of this would be an electrocardiogram (ECG) machine in a clinical environment, where the person connected to the device would be able to hear and see their heart rate. Similar body sensors allow games to alter their virtual environments based on the user that is playing them. Elaborating, emotion is quantifiable through sensor measurements. A virtual game environment becomes dynamic, if it reacts to emotion. A strong case study for such an application is Dynamic Difficulty Adjustment (DDA) in games.

A game such as those from Electronic Arts' *FIFA* [26] series can generate an enormous amount of frustration for players; with a number of players reporting they quit playing the game because they felt it unfairly caused them to lose. In future consoles, controllers could embed heart rate monitoring sensors. The data produced could in turn generate a crude measure of emotion, calculated through computer algorithms that translate raw sensor data to meaningful information. Therefore, the level of emotional distress becomes the value for adjusting the difficulty in the game. This adheres to the theory of flow by Csikszentmihalyi [27]. The channel of flow exists between challenge and achievement. A game that dynamically alters its difficulty based on the player's emotion, can help keep gameplay within the channel. The Internet of Things (IoT) and serious games provide more detail and background on this topic.

The ability for the affective information about players to be shared with third-parties [28], such as in online multiplayer gaming environments, presents interesting opportunities. Consider the illustrative example of a mock-up interface provided in Fig. 13.1, where the virtual game environment has been augmented with data about the human players controlling the in-game avatars. In this simplistic example, we observe the presentation of raw biosensor data alongside a higher-level summary of affective state. In this exemplar, raw heart-rate data in beats-per-minute is presented numerically in a heart icon on the left of the pop-out window. In the middle is an emoji icon, which might be derived by a range of different sensors or other mechanisms, but with the intention of providing a summary representation of the player's emotional state. Finally, on the right side of the pop-out a lightning bolt, which fills up with an orange colour, provides an indication of the galvanic skin response (GSR) data values of the player. Although visual paradigms and designs have been adopted for the purposes of communicating these concepts clearly in a written form, there is of course no reason why this information could not be communicated in alternate mode, such as sonification or tactile feedback.

Fig. 13.1 Multiplayer game mock-up with affective data visualisations. Image Copyright © Stuart Cunningham 2019

13.5 The Internet of Things and Games

Research is helping bridge the gap between sensors and games. In 2015, Favorskaya et al. [29] presented their book into smart serious games. The idea behind the term is games that incorporate the benefits of the Internet of Things (IoT) with the applications of serious games. Existing research in the field investigates measuring student engagement through the IoT and serious games [30]. Developing data algorithms forms a key component for the integration of IoT with games. It is possible to exclude them in games where sensors are limited to direct input. An example of such games is *Kinect Sports* [31], where the Kinect acts as an input device for controlling a player in the virtual environment. However, such games constrict their scope of application, as the data could be interpolated into something grander and more meaningful.

However, this idea can become more abstract, and potentially, more beneficial if we consider the combination of IoT with games technology. Henry et al. [32] produced a framework that illustrates the backbone for merging serious games with IoT, however as the framework did not focus on a case study, it is also valid for the broader spectrum of game technologies. The potential for this line of research is near unlimited.

Figure 13.2 illustrates the untapped potential for this academic domain in the present day. This validates the theories and ideologies presented in this chapter, and produces a stepping-stone to realising them. Research is continuing

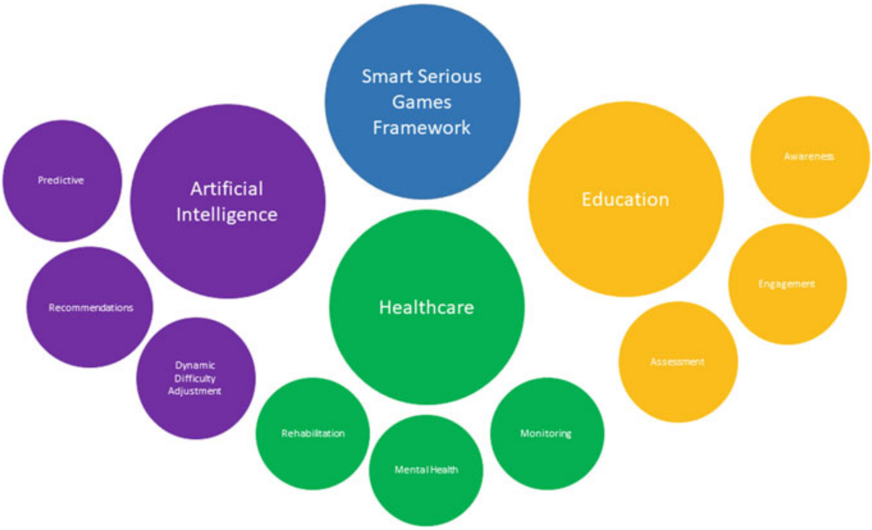

Fig. 13.2 Potential applications for Henry et al. framework on serious games and the Internet of Things

into understanding the relationship between all aspects of game applications and harnessing their potential.

Research is emerging into combining IoT with Gamification applications. Crowley et al. [33] proposed a system where users can report issues within their local environment through gamification. Users would be awarded for contributing and could send the information through their smartphones. Research by Islam et al. [34] into advancements of IoT healthcare applications suggested wearables to bridge patient engagement and public health information. In industry, smartwatches have turned this concept into reality. Companies such as Apple utilise sensors to monitor the activity of its user and promote healthier habits by awarding badges and forming competitions with friends that own the same product. This is an example of gamification and IoT in applications. The method for engaging users with their health and maintaining their commitment is gamification, utilising game elements to an application outside the definition of a game.

It is evident that games are much more than just entertainment software, and this remains true for game technology. Research utilises game technology to solve specific problems in domains such as business modelling and smart cities. Maines et al. [35] introduced a third dimension for Business Process Model and Notation, in an attempt to overlay the security requirements of a system in its design stage, therefore increasing its security at implementation. This solution was developed utilising the Unity 3D game engine. If Maine's research were to introduce IoT, it could assess existing physical and virtual systems and highlight vulnerabilities based on current standards. Tully et al. [36], presented a methodology for rendering large map data for crisis management. This application ties into the principles of smart cities and provides perspective to the future tools that emergency services may use to run more efficiently during a crisis.

When reflecting on the progress research is making in this domain, it becomes evident that sensors and the IoT generate more than novel applications or theoretical frameworks, but a new perspective. This perspective allows all existing research into serious and traditional games to be re-examined with the inclusion of the IoT. The following section describes the technical challenges developers of ‘smart serious games’ solutions face today, and how they may be tackled in future.

Regarding the combination of IoT and serious games, the biggest technical challenge is heterogeneity. As the number of manufacturers producing Internet interconnected solutions increases so does the competition, driving prices down and encouraging exploration. However, this competition generates segregation in the industry and causes development to be cumbersome. There are devices that only work within a manufacturer’s ecosystem, such as Samsung’s ecosystem of Smart appliances, devices that require bespoke bridges to connect with the Internet, and devices with bespoke online portals.

The only method for tackling the increasing segregation in the Internet of Things is standardisation. Wireless charging is an example for the effective use of standardisation. Without the Qi standard [37], devices would require their own type of wireless charger. In such a scenario, large technology companies such as Apple and Samsung would develop their own versions of wireless charging that would only be compatible with their ecosystems. Therefore, wireless charging in cars or in embedded surfaces would become challenging.

13.6 Measuring Affective Response

Sykes and Brown [28] conducted a small-scale investigation to determine how the affective response of players would be influenced by increasing game difficulty in a remake of the classic arcade game *Space Invaders* [38]. Their study employed a sample of ten participants who each played the game at three randomised levels of difficulty. During each period of gameplay, the pressure with which players pressed the analogue button to move their game character was recorded. The authors argue that the pressure of button presses may give an indication of the player’s level of emotional arousal, drawing upon earlier findings in the field of *sentics* [39]. The results obtained gave an indication that at the hardest difficulty level, the pressure applied was significantly different than at the easy and medium levels. As an early work these results are compelling, although a larger sample would be desirable along with more rigorous statistical analysis of the data. There is doubt about the ability of touch universal method to communicate human emotion [40], although for most games players this may be an intuitive and appropriate scenario and might be one that could be learned for each individual over a period of time. Nevertheless, the method employed is interesting, especially since the authors justify the use of button pressure measurement as being something that can be employed in game controllers with analogue buttons, meaning that more elaborate equipment and setups can be avoided. This is hugely beneficial given that the control devices, such as gamepads, touchscreens, buttons and joysticks, are the main physical interaction mechanisms that the player has with a game.

Following the convention of making use of game controllers for affective feedback, Bacchini et al. [41] attempted to integrate several biofeedback mechanisms into a common gamepad design. As such, they augmented an existing console style control pad with sensors designed to detect GSR, skin temperature, pressure/force and heart rate statistics via photo plethysmography (PPG). Thus, the device itself is one that is already well accepted in the gaming community and presents minimal disruption to the ergonomics of the typical gamepad. Their work was undertaken with the specific design intention that such a device would lend itself to affective gaming applications, which might be used for a variety of purposes, including entertainment as well as serious game situations. The gamepad was evaluated using a linear horror game named *Death*: *Unknown* [42], which was an independent game available freely to download. The device itself showed promise in being able to successfully detect scare events in the game. Data obtained in the reported trial of 31 participants shows promise in being able to successfully detect expected scare events. However, the analysis makes limited to no use of additional sensor data and is largely focused upon use of GSR data.

Simões et al. [43] developed a serious game to help individuals with Autistic Spectrum Disorder, measuring the levels of independence and performance in the context of a serious game designed to simulate the performance of an everyday task—planning a bus route, making the journey and interacting with others along the way. The key metric to measure anxiety in this scenario was via the use of electrodermal activity (EDA). It is interesting to note that the VR game itself attempts to mimic real life (to a reasonable degree), rather than obtusely stimulate emotional responses.

Kivikangas and Ravaja [44] report upon the affective responses encountered in users playing against one another in a multiplayer scenario compared with playing against the computer. Measurements of emotion were recorded using electromyography (EMG) and EDA sensors. As such, there was no direct affective feedback loop returned to the game nor was there specific measurement of pre-defined game mechanics designed to provoke emotion. Rather, the authors were evaluating the effect of the outcome of playing the game (winning or losing) and how the relationship between each player and their opponent (whether they were friends, strangers or a computer-controlled character) impacted their emotions. Their study involved 33 participants and used the game *Duke Nukem Advance* [45], a version of the classic first-person shooter game adapted to be played on a portable gaming console; the GameBoy Advance. The findings showed that positive affect occurred every time the player won a game, but also when they lost. The positive responses to victory became stronger when playing against another human, rather than a computer-controlled character. One intriguing anomaly is that the authors note "…*a curious effect of negative response to victory over a friend, for which we presented numerous possible explanations, although we cannot say which one would be the most plausible*

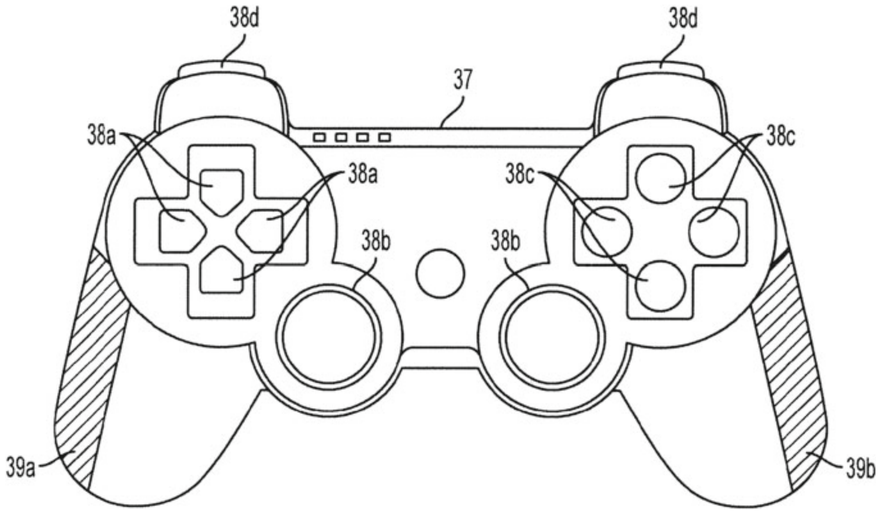

Fig. 13.3 Game controller equipped with bio-sensors (points 39a and 39b) in Sony Patent [46]

one." Broadly, the work is supportive of the concept that relationship is an important factor in the intensity of emotional response in players.

An early study of how affective feedback can be used to influence in-game actions used a simple competitive two player racing game, appropriately entitled *Relax-to-Win* [13]. The notion of incorporating biofeedback has also received attention from a number of large games console manufacturers, with a notable example being the patent held by Sony [46] that depicts various interface and game control devices that have notably been fitted with bio-signals, shown in positions 39a and 39b in Fig. 13.3, designed to be used as inputs to the game. The patent goes on to discuss a range of such signals and systems that may be used to generate data to be sent to the game or interactive software. Such an approach is flexible and avoids over-reliance upon a particular type of signal. The validity of skin response equipment may be brought into question under certain gaming circumstances, especially in demanding scenarios where intense movement of the muscles, usually in the hand, is required [28].

13.7 Suggestions for Future Work

13.7.1 Measuring the Efficacy of Affective Games

An initial piece of research to be done would examine the effects of incorporating biofeedback within networked multiplayer video games. This research could use a participatory study to demonstrate the effects of biofeedback technologies on the experience players have of the video game, particularly with regard to their immersion, sociability, experience and overall enjoyment of the game. This would make use of a range of bio-sensors attached to players of the game. For the purposes of a start point, we suggest that indicators of players' ECG, EDA and electroencephalography (EEG) are selected.

The research could provide a simulated game environment that displays biofeedback information about competitors on the computer screen, much like the mock-up presented in Fig. 13.1. Suitable methods of visualisation and sonification of this data may be used, which would enable participants to perceive the data in an accessible manner appropriate to the video game medium. Participants would play the video-game in a head-to-head or collaborative scenario, comparing the video game experience without biofeedback to the one with biofeedback (one group of participants will play with biofeedback, another group will play without). As such the study would broadly follow the approach of a randomised controlled trial. Both subjective, self-report data, using instruments such as the GEQ outlined earlier could be used to capture player experience alongside other objective measures such as playing time, success metrics in the game itself, video footage of each player and so forth.

13.7.2 Affective Games and Altered States of Consciousness

In previous work, several prototypes were created which explored the use of consumer-grade biofeedback headsets as controllers for interactive artworks and games. One of these: *Psych Dome* [47] utilised a NeuroSky MindWave to control the generation of a visualisation and sound in a mobile full-dome. While the design of the sound and visualisation were based on the concept of altered states of consciousness, using biofeedback allowed properties of the simulation to be linked to the brain activity of the person seeing it. This type of interaction is largely non-volitional (that is, the individual tends not to be able to control their brain in such a way that they can choose to influence the signals in a particular way), but instead provides a form of 'passive' interactivity that can enrich the sense of interactivity. In a related project, *Quake Delirium EEG* [48], this passive interaction was again provided for an adapted video game, which aimed to simulate an intoxicated state of hallucination, for which graphical and sound properties were linked to the EEG signals. These projects are based on practice-led research, in which prototypes are developed, but the prototypes can then use empirical research approaches to measure the experience of participants. Eventually such approaches could lead towards the possibility of 'altered states of consciousness simulations', as proposed by Weinel [14].

In relation to the latter, it has been shown that there are significant therapeutic benefits that can arise from altered states of consciousness facilitated by drugs such as MDMA, LSD or psilocybin (e.g. Mithoefer et al. [49]; Bogenschutz and Johnson [50]). Technologies such as VR have been widely touted as capable of simulating real-world experiences that could have therapeutic applications—could VR also be used to effectively simulate an altered state? Some early projects such as *Guided Meditation VR* [20] hint at this possibility, yet there are also good reasons to be sceptical about the benefits such experiences can actually provide when compared with real meditation practices. What is therefore needed is research that takes bespoke designs aimed to simulate altered states of consciousness through games or VR, and measures the response of players, in order to demonstrate the extent to which these designs are effective. Such research can then feed back into the generation of new designs, perhaps allowing us to create virtual experiences that are tailored towards particular kinds of perceptual experiences, eventually simulating altered states of consciousness.

13.7.3 Measuring the Social Aspects of Multiplayer Affective Games

Research on the level of connection and social presence [51] between players in multiplayer gaming scenarios is underrepresented when compared to the amount of information available about the single player experience. This is especially true when considering the range of sensor data that affective gaming systems can provide. Ekman et al. [52] recognised this, defining the metric entitled *physiological linkage* and postulated that it may be associated with the social presence experienced by players. The concept itself is simple to understand: the physiological measures of players are likely to display patterns of synchronicity or correlation to one another, meaning that it "*…can be used as a measure of the intensity of the interaction between participants*" [52].

As explained earlier, when dealing with affect in multiplayer games it would be highly desirable to examine how social elements of the gaming experience contribute to player affect and, in turn, how the feedback of a player's affective data might influence other players. Accurately determining multifaceted concepts of game user experience such as social presence, immersion and flow can be tough when using only biosensors. Similarly, mechanisms to verify the affective responses predicted from these sensors are also desirable. As such, a challenge exists in being able to measure these complex phenomena of the human condition. It is here where self-report mechanisms become useful and there are several good examples of tools to measure many of these concepts. In their work, which also highlighted objective measures for immersion, such as eye-tracking, Jennett et al. [53] developed a series of self-report questionnaires to be issued to games players. Factors they recognised as signifying immersion in players included: affect; cognitive involvement and detachment from the real-world. Contributing to the level of immersion experience were also factors produced by the game itself, namely, that of challenge and control. Whilst Jennett et al.'s work deals with measuring the experience of the individual, it was not purposely intended to examine social aspects and connection with other human players in the game.

One of the most commonly employed tools in the field of computer games research is the Game Experience Questionnaire (GEQ) and its component instrument, the In-game GEQ [54]. The tool integrates aspects of: competence; immersion; flow; tension; challenge and affect. Additionally, it offers a social presence module, which is designed to "…*investigates psychological and behavioural involvement of the player with other social entities*…" [54], where these social entities may be other human players or computer-controlled characters. The social presence element of the GEQ consists of a total of seventeen questions that participants rate using a five-point Likert scale. These questions provide scores under three themes of: empathy; negative feelings and behavioural involvement. The first two of these have a strong resonance in affective gaming, leading to useful indicators of how well an affective game might be communicating the emotional state of other players (empathy) and how this information might impact the player observing such information (negative feelings—incorporates elements of influence from others as well as a sense of revenge or retribution). Lastly, behavioural interaction, seeks to determine how the in-game actions of other players would change what the player in question did in the game, as well as providing some indication of how meticulously players observed one another. Consequently, the GEQ appears to be an effective mechanism for the subjective evaluation of experience in affective multiplayer games. Its social presence module certainly takes a step in the right direction to gauge the nature of interaction and influence between players, but it would be useful to consider other instruments that attempt to measure how connected or 'close' players feel to one another during gameplay. A solution to this may be to append the In-Game Relatedness items from the Player Experience of Need Satisfaction (PENS) questionnaire [55]. Such a hybrid approach, combining overlapping aspects from a range of game experience instruments is advocated by the work of Denisova, Norden and Cairns [56].

13.8 Ethical Considerations

There are ethical concerns relating to the combination of serious games and IoT. Games in traditional forms store little information regarding their players—commonly scores, an alias or their real name. The advances in mobile gaming have transformed the data that a game can access. Numerous games require you to sign into a social media account. Once you have signed-in, the company has access to personal information about the player and a list of the player's friends. Introducing the IoT only increases the amount of information games would retain about its users.

As discussed, an IoT enabled game could record a player's heart rate to dynamically alter a virtual environment, or help a player progress in it. The idea of a game company holding such personal data could become uncomfortable to players; however, there are arguments to counter this perspective too. As younger generations are introduced to technology from an increasingly early age, their perception of sharing data could be different in comparison to generations that were introduced to technology at an older age.

Irrespective of the discomfort users may have, there is an irrefutable fact that games of this nature will need to store very sensitive information on its users. This raises concerns regarding security. The General Data Protection Regulation (GDPR) law in Europe [57] is a conscious effort to increase liability on developers regarding storing personal data securely. This pressure increases the priority of securing new interconnected systems and the data that flows within it. However, there are still many challenges that the Internet of Things faces regarding security, many of which stem from the lack of standardisation. Therefore, when embedding IoT with Games, these challenges will relate to games too.

Associated with the work discussed here, which proposes to utilise affective data and bio-sensor signals as input to game environments that may be socially oriented, are concerns over psychological effects. Consider the first research activity proposed earlier, for example, which would involve the visualisation and sharing of bio-sensor information in collaborative or competitive games between human players. Certain parallels might be drawn with aspects of the Stanley Milgram's controversial experiment [58] into behaviour and obedience. If one player of a game is competing against another and sees that their opponent's heart rate has elevated to abnormally high-levels, will they attribute this situation to themselves and would guilt and blame be attributed to them should their real-life opponent suffer cardiac problems? Perhaps the answer is that the sensor attached to their opponent is simply faulty, but without knowing this, the player might still suffer anxiety or low mood as a consequence. One rebuttal to these fears may be that multiplayer gaming is not a new concept and so simply presenting this information is only making visible a phenomenon that may have been occurring already. Nevertheless, there is a duty of care to be considered once this information has come to light. As recently pointed out in an article by Tidsdale, "*…video gaming has been claiming victims for decades*" [59] and with the enhanced sense of immersion, social connection and presence that we propose here, we would be wise to approach research in this field with due care and diligence.

References

1. ART | meaning in the Cambridge English Dictionary, Dictionary.cambridge.org. [Online]. Available: https://dictionary.cambridge.org/dictionary/english/art. Accessed 30 May 2019
2. Gee, J.P.: Why game studies now? Video games: a new art form. Games Cult. **1**(1), 58–61 (2006)
3. Smuts, A.: Are Video Games Art? Contemporary Aesthetics, vol. 3, no. 1 (2005)
4. Melissinos, C.: Video Games Are the Most Important Art Form in History, 22 Sept 2015. [Online]. Available: https://time.com/collection-post/4038820/chris-melissinos-are-video-games-art/. Accessed 27 June 2019
5. Picard, R.: Affective Computing. The MIT Press, Cambridge, MA (2000)
6. Schwartz, M.S., Andrasik, F. (eds.): Biofeedback: A practitioner's Guide. Guilford Publications, New York, USA (2017)
7. Maskeliunas, R., Damasevicius, R., Martisius, I., Vasiljevas, M.: Consumer-grade EEG devices: are they usable for control tasks? PeerJ **4**(e1746) (2016)

8. Parak, J., Korhonen, I.: Evaluation of wearable consumer heart rate monitors based on photoplethysmography. In: 36th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (2014)
9. Wright, S.P., Hall Brown, T.S., Collier, S.R., Sandberg, K.: How consumer physical activity monitors could transform human physiology research. Am. J. Phys. Regul. Integr. Comp. Physiol. **312**(3) (2017)
10. van den Broek, E.L., Westerink, J.H.: Considerations for emotion-aware consumer products. Appl. Ergon. **40**(6), 1055–1064 (2009)
11. Rouse, R.: Game Design: Theory & Practice. Jones and Bartlett Publishers, Burlington, MA (2004)
12. Oxland, K.: Gameplay and Design. Pearson Education UK, London (2004)
13. Bersak, D., McDarby, G., Augenblick, N., McDarby, P., McDonnell, D., McDonald, B., Karkun, R.: Intelligent biofeedback using an immersive competitive environment. In: Designing Ubiquitous Computing Games Workshop at UbiComp (2001)
14. Weinel, J.: Inner Sound: Altered States of Consciousness in Electronic Music and Audio-Visual Media. Oxford University Press, New York (2018)
15. Russell, J.: A circumplex model of affect. J. Pers. Soc. Psychol. **39**(6), 1161–1178 (1980)
16. Gabrielsson, A., Lindstrom, E.: The Role of Structure in the Musical Expression of Emotions, in Handbook of Music and Emotion: Theory, Research, Applications. Oxford University Press, Oxford (2012)
17. Calleja, G.: In-Game: From Immersion to Incorporation. MIT Press, Cambridge, MA (2011)
18. Rouget, G.: Music and Trance: A Theory of the Relations Between Music and Possession. University of Chicago Press, Chicago (1985)
19. Epic Games (2017) Fortnite
20. Cubicle Ninjas (2016) Guided Meditation VR
21. Giant Squid (2018) ABZÛ
22. Feiner, S.K.: Augmented Reality: a new way of seeing. Sci. Am. **286**(4), 48–55 (2002)
23. Sony, PlayStation Camera | More Ways to Play | PlayStation, Sony Interactive Entertainment Europe Limited, [Online]. Available: https://www.playstation.com/en-gb/explore/accessories/playstation-camera/. Accessed 30 June 2019
24. Microsoft, Kinect for Xbox One | Xbox.com. Microsoft (2016). [Online]. Available: http://www.xbox.com/en-US/xbox-one/accessories/kinect. Accessed 30 June 2019
25. Parkin, S.: Death by Video Game: Tales of Obsession from the Virtual Frontline. Serpent's Tail (2015)
26. E.A. Inc, FIFA Video Games—Official EA Site, [Online]. Available:https://www.ea.com/en-gb/games/fifa. Accessed 30 June 2019
27. Csikszentmihalyi, M.: Flow: the psychology of optimal experience. Acad. Manag. Rev. **16**(3), 636–640 (1991)
28. Sykes, J., Brown, S.: Affective gaming: measuring emotion through the gamepad. In: CHI'03 Extended Abstracts on Human Factors in Computing Systems (2003)
29. Favorskaya, M., Sharma, D., Jain, L., Howlett, R.: Advances in Smart, Multimedia and Computer Gaming Technologies. Springer International Publishing, New York (2015)
30. Henry, J., Tang, S., Hannenghan, M., Carter, C.A.: Measure of student engagement for serious games and IoT. In: Edutainment 2017: E-Learning and Games (2017)
31. Microsoft Game Studios (2010) Kinect Sports
32. Henry, J., Tang, S., Hanneghan, M., Carter, C.A.: Framework for the integration of serious games and the Internet of Things (IoT). In: Henry, J., Tang, S., Hanneghan, M., Carter, C. (eds.) A framework for the integration of serious games and the Internet of Things (IoT). 2018 IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH) (2018)
33. Crowley, D.N., Breslin, J.G., Corcoran, P., Young, K.: Gamification of citizen sensing through mobile social reporting. In: 2012 IEEE International Games Innovation Conference (2012)
34. Islam, S.R., Kwak, D., Kabir, M.H., Hossain, M., Kwak, K.S.: The internet of things for health care: a comprehensive survey. IEEE Access **3**, 678–708 (2015)

35. Maines, C.L., Llewellyn-Jones, D., Tang, S., Zhou, B.: A cyber security ontology for BPMN-security extensions. In 2015 IEEE International Conference on Computer and Information Technology; Ubiquitous Computing and Communications; Dependable, Autonomic and Secure Computing; Pervasive Intelligence and Computing (2015)
36. Tully, D., Rhalibi, A., Carter, C., Sudirman, S.: Hybrid 3D rendering of large map data for crisis management. ISPRS Int. J. Geo-Inf. **4**(3), 1033–1054 (2015)
37. Van Wageningen, D., Staring, T.: The Qi wireless power standard. In: Proceedings of 14th International Power Electronics and Motion Control Conference EPE-PEMC (2010)
38. Midway (1978) Space Invaders
39. Clynes, M.: Sentics: The Touch of Emotions. Anchor Press, Harlow, UK (1977)
40. Trussoni, S.J., O'Malley, A., Barton, A.: Human emotion communication by touch: a modified replication of an experiment by Manfred Clynes. Percept. Mot. Skills **66**(2), 419–424 (1988)
41. Bacchini, P., De, T., Barbosa, A.: Emopad: an affective gamepad. Int. J. Comput. Appl. **102**(15), 5–12 (2014)
42. Johansson, J. (2013) Death: Unknown, Entyro
43. Simões, M., Bernardes, M., Barros, F., Castelo-Branco, M.: Virtual travel training for autism spectrum disorder: proof-of-concept interventional study. JMIR Serious Games **6**(1), e5 (2018)
44. Kivikangas, J., Ravaja, N.: Emotional responses to victory and defeat as a function of opponent. IEEE Trans. Affect. Comput. **4**(2), 173–182 (2013)
45. Take-Two Interactive (2002) Duke Nukem Advance
46. Weising, G.: Biometric interface for a handheld device. Washington, DC: U.S. Patent and Trademark Office. Patent U.S. Patent No. 9,557,814. (2017)
47. Weinel, J., Cunningham, S., Roberts, N., Roberts, S., Griffiths, D.: EEG as a controller for psychedelic visual music in an immersive dome environment. Sonic Ideas/Ideas Sonicas **7**(14) (2015)
48. Weinel, J., Cunningham, S., Roberts, N., Griffiths, D., Roberts, S.: Quake delirium EEG: a pilot study regarding biofeedback-driven visual effects in a computer game. In: The Sixth International Conference on Internet Technologies and Applications (ITA 15) (2015)
49. Mithoefer, M., Wagner, M., Mithoefer, A., Jerome, L., Doblin, R.: The safety and efficacy of 3,4-Methylenedioxymethamphetamine-assisted psychotherapy in subjects with chronic, treatment-resistant post-traumatic stress disorder: the first randomized controlled pilot study. J. Psychopharmacol. **25**(4), 439–452 (2010)
50. Bogenschutz, M., Johnson, M.: Classic hallucinogens in the treatment of addictions. Prog. Neuropsychopharmacol. Biol. Psychiatry **64**, 250–258 (2016)
51. Biocca, F., Harms, C., Burgoon, J.K.: Toward a more robust theory and measure of social presence: Review and suggested criteria. Presence: Teleoperators Virtual Environ. **12**(5), 456–480 (2003)
52. Ekman, I., Chanel, G., Järvelä, S., Kivikangas, J.M., Salminen, M., Ravaja, N.: Social interaction in games: measuring physiological linkage and social presence. Simul. Gaming **43**(3), 321–338 (2012)
53. Jennett, C., Cox, A.L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., Walton, A.: Measuring and defining the experience of immersion in games. Int. J. Hum Comput. Stud. **66**(9), 641–661 (2008)
54. Ijsseltein, W., de Kort, Y., Poels, K.: The game experience questionnaire: Development of a self-report measure to assess player experiences of digital games. Technical University Eindhoven (2008)
55. Rigby, S., Ryan, R.: The Player Experience of Need Satisfaction (PENS) Model. Immersyve Inc (2007)
56. Denisova, A., Nordin, A.I., Cairns, P.: The convergence of player experience questionnaires. In: Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play (2016)
57. Regulation (EU) 2016/679 Of The European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC General Da (2016)
58. Milgram, S.: Behavioral study of obedience. J. Abnorm. Soc. Psychol. **67**(4), 371–378 (1963)

59. Tisdale, A.: Gaming In Virtual Reality Could Be the Very Real Death of You, Vice Media LLC, 8 June 2016. [Online]. https://www.vice.com/en_uk/article/4w5g7d/gaming-in-virtual-reality-could-be-the-very-real-death-of-you-911. Accessed 4 June 2019

Part V
The Convergence of Digital Design, the Arts, Computing, and the Environment

Chapter 14
Chandini (A Bride for the Moon)

Rachel Davies and Daniel Saul

Abstract *Chandini (A Bride For The Moon)* is an art/science project led by R&D Studio which explores the dream of India's ambition to be the fourth nation to make a soft landing on the moon. In collaboration with a dancer, musician and scientists, poetic visual and performative metaphors are developed that represent the progress of Indian society in the technological age. This chapter describes the ongoing project from the authors' perspective; how they collaborated, in response to different opportunities and changing circumstances, the obstacles they encountered and how the public engaged with their artworks at events and festivals between 2017 and 2019 in the UK and India.

Keywords Filmmaking · Choreography · Art/science · Collaboration · Documentary · Projection mapping · Outdoor arts · Space · Lunar landing · Moon · India

14.1 Introduction

Chandini (A Bride For The Moon) is an art/science project led by R&D Studio [1] that explores the hopes and dreams of India's ambition to be the fourth nation to make a soft landing on the moon. Working in collaboration with artists and scientists they develop poetic visual metaphors to consider notions of progress to Indian society in the technological age.

R&D Studio is a coming together of two artist filmmakers; Rachel Davies and Daniel Saul. They describe here how their artistic responses to a subject have evolved creating various iterations of the project over a two-year period.

Both artists have experience of working with Indian documentary subjects and dancers. Rachel with short Channel 4 dance films, collaborations with Mavin Khoo

R. Davies (✉)
Kingston University, Kingston, UK
e-mail: r.davies@kingston.ac.uk; rachel@racheldavies.co

D. Saul
Royal College of Art, London, UK
e-mail: d.saul@arts.ac.uk; dan@rachelanddaniel.co

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_14

(*Khooyile*) [2] and Akram Khan (*Loose in Flight*) [3] which toured internationally with the British Council [4]; and Daniel's film *The Morris Jelly House of Fashion* (Channel 4) [5] which drew on his personal experience of being from an Anglo-Indian family originating from Calcutta.

The artists remember when India was characterised in the UK as an indigent recipient of foreign aid. However recently India has positioned itself on the global stage with a symbolic ascendency to become a self-proclaimed leader in space technology. This project reflects on these contrasting contemporary global perceptions of an India which has been transformed by technology yet in many ways whose traditions have stayed the same.

For *Chandini (A Bride For The Moon)* R&D Studio worked with Hemabharathy Palani a dancer/choreographer [6] and *TeamIndus* [7] a private aerospace company, both based in Bangalore, to produce short films, choreography, performances, projection mapping and installations that engaged audiences through broadcast and performances in the UK and India.

The wider project began as a response to an open call from the British Council/Big Dance Shorts in 2017 [8]. The commissions were seeking dance and film collaborations between the UK and India to mark 70 years of Indian Independence from Britain, a complex relationship from the outset. It was then that R&D Studio decided to focus on a small private company of mainly young people who were late entrants to the Google's 2007 Lunar X-Prize; a $30 million international competition open to non-governmental agencies to land a robot on the Moon, have it travel 500 m, and broadcast high resolution captured images back to Earth [9].

TeamIndus [10] presented themselves in a markedly different way from more grandiose national Space agencies. They cast themselves as young dreamers working to creatively inspire other young minds in India. When we initially contacted them we said, "*We want to make a film about your rover, but using contemporary dance.*" They replied "*So cool*!"

Simultaneously we began a search for an Indian dancer who could translate a science story into a personalised performance. Emma Gladstone (Artistic Director Dance Umbrella) [11] recommended Hemabharathy (Hema) Palani. Hema was based in Bangalore, as were TeamIndus. From this point our themes developed. We discovered that TeamIndus' robot, as often with ships or craft, was referred to as 'she' by the team who made her. TeamIndus co-founder Sheelika Ravishankar told us "*When I received your proposal the first thing I asked was, is your dancer female?*" Hema told us that the one-way nature of the robotic moon mission reminded her of a common Indian female experience; when a young woman moves from her birth family's home to the new home of her husband, it is sometimes said that "*She will only ever return as ashes.*" A parallel story began to emerge. We would track the journey of an Indian robot on the moon echoed by an Indian woman's journey on Earth. Our filmic mise-en-scène became Bangalore; once a small colonial outpost, now rapidly transforming into an Asian information technology-driven megalopolis. A city containing both ancient tradition and a world-beating aerospace industry. Our project became a container for exploring a dialogue between these two ideas. Figure 14.1

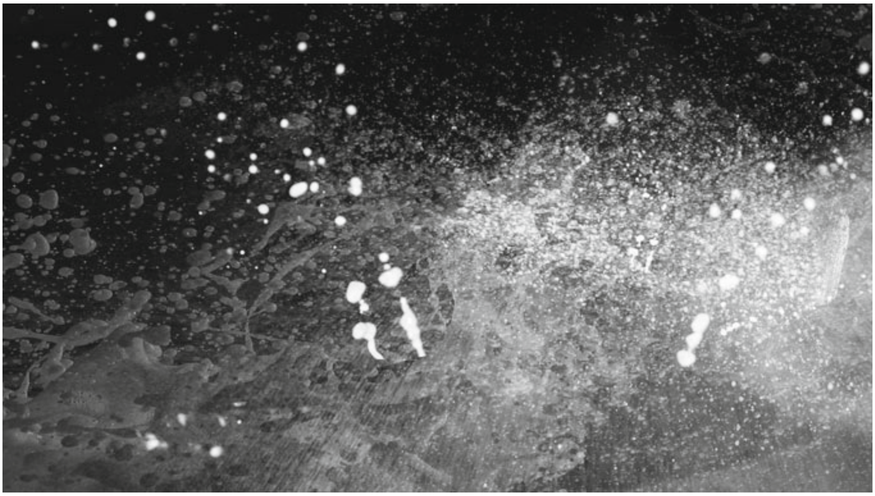

Fig. 14.1 R&D Studio 2018. Evocation of the cosmos created in milk droplets

shows a frame of an animation rendered in development workshops, and eventually used in large-scale projection within live performances in Bangalore and Dorset.

14.2 A Changing Real-World Context

One of the challenges of documentary-making is access. The subject matter of the Indian Space programme could have presented us with several obstacles. ISRO [12], the governmental space agency responsible for nearly all of India's activities in space, are not known for being an open access organisation and we had heard rumours that they were very unlikely to allow foreigners to visit them. We made several attempts to contact ISRO and received no response.

Finding TeamIndus was a blessing as they were wonderfully open and generous and once in India facilitated our visits thoroughly and gracefully. However, we did not know if we would be able to find empathy between our very different professional disciplines. We spent a lot of time preparing our questions and equally allowed our interviews to unfold in a relaxed and unhurried atmosphere. When we first met TeamIndus in 2017 many teams from other countries had dropped out of the Lunar X-Prize and TeamIndus were ranked as favourites among the surviving four. It had been a white-knuckle ride with many delays and last minute deadline extensions. In January 2018, TeamIndus announced that they were scheduled to launch their spaceship in March–April that year. However, it was not to be. TeamIndus had to cancel their contract with ISRO (Indian Space Research Organisation), their launch provider [13]. It was a heart-breaking moment for the team. Google announced the closure of the Lunar X-Prize without a winner. However, it was clear that the idea had been timely and had stimulated imagination in the private sector. A slew of new international missions to the moon were announced during this time, by national agencies such as NASA and ISRO and also many private companies around the world.

In March 2019 the 'new space race' dramatically intensified. In a speech at NASA's Marshall Space Flight Center in Huntsville, Alabama Vice-President Mike Pence announced, in the most nationalistic terms, the U.S. government's challenge to NASA to "return astronauts to the moon within the next 5 years." Also saying, "The United States must remain first in space in this century as in the last. Not just to propel our economy and secure our nation, but above all because the rules and values of space, like every great frontier, will be written by those who have the courage to get there first" [14]. Also in March, Narendra Modi declared India to be the 'Fourth Space Superpower' after ISRO successfully destroyed one of its own satellites with a missile launched in space. Creating an estimated 6,500 pieces of space debris (in an exact echo of the opening sequence from the film 'Gravity') Modi announced a day of national celebration and called the action something that would "impress India's rivals" [15]. In this year too the Trump administration announced the creation of a 5th branch of the United States armed forces called the 'space force' [16]. In April 2019, Israel's Space IL, also a competitor in Google's Lunar X-Prize, successfully launched the world's first private moon mission on an unusual orbital trajectory. They proved just how challenging lunar expeditions could be as the craft unexpectedly crash-landed on the moon's surface [17].

On 31 May 2019, TeamIndus tweeted that they had successfully partnered with American company Orbit Beyond and were once gain hoping to launch in 2020 as part of NASA's CPLS programme [18]. On 15 July 2019, ISRO was set to launch its most complex lunar mission and hoping to make India only the 4th nation to soft-land on the moon. They cancelled due to technical difficulties only 56 min before launch [19]. The mission successfully launched 2 weeks later, but tragically communication with the lander was lost just before touch down when the craft was reported to be just 2.1 km from the lunar surface [20]. As of writing the craft is presumed to have crash-landed, demonstrating perhaps, together with the Israeli attempt, the scale of the technological challenge involved in reaching earth's closest neighbour.

The dramatic twists and turns of the story have meant that our project also has had to be fleet of foot, able to respond quickly to an ever-changing back-story. Within each development, and beside the grandiose and gung-ho statements of some players, we feel that our story offers up an Indian female human perspective, the 'small dream' of hope, set against the backdrop of an escalating international space race.

14.3 Short Film

Ek Choti si Asha (A Small Dream) Dance film, 4 min, Channel 4 Television 2017

The overall project had to meet considerable challenges: creative, technical and organisational, with many aspects that we had not tried before. The collaborations, though exciting, presented us with potentially difficult paths to negotiate. We first met Hema in Verbania north Italy, to watch her perform her own choreographic pieces in a dance festival. We were hugely impressed by her work, delicate and edgy at the same time.

The first iteration of the project was a short film commissioned for Channel 4 television; ***Ek Choti si Asha (A Small Dream)*** [21]. Our collaboration, including costume design, was developed across continents and time zones via Skype and WhatsApp. It was necessarily quick as we had limited time to develop the work. We designed a container for Hema to contribute to, sending video storyboards to her whilst she sent rehearsal clips of ideas and movements. Decisions were made quickly and the planning was precise. We attempted to present the audience with a deliberate conceit—that the inclusion of one narrative thread would be appropriated to explore another. In this case, the voices of young Indian space engineers would be featured describing how their robot would cope with physical challenges and obstacles on her perilous journey. This audio would be set against imagery of an Indian female traveller negotiating the busy streets of Bangalore; people, animals, traffic and the male gaze; the combination of voice and choreography allowed us to explore parallels between the Earth and Moon stories without literal space or moonscape being shown.

Further to this idea, we decided to incorporate TeamIndus' use of the feminine pronoun and request that they always refer to the robot as 'she'. Interestingly at this point the two young male engineers warned us "You won't get an emotional response from us. We are engineers and technicians." They then proceeded to make recordings that were infused with obvious emotion as they described the robot that they had been creating for the past six years.

We continued our remote video dialogue with Hema, sending her animatics (edited voice-over with improvised visuals) with Hema responding with small sections of dance recorded in her studio. In this way the ideas and the interplay between words, dance and imagery evolved and a larger narrative emerged.

The specific aspects of the mission meant that the robot rover, named 'Ek Choti si Asha' (E.C.A. for short), meaning 'a small dream' in Hindi, would only survive whilst her solar panels could be in direct sunlight. One lunar day is equivalent to 14 earth days. ECA would travel from Earth to Moon with her batteries switched off. She is only powered on when her wheels touch lunar soil. From this moment the engineers would be able to control her movements on the Moon from the Earth for a fortnight [22].

For us it meant we could give Hema a structure for her choreography. The young character ECA would begin asleep in a black space then wake and start her journey outdoors (Fig. 14.2). A dawn to dusk framework in the 4-min film would inform the remaining narrative that also included the entire lifespan of the character. At the end

Fig. 14.2 R&D Studio 2017. *Ek Choti si Asha.* Opening shot in Bangalore residential street, where Hema starts her walk. https://vimeo.com/240144999

of the day, she faces the future with the knowledge that her end is imminent. Hema introduced tropes from marriage rituals [23] and developed her female character's narrative, conceived of her as a contemporary Indian woman, yet bound by tradition and family. Simply told, she would leave home, full of hope as a young woman embarking on married life, yet she faces anxiety when she realises that her freedoms must change forever and she can't go back.

The storyboard and animatic followed this format, building mini-scenes or chapters based on different technical challenges that the engineers described in detail. Individuated sections were based on how to move the robot in low gravity, how to negotiate obstacles such as rocks and gradients, and how to remain safe from very fine electro-static moon dust. These factors meant that the engineers estimated they would be able to move ECA no faster than 5 cm/min. In response Hema's first task was technical too—how to choreograph a walk so slow it resembled time-lapse. It was pleasing when we filmed tests and rehearsals outdoors that Hema's choreography appeared to resemble slow motion, nicely belied by the figures around moving at normal speed.

This first iteration enabled us to start building a film language that blended documentary interviews with choreography and interwove a journalistic story with a fictional character. Ground rules were established and a simple narrative framework was conceived. For all the constraints of time and distance the simple structure worked very well and all three artists were satisfied with the result.

For Hema the project also became expansive. During 2018 we began working in the context of a larger framework beyond the short film and a departure into live performance.

14.4 Outdoor Performance

A Little Big Dream. National Gallery of Modern Art, Bengaluru January 2018

In January 2018 the British Council in India was in the process of concluding a year of cultural events marking 70 years of Indian independence. Luke Jerram's Museum of the Moon sculpture [24] was brought to Bangalore; a 7-m diameter spherical sculpture printed with high-resolution NASA photographs of the Moon's surface.

Hemabharathy Palani and R&D Studio were invited to make a performance beneath this artwork on the night of the 'super moon' on the 31 January 2018 outside the National Gallery of Modern Art [25].

The performance outdoors under the enormous moon sculpture immediately gave a sense of scale and suggested a duality of strength and fragility: a hardy robot built to withstand other worldly forces and yet tiny against the vastness of space. Hema's choreography included a team of about 20 dancers who made a chorus surrounding her. She, however, was still alone, marooned on an island in the centre of an artificial pond, visually separated from the other performers. The audience were given an image of a lone explorer supported by a big team who were nevertheless separated from her and less and less able to control her as she journeyed further away.

Luke Jerram's Moon and the central performance were both reflected perfectly in the still water around her, a material existing in a non-solid state; an ethereal inverted echo transposed within another atmosphere and space. Pre-recorded video close ups of Hema's movements projected into the decorative masonry and structure of the museum echoed her live performance, yet were strangely remote and disconnected too. The engineering team growing ever distant echoed a fading connection with birth parents. These key images expanded our metaphorical lexicon and represented several ideas at once (Fig. 14.3).

14.5 Objects and Projections

Residencies: Leverhulme & 101 Outdoor Creation Space Spring/Summer 2018

Hema was invited by Ballet Rambert to develop new work during a residency sponsored by Leverhulme [26]. Together with theatre producers Fuel [27], we started to develop ideas for a larger outdoor show, both in Rambert Studios London, and by securing a further 'Seedbed' residency at 101 Outdoor Arts Creation Space near Newbury [28], a large rehearsal space intended for artists to develop outdoor work at scale.

In order to expand the film story into a live performance; narratively, choreographically and visually, this more open-ended collaboration presented more challenges in terms of balancing our creative voices with our different cultural backgrounds, artistic training and preferred methodologies.

We wanted to further develop the work as site-specific location-based, working outside to enable extreme contrasts in scale, the tiny robot in amongst the vast cosmos.

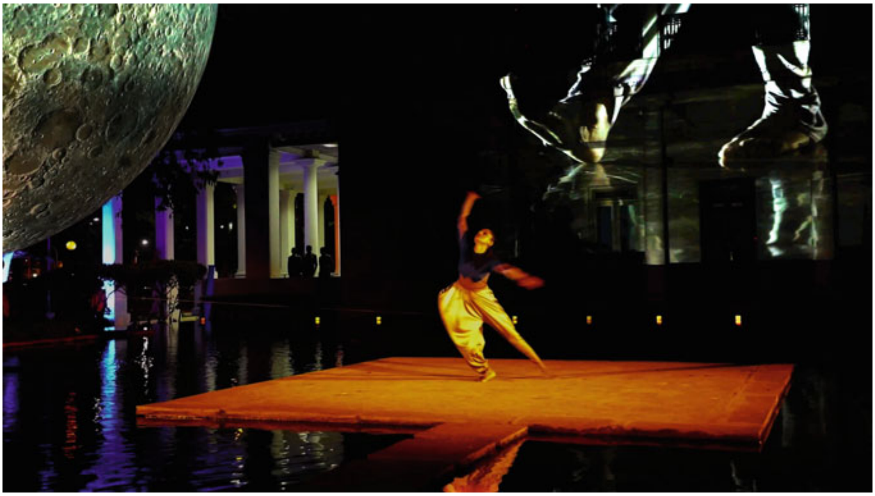

Fig. 14.3 R&D Studio 2018. *A Little Big Dream.* https://vimeo.com/256314451

During these residencies, we conceived of making a wordless visual theatre show that would bring an Indian dimension to 2019, the year of the fiftieth anniversary of Apollo 11.

During the Leverhulme residency we made a series of physical experiments, inventing mechanisms to create a sequence of images to carry a basic narrative. If we were aiming to tell a parallel story between a robot travelling from Earth to Moon and a woman moving between houses on Earth then perhaps simple contrasts could serve as starting points. We experienced a break-through when we began to play with objects and projectors in a darkened space. Choreography could be very small, just hands and small objects, while projections could be huge and immersive suggesting space or other worlds. We imagined how to combine content made with high technology with other images made with domestic objects, playing with large and tiny projections, with the body and with objects on a table-top (Fig. 14.4).

During the 101 Residency, to increase our emotional range we invented a second character, a 'mission controller' who would appear on stage both as a live musician and a kind of director, tracking Hema's character (who we called 'Chandini'—translating as 'a bride for the moon'), and arranging small domestic objects on a table-top. For example, a cup of tea would become a surface for small focused projections that would be re-filmed and re-projected on a large scale thus suggesting immense objects or vast landscapes. Technical and visual experiments such as this were combined with narratives, expanded to take place on three stages: 'Earth', 'Mission Control' and 'Moon'. The action would take place live in an outdoor setting in front of an audience but also filmed and projected on three large screens. The Earth and Moon stages would also have cameras directly above looking down, and the Moon stage would be covered with water.

Fig. 14.4 R&D Studio 2018. *Table Top Moon.* Leverhulme residency film. https://vimeo.com/266294389

We considered the potential use of a drone above the performer and audience, used to stream live images of Chandini's journey to a large-scale outdoor audience. We took drone footage above Greenham Common around 101 Creation Space which, when treated, appeared like an alien landscape. (This footage was later used for subsequent stage iterations.)

Via digital interactive tools a nuanced relationship between Chandini and her maker/controller/family became a further theme explored. Chandini arrives with a live camera attached to her head, whose feed is received and augmented by the mission controller and streamed onto the big screen for the audience.

Interactive sensors attached to the dancers' wrists created a cascade of ceremonial floating flowers symbolising marriage vows (Fig. 14.5).

We mapped out a partially visualised narrative for a full-length outdoor piece in the form of a diagramatic triptych film incorporating spoken and labelled description with footage gathered from both residencies. *Chandini Animatic* (Fig. 14.6).

14.6 Choreography

Chandini—Work in Progress Ranga Shankara Auditorium Bangalore, Attakkalari Interim Festival, 2 February 2019

Having focussed on technical possibilities the previous year, it was now time to develop the choreography. Hema worked on the identity and story of the character 'Chandini' with several days of devising alone before our arrival in Bangalore. The

Fig. 14.5 R&D Studio 2018. Overhead image of Hema with augmented animated flowers

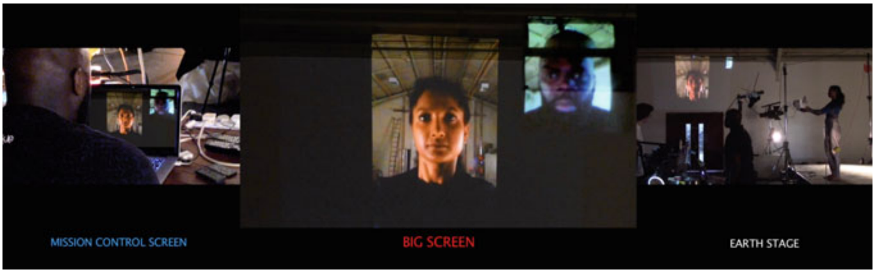

Fig. 14.6 R&D Studio 2018. *Chandini Animatic*. Triptych diagramatic film. https://vimeo.com/297342932

approaching public showing focused our energies and brought together the choreographic and visual aspects of the piece. Hema's choreography comes from working closely with music and we collaborated with PK a young Bangalore-based musician who formed a series of digital soundscapes. In rehearsal sessions we mapped a story of Chandini's journey on the moon; from the dream of her landing, adapting to her unforgiving environment physically and psychologically, her fears and struggles with a perceived feminine role, and her ultimate realisation that she is facing her new world alone.

In the theatre film, animation sequences (e.g. Fig. 14.1) were projected onto dark surfaces and in ultra-wide-angle, bathing the whole auditorium and extending beyond the stage, exploring the impact of moving images as a vast spatial environment into which the small Chandini struggles to find her place (Fig. 14.7).

Fig. 14.7 R&D Studio 2019. *Chandini—Work in progress.* 20 min dance performance. https://vimeo.com/320478323

14.7 Festival

A Small Dream at Dorset Moon Festival June/July 2019

R&D Studio was invited to propose 'Under The Moon' ideas for 'Dorset Moon' Festival in summer 2019, a special one-off festival to coincide with the 50th anniversary of the Apollo 11 moon landing. Dorset Moon was curated by three partners in Dorset; Activate, producers of the Inside Out Festival, Dorset, Bournemouth Arts by the Sea, and b-side [29].

Using three spectacular settings we created *A Small Dream* [30] to showcase the story of 'Chandini' in three chapters: *Launch, Journey* and *Arrival,* comprising two outdoor performances and a video installation across 3 consecutive weekends in July 2019.

Each show was different and each was intended to work alone. By viewing all three the audience were able to track the story of a tiny female robot on a perilous 400,000-km journey. Families, walkers, beach lovers and culture vultures encountered a perambulatory dance through seaside gardens, films projected to look like stained glass windows and a final performance in a fort built out into the sea. The festival was the project's most ambitious outing so far and once again we diversified our approach, developing and extending our metaphors.

Hearing that ISRO's Chandrayaan robot mission was planned for the same summer we also updated Chandini to embody her perspective within this current bullish and intensifying commercial race.

14.8 Live Art

Launch Bournemouth beach and St. Peter's Church 28–30 June 2019

Chandini's Dorset journey began on Bournemouth beach. It was the first sunny weekend of the season and the hottest day of the year thus far. People thronged to the beach. In amongst them squatting close to the pier Chandini gazed out to sea, a Go-Pro camera strapped to her head, recording her view. She gathered sand in her hands and made a ritual offering, a puja, to the sea. Slowly standing up Chandini began to pick her way across the sand, her slow cautious progress echoing that which might be taken on an alien surface. The imagery of the packed beach, as seen from Chandini's headcam, is extraordinary. The camera picks up a strange world in which people are gingerly adapting everyday movements to an unfamiliar environment. Both staring and pretending not to look, the pleasure-seeking beachgoers are strangely unclothed and vulnerable. Chandini slowly passes through crowds, up close and intimate, provoking curiosity with a slow and mysterious approach towards Luke Jerram's moon installed in St. Peter's Church nearby [31].

After performing another puja at the door and taking off her shoes and headcam, Chandini enters the church to make a ten-minute performance under the moon including drawing the orbital path of ECA's journey to the moon in a blue sand rangoli on the floor of the nave.

After the performance audience members were asked, why do you think she is going to the moon? Echoing the question, why are 'we' as a species heading back to the moon after 50 years?

The main form of this piece was not drawn from dance or theatre but from Live Art. Durational, interactive and placed in the real world this medium situated our character again in a new context and with a new relationship to an audience who may not even know they are witnessing an artwork (Figs. 14.8 and 14.9).

14.9 Video Installation

Journey Sherborne Abbey [32] 5–7 July 2019

We next encounter Chandini's journey installed in the magnificent eighth century Sherborne Abbey [32] in video projections in the shape of stained glass windows.

In the quiet devotion of the ancient space, film imagery (such as a turmeric hand clap in slow motion and the cosmos as suspended milk droplets) was combined with the beach point of view scenes from Chandini's Bournemouth headcam, and embedded into the crenulations of a 'blind window'.

Headphones played a musical score peppered with audience responses captured during the week, with the aim of subtly drawing viewers into current conversations about space exploration.

The technique used here was projection mapping. Two projectors carried synced video imagery mapped into eleven complicatedly shaped windows. The venue echoed

Fig. 14.8 R&D Studio 2019. *A Small Dream: Launch.* Hema's slow walk

Fig. 14.9 R&D Studio 2019. *A Small Dream: Launch.* Hema's headcam POV

Fig. 14.10 R&D Studio 2019. *A Small Dream: Journey*

Hema's ritualistic and ceremonial interpretation of the scientific narrative. We almost literally created a window onto another world (Figs. 14.10 and 14.11).

14.10 Outdoor Dance Theatre

Arrival Nothe Fort, Weymouth [33] 12–14 July 2019

The final part of the Dorset Moon trilogy was the largest and most ambitious chapter. The setting of Nothe Forte, a nineteenth century military fort built on a promontory with sea on three sides gave a grandeur to our performance and we consciously wanted to provide a spectacle for the 300+ audience.

Fig. 14.11 R&D Studio 2019. *A Small Dream: Journey (seen through arch)*

We placed the audience up on the ramparts looking down into the fort where Luke Jerram's Museum of the Moon was suspended from a crane. A stage was built just off centre beside the moon and we immersed Hema's live performance in a huge projection extending 27 m across the circular floor of the fort (Fig. 14.12).

Finally arriving on the moon Chandini appears, small and fragile, in the centre of a cosmos projected at scale over the sunken grounds of the amphitheatre-like fort. The audience looks down on her as she wakes in an alien world surrounded by danger. Chandini confronts and struggles with her new environment whilst we realise she is ultimately abandoned.

Being the grand finale to our constructed story developed over the three weekends this piece was more akin to theatre. Using rehearsed choreography, projection mapping onto a square stage and within a larger elliptical surface, lighting and a live camera effect, the techniques were interwoven into the narrative. In addition to combat the prevailing sound of a windy environment, the audience wore wireless headphones so they could hear the soundtrack including its subtleties and speech.

This performance presented large challenges as we moved from the medium of film to large-scale outdoor site-specific theatre and a variety of technical difficulties had to be overcome. The greatest challenge, however, was narrative; how to convey our emotional story also based on the current real lunar Indian mission, in the context of a family-based festival marking the 50th anniversary of Apollo 11. We tackled this with soundtrack; the performance begins with a cacophony of sounds and voices

Fig. 14.12 R&D Studio 2019. *A Small Dream: Arrival.* View of Nothe Forte performance from ramparts

including current bold statements of ambition from national agencies, contrasting this later with the voice of TeamIndus' Sheelika Ravishankar describing the diurnal cycle on the moon alluding to the emotional journey of the character Chandini.

14.11 Documentary

The Vyomanaut 30 min film October 2019

Figure 14.13 shows a frame from the film Vyomanaut.

Whilst making the choreography in India we began to record and document our process behind the scenes (Fig. 14.14). We also interviewed Hema about her feelings towards the work and also about her life in general. We felt as if we had an extraordinary resource in her. Fiercely independent and fearless, she did not have an academic background and doesn't consider herself an intellectual. Not from an artistic family her first love was sports. Yet we found her to be a gifted creative and naturally articulate. She talked about her parents, how her father was supportive of everything she did but how her mother approved of her traditional performances but had refused to see any of her contemporary work. Almost constantly on tour, travelling the world and performing extraordinary edgy works that she had created herself, Hema is a cultural warrior steeped in Indian tradition and mythology. It was apparent that Hema herself embodied the same layers and complexities that the Indian space programme itself contained: simultaneously ground-breaking at the leading edge of innovation and entirely shaped by ancient culture.

Fig. 14.13 R&D Studio 2019. *The Vyomanaut.* Hema creating soundtrack. https://vimeo.com/327502293

Fig. 14.14 R&D Studio. *The Vyomanaut.* Super slow-motion shot of Hema's feet landing in milk (the moon). https://vimeo.com/327502293

The original conceit, the parallel story of a robot on the moon and an Indian woman journeying on earth, remained intact even though the film subtly shifts attention to our choreographer herself. In fact the metaphors deepened. Our documentation film became a portrait of Hema interwoven with a further exploration of the space mission. We visited TeamIndus again, with Hema, and gaining more insights into their evolving story, explored with them the parallels between their endeavours and

Hema's creative world. Also, being appreciative of Hema's love for speed, we made another visual encapsulation for the film: in contrast to her slow-motion walk, we filmed her dynamically running through Bangalore's streets.

The film allowed us to develop themes of speed, freedom for women in India, family, nature and science, wrapped up in a human portrait. It also exists as a document of our entire collaborative process from beginning to end, a video accompaniment to this chapter and a creative documentary film in its own right, incorporating different textures of fly-on-the-wall documentary to highly rendered visual images (Fig. 14.14). It is currently being completed and will be pitched to dance film/science festivals in 2020/21.

14.12 Conclusions

When we began making the Chandini project it was already a hybrid creature, mixing the worlds of contemporary dance, documentary film and animation. But we hadn't planned for it to diversify into so many different forms. All three of our individual practices are predicated on a playful intermingling of ideas and techniques and what we hope is healthy disregard for the traditional silos that some art forms find themselves constrained within. It is therefore unsurprising that our collaboration has become a multi-headed creature.

We would argue that this process has not been schismatic but rather the opposite. The original playful conceit of the parallel story remains a constant, as does the overarching narrative of a one-way journey.

Observing the engineers at TeamIndus search for innovative solutions to technical problems made us consider how adopting an expansive and exploratory approach could push our work forward in unexpected ways [34] and furthermore to ask—what is the purpose of creative research?

By responding to layers within a story in the real world our iterations were driven by form following content, through deliberate meanderings across genre, form and technique, enabling us to examine the facets of our diamond in different lights, a challenging and illuminating process.

References

1. R&D Studio. www.rachelanddaniel.co
2. Khooyile. Channel 4/Walk Clements (1999). https://vimeo.com/8150040, https://www.bfi.org.uk/films-tv-people/4ce2b835a4d26/
3. Loose in Flight. Channel 4/Walk Clements (1999). http://www.akramkhancompany.net/productions/loose-in-flight-2000/
4. Mitra, R.: Auto-ethnography and loose in flight. Akram Khan: Dancing new interculturalism. Palgrave (2015). https://www.palgrave.com/gp/book/9781137393654
5. Morris Jelly House of Fashion. http://film.britishcouncil.org/the-morris-jelly-house-of-fashion

6. Hemabharathy Palani. http://www.attakkalari.org/index.php?page=dancers
7. ET Rise [online]. https://economictimes.indiatimes.com/small-biz/startups/how-axiom-research-labs-has-emerged-as-indias-first-first-private-aerospace-company/articleshow/57101170.cms
8. British Council. https://uk-india.britishcouncil.in/big-dance-shorts-india. Big Dance http://www.bigdance.org.uk/big-dance-shorts-india/
9. Google Lunar X Prize. https://lunar.xprize.org/prizes/google-lunar
10. The Hindu. https://www.thehindu.com/todays-paper/tp-national/Indian-team-in-lunar-rover-competition/article14678319.ece
11. Dance Umbrella. http://www.danceumbrella.co.uk/
12. ISRO. https://www.isro.gov.in/
13. News Minute. https://www.thenewsminute.com/article/end-team-indus-mission-moon-contract-isro-cancelled-report-74403. Jan 2018
14. NASA. https://www.nasa.gov/press-release/nasa-administrator-statement-on-return-to-moon-in-next-five-years. March 2019
15. India Today. https://www.indiatoday.in/india/story/mission-shakti-narendra-modi-full-speech-1487838-2019-03-27. March 2019
16. USA Today. https://eu.usatoday.com/story/news/politics/2019/08/29/donald-trump-space-force-closer-reality-new-space-command/2149265001/. Aug 2019
17. BBC News. https://www.bbc.co.uk/news/science-environment-47879538. April 2019
18. QZ. https://qz.com/1633918/americas-first-private-moon-lander-will-be-engineered-in-india/. June 2019
19. Business Standard. https://www.business-standard.com/article/current-affairs/experts-say-chandrayaan-2-delay-was-pre-emptive-mission-not-a-failure-119071500600_1.html. Sept 2019
20. BBC News. https://www.bbc.co.uk/news/world-asia-india-49615665
21. Ek Choti si Asha—A Small Dream. Random Acts Channel 4. https://randomacts.channel4.com/post/167939666571/a-small-dream-hemabharathy-palani-in-2018-india
22. R&D interview with Shileeka Ravishanka at TeamIndus, 9 July 2017
23. Gaye Halud. https://steemit.com/colourchallenge/@eshani/turmeric-beautiful-significance-in-indian-weddings-2017712t202722301z
24. Luke Jerram. https://www.lukejerram.com/
25. National Gallery of Modern Art, Bangalore. http://ngmaindia.gov.in/ngma_bangaluru.asp
26. Leverhulme Trust. https://www.leverhulme.ac.uk/research-fellowships
27. Fuel Theatre. https://fueltheatre.com/
28. Creation Space. https://www.101outdoorarts.com/
29. Dorset Moon Festival. https://dorsetmoon.com/
30. A Small Dream. https://activateperformingarts.org.uk/a-small-dream-hemabharathy-palani-and-rd-studio
31. Chandini at St Peter's Church Bournemouth. https://www.alamy.com/stock-photo/hemabharathy.html
32. Sherborne Abbey. https://www.sherborneabbey.com/
33. NotheForte Weymouth. https://nothefort.org.uk/
34. TeamIndus blog. https://medium.com/teamindus/teamindus-the-next-phase-d133629e0430

Chapter 15
Digital Moving Image Installations and Renewable Energy: 1994–2018

Chris Meigh-Andrews

Abstract In the period between January and April 1994, while I was artist in Residence in Digital Imaging in the School of Visual Arts, Music and Publishing at Oxford Brookes University, I developed *Perpetual Motion*, a gallery-based installation presenting a computer animation powered via a wind turbine. This early work initiated a series of installations presented within a "white cube" gallery setting and outside in the landscape in which renewable energy systems were integral to the themes and functioning of the work and to the ethos and concerns of my approach to working with moving image and sound technologies. This chapter traces the development of a significant body of work produced spanning a twenty-five-year period from this initial project to some of my most recent installations, discussing my ideas and intentions; describing the functioning and operation of the work; and identifying my influences, context and approach as well as the challenges and issues that I encountered.

Keywords Renewable energy · Solar energy · Wind turbines · Video art · Video installations · Video sculpture · Site-specific installations · Computer-generated images

15.1 Introduction

Throughout the period that I have been engaged in making moving image and sound installations, which includes all the works under discussion, I have aspired to produce works which are temporary and ephemeral. In every case, the installations involved the use of readily available objects and materials that were assembled to perform and function for a brief and finite period of time, usually simply for the period of the exhibition. The installations were subsequently disassembled and dismantled; the equipment and materials were reused or recycled whenever possible. This ethos is central to the work and to my intentions and continues to underpin my approach

Chris Meigh-Andrews (✉)
University of Central Lancashire, Preston, UK
e-mail: meighandrews@btinternet.com

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_15

to working with renewable energy and to my engagement and use of technological systems within my work in general.

15.2 Perpetual Motion

Perpetual Motion (Fig. 15.1) was the first installation I made using a computer to produce and present a moving image. Previously images within my work had been originated using analogue video techniques, although I had increasingly made use of digital effects and non-linear editing systems during the post-production since the mid-1980s. *Perpetual Motion* was conceived for a "white cube" gallery space and intended to be viewed within what I considered at the time to be a sculptural context. As with my previous sculptural video installations *Eau d'Artifice* (1990–93), *Stream Line* (1991–94) and *Cross-Currents* (1992), I hoped the work would be encountered and interrogated conceptually, by which I mean that I intended visitors to become engaged with an exploration of the elements and components of which the work was constructed and to trace the "logic" of its presentation and functioning to reach an understanding of the ideas and concerns of the work. Over time and with hindsight, I have come to recognize that this idea was both problematic and presumptive, but

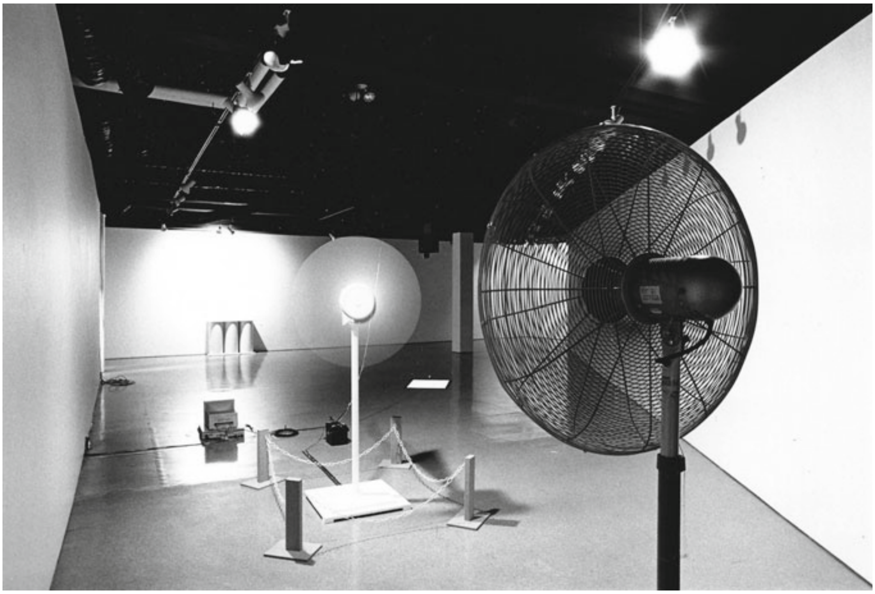

Fig. 15.1 ***Perpetual Motion*** (1994): Installation for computers, wind machine, wind turbine, video projector and video monitor. Funded by Southern Arts, Oxford Photography and the Ontario Ministry of Culture & Arts, Canada. (Visiting Artist Award). Copyright © Chris Meigh-Andrews, 2019

during this early period, I believed my work was sufficiently grounded in fundamental ideas and concerns as to be universally understood and decoded from "first principles".

A basic description of *Perpetual Motion* is as follows: a digital animation of a flying kite was produced using "Adobe Photoshop" and "Macromind Director" (animation software) and displayed as a continuously repeating loop on a ceiling-mounted DC powered CRT video monitor which was connected to a 12 V battery on continuous charge via a small wind turbine. The turbine was subjected to a continuous blast of air produced by a large industrial fan at the far side of the gallery, which in turn was plugged into a conspicuously located mains socket. A second computer-processed video sequence of swaying grass was projected onto the gallery floor via a ceiling-mounted video projector.

This work was subsequently exhibited in three different venues: Oxford Brookes University and the Saw Gallery of Contemporary Art, Ottawa in 1994 and Castlefield Gallery, Manchester in 1996 with the same basic configurations and components, although each time requiring minor modifications due to the differing architectural circumstances and logistics of the venue. In all three iterations, it was of central importance that the wind machine produced a sufficient flow of air to turn the turbine and provide enough current to maintain the charge to the 12 V battery powering the CRT monitor displaying the kite sequence. This flow of air was also a significant physical presence in the gallery, both in terms of the sound and the force of the airflow, contributing to what I considered at the time to be the "sculptural" experience.

In her perceptive discussion of the installation for the exhibition catalogue, the curator Lowena Faull identified many of the key ideas and tensions behind the work:

> Perpetual Motion *uses space in an intelligent way- using the dimensions of the gallery to create a sculptural installation which poses a series of relationships between the viewer, the physical presence of the objects and the technologies at work in the piece. There is a flow of the viewer's imagination as s/he makes associative leaps between the wind machine driving the turbine and the image of the kite on the monitor. Meigh-Andrews has left creative gaps in his work, so that the audience is left to create a simple technical narrative- how it all works- and to create a narrative of meaning within the work itself.....the effect is both meditative and engaging....This is a circuit of energy, imagination and visual representation through which the artist comments on the representation of landscape, the desire of both art and science to represent and imitate the natural world, to force from its disorder, structure, to take its structures and create a more perfect replica. If there is an implied synergy / dependency / inspiration between nature and the machine- there is also an implied critique of that relationship* [1].

15.3 Fire, Ice & Steam

In 1995, I was given the opportunity to develop a new work for the Middlesbrough Gallery while engaged in an artist's residency in Cleveland, North Yorkshire. The installation of *Fire, Ice & Steam* (Fig. 15.2) occupied three linked spaces in the Middlesborough Art Gallery, and although following on from *Perpetual Motion,* I

Fig. 15.2 ***Fire, Ice & Steam*** (1995): Installation for solar panels, halogen lamps and LCD screen. Funded by Northern Arts and the UK Foundation for Sport and Art. Copyright © Chris Meigh-Andrews, 2019

was keen to continue developing new work featuring renewable energy components, only one of the rooms in the exhibition featured solar panels. As the focus of this chapter is on the development of my work with renewable energy systems, I will restrict my description to this aspect of the installation. The display in this room consisted of four framed and wall-mounted photovoltaic panels, connected to a 12 V "deep-cycle" battery powering a miniature LCD screen, displaying a repeating time-lapse forward/reverse video loop of melting and refreezing ice cubes. The melting and reforming ice was arranged to represent the written phrase "that time". Each of the four walls of the room containing a framed solar panel was lit by powerful spotlights timed to switch on and off alternately, so that the light would sequentially rotate in a clockwise manner around the space across the day during the period while the gallery was open. The inspiration for this three-part installation was related to the industrial heritage of the region, and I was keen that the work was understood to be a representation of the complex and dynamic relationship between energy, light and time.

This work provided me with my first opportunity to explore the potential of solar panels as a sculptural element within a gallery installation and provided the initial inspiration for further research. However, although the challenge of developing a work using the energy produced by photovoltaic panels in *Fire, Ice & Steam* led to further ideas, other installations took precedence (*Vortex*:1995 and *Mind's Eye*:1996, see http://www.meigh-andrews.com/installations), and it was not until 1998 that I obtained the opportunity and the funding to develop *Mothlight*, a new installation involving renewable energy.

15.4 Mothlight

My starting point for *Mothlight* (Fig. 15.3) was an apocryphal story about the origins of the term "bug in the system" to describe problems associated with computer programming. According to the version of the story I came across, an early prototype computer system at the computer lab at M.I.T. in Boston developed an operational fault. Because the room-size machine's electronic valves needed to be kept cool during the long hours of calculation, all the windows in the lab housing the machine had to be kept open and during the night flying insects had entered the room, adversely affecting the operation of the computer. The engineer's log for that particular day included a description of the fault as being due to "bugs" in the apparatus, and according to the story the log had even included the insect in question—a moth, carefully preserved between the pages! The flying insects in *Mothlight* were computer-generated, intentionally making what I considered to be an ironic reference to this bit of scientific history, alluding to the uneasy relationship between the natural and the technological worlds.

Fig. 15.3 ***Mothlight*** (1998): Installation for solar panels, halogen lamps and CRT Monitors), Funded by North West Arts, with support from the University of Central Lancashire. Copyright © C. Meigh-Andrews, 2019

Fig. 15.4 ***Mothlight***, Rich Women of Zurich, London 1998. Copyright © Chris Meigh-Andrews, 2019

The decision to produce a computer-generated artificial moth was inspired by this story, but it was also in keeping with my approach to representation in previous works. (For example *Eau d'artifice* (1990), an electronic fountain created from separately recorded elements playing out over a simulated "day"; *Streamline* (1991), an artificial stream made of nine separate but related sequences pieced together to form a "narrative", or the previously mentioned *Perpetual Motion* (1994) in which kite, clouds, sky and grass were electronically combined to suggest a landscape.) In these installations, themes of conflict and interrelationships between the natural and artificial—"the made and the born"; between technology and nature—were at the heart of much of my video work during this period. This review, published in an Italian issue of "Flash Art", identifies this relationship between the natural and the artificial, suggesting an engagement with the transmutation of matter, and picks up on both my fascination with creating parallels between the flow of matter and the flow of thought that had been inspired by my interest in the ideas of the physicist and philosopher David Bohm (1917–1994) [2].

> *In his research, (Meigh-Andrews) grew increasingly interested in natural images transfigured through a series of manipulations which create an artificial, alchemical world. The installations of the 90s focus, lastly, on a fundamental topic – the physic flux and its parallelism with the mental flux, and the possibility that one activates the other. The installation*

> *at Calci plays on this twofold aspect – some halogen lamps illuminate four solar panels which feed some monitors which generate some moths. The whole process is an infinite cycle that the spectator mentally builds through a linear series of logical passages. The thinking flux also establishes a connection among spatially discontinuous elements.* ***Mothlight*** *puts forward another characteristic also present in other works of the artist – the search for contradiction, specifically the "ironic" exploitation of alternative energy. The viewer that has patiently reconstructed the path of energy cannot miss the fact that the solar panels are fed by the halogen lamps* [3].

My video installation work at this time involved both sculpture and the moving image in interrelationship. In *Mothlight*, I sought ways to highlight the interdependence of the elements which were the core of the work—the repeating cycle of the fluttering moths and the suspended solar-powered video screens illuminated by the halogen lamps were all connected to form an interrelated cycle of meaning. The light was an important theme in this piece—illuminating, powering and conceptually connecting the images and objects within the work.

As stated above, my interest in the relationship between technology and nature was a major concern. In *Mothlight* the use of "renewable resources" was intended to be subversive. The solar panels were not used to generate electricity but to act as passive conductors which were transducing light from the domestic mains powerpoint. In my thinking at the time, I felt that by inverting the "conventional" application of renewable energy with electricity, I was serving the poetic rather than the technological.

The structure of *Mothlight* was an attempt to make a work that suggested both balance and movement, and I attempted to make the mobility of the linked elements clearly visible insofar as was practically possible. The various elements which constituted the work were held in a physical balance—the solar panels, the illuminating lamps, and the video screens were arranged in counterbalance, in an attempt to make the physical balance echo the conceptual balance of the interrelated elements.

The whole work was also of course a play on the idea of a "mobile", and I wanted to make reference to the image of the moth as an illusion of mobility. The animated insect was tied to a predictable and endlessly repeating flight path, tethered as much as the various functioning physical elements of the work were constrained by the trailing cables and its relationship to the forces of gravity, and this illusion of movement was at the heart of the piece. The video monitors were placed in such a way that the viewer accepted (even if she/he knew better) the possibility that the moth was flying across the gallery space—flitting from one suspended screen to the other, and this was reinforced by a panning soundtrack and by the movement of the animation through the illusory space of the TV screen. I also observed that it might be possible to see the fluttering moth sequence as a reference to the flickering origins of the film and video image itself and had aspirations that the work could be read as a set of "nested" illusions—starting with the flickering origins of moving-image technology and outwards through the illusion of movement via the mechanics of perspective (both sound and picture) to the illusion of the mechanical mobility of the sculptural form of the entire installation.

Mothlight was exhibited on three separate occasions: the Museum of Natural History in Pisa, Italy; the Glass Box Gallery at the University of Salford, Manchester; and the Rich Women of Zurich, Hatton Garden, London. Each installation was presented in the same basic configuration, but with minor modifications to accommodate the architectural and logistics of the different venues. Each gallery required some adaptations and adjustments—some technical, others more practical. For example, the Natural History Museum, located just outside Pisa in Calchi, was exhibited in a space with an ancient ceiling and required a special fixing to be installed to support the combined weight of the installation. In the Glass Box Gallery, the work could only be viewed from outside the gallery through large windows on four sides of the space. As the work was completely contained within this space, the buildup of heat from the halogen light sources caused a significant voltage drop from the solar panels necessitating the hiring of a portable air conditioning unit. At the Rich Women of Zurich, the length of mobile support arms had to be modified to fit the gallery space.

In 2001 a variation of this installation was developed for the 291 gallery in Hackney, London, replacing the CRT monitors with data projectors displaying the moth flight sequences onto suspended sheets of translucent glass. The images of the moth were sent via infrared to the projectors, and the transmitters were powered via the solar panels, which I considered at the time added a further conceptual level to the work, making a feature of the video signal "flying" through space from its source to reach the screen. The scale of *Mothlight II* was more substantial and the greater ceiling height in the 291 gallery provided an opportunity for a more monumental installation, while retaining its ephemerality.

15.5 For William Henry Fox Talbot (The Pencil of Nature)

In 2002, I had the opportunity to realize a project that I had been considering for several years. In response to an invitation to make a new work for "Digital Responses" a group exhibition at the Victoria and Albert Museum, London, I proposed to install a solar-powered live video camera at Lacock Abbey, in Wiltshire—the former home of the pioneering scientist and inventor William Henry Fox Talbot. Electricity produced from a solar panel was harnessed to power a digital video camera focused on the large latticed window which had first been photographed by Fox Talbot in August 1835. The image from the camera was composed to exactly reproduce Fox Talbot's pioneering "photogenic drawing", the world's earliest surviving photograph. This digital facsimile was relayed via an ISDN phone line to the V & A, the resultant "live" digital image of the window presenting a full-size image of the window in "real time". This digital replica of the oriel window at Lacock was presented in a special display beside an original copy Fox Talbot's book, *The Pencil of Nature* (Longman, Brown, Green & Longmans, London, 1844), the worlds' first book to be illustrated with photographs (Fig. 15.5). Researcher and curator Vince Dziekan described his encounter with the work when it was installed at the Victoria and Albert Museum in his essay "*Distributed Aesthetics and the Tele-image*":

Fig. 15.5 ***For William Henry Fox Talbot*** *(The Pencil of Nature)*, (2002): Site-specific installation for solar panel, video camera, ISDN phone line, and data projector.) A site-specific installation for "Digital Responses", Victoria & Albert Museum, London, Sept-Oct. 2002. Curated by Paul Coldwell. Technical Consultants: David Dorrington (Internet) and Richard Monkhouse (Solar energy). Funded by The University of Central Lancashire, The Arts & Humanities Research Board and the London Institute with sponsorship from Canon UK, Solar Century PLC, with support from British Telecom, Bow Arts Trust and The National Trust. Copyright © Chris Meigh-Andrews, 2019

> *At first, this fleeting projection could just as easily be dismissed as a case of the morning light outside being cast through the windows lining the length of this narrow gallery. Upon closer inspection, however, the shadow play seemed uncannily to re-enact the exact characteristics of this famous photographic image. To refer to this digital image as a representation seems a somewhat inadequate description in that the image gently playing on the wall surface I was facing involved the direct transmission of the light passing at that very moment, not through the windows in the very room in which I was standing, but through the actual windows of Lacock Abbey in Wiltshire, near Bath in the west of England. Titled, For William Henry Fox Talbot (The Pencil of Nature), the work was an exact re-composition of Fox Talbot's famous 'photogenic drawing', here captured by a solar-powered digital camera and relayed 'live'* via *an ISDN phone line to the gallery in South Kensington, where it was presented at actual size in 'real time'* [4].

With this installation, I wanted to imply the complex web of interrelationships between art, technology, light, time and physical space and reference the origins of photographic imaging and the nature and significance of light and vision and its relationship to the flow of communication systems and to the interconnecting of two geographically separate sites. The work sought to build on ideas developed in previous installations such as *Perpetual Motion* and *Mothlight* which presented "renewable energy" as a metaphor. In this new work, the daylight at the site of

Fig. 15.6 The author setting up the video camera, Lacock Abbey, Wilshire. Copyright © Chris Meigh-Andrews, 2019

the abbey passing through the historic and culturally significant window at Lacock Abbey set the entire work in motion, reflecting my intention to present an installation in which the past, present and future were linked electronically, geographically and conceptually.

15.6 Interwoven Motion

At the edge of a wooded area in Grizedale Forest, Cumbria, overlooking Coniston Water in the English Lakes, a large tree was temporarily equipped with four video surveillance cameras arranged in a circular formation around the trunk at the height of approximately eight metres. The images produced by the four cameras were relayed via a switcher to a weatherproof LCD video display mounted at the base of the tree. The speed and direction of the camera image flow was determined by the velocity and direction of the wind. The entire system was powered by a wind turbine extended beyond the height of the forest canopy and four solar panels which were mounted within the tree itself (Fig. 15.9).

Since beginning this period of work to develop renewable energy installations, all of the works I had developed were necessarily intended to be for interior locations, but for some time I had wanted to make an outdoor video installation that responded to its environment [5]. Working with video artist Catherine Elwes and engineer Dr.

Fig. 15.7 Richard Monkhouse and the author on the roof of Lacock Abbey. Copyright © Chris Meigh-Andrews, 2019

John Calderbank in the early 1990s, I had conducted a period of research into the feasibility of building a permanent outdoor video sculpture for the Chiltern Sculpture Trail at Cowleaze Wood in Oxfordshire, although this early project did not proceed beyond the report stage [6].

The notion of constructing an outdoor video installation in the landscape contained many of the contrasting and contradictory aspects that I enjoyed working with at the time and which continue to some extent in my most recent works. *Interwoven Motion* juxtaposed the natural and the artificial and made use of technology which was intended for interior use placed outdoors. I was interested in finding ways to contrast the strength and fragility of the technology with the durability and vulnerability of the tree it was temporarily connected to and the landscape it was part of. I was also interested in highlighting and contrasting different notions of temporality, permanence and impermanence. The specific video images produced by the installation were in themselves of no direct consequence—they were simply part of a flow of very subtly changing ephemeral moments. For me, the relationship between the light and the wind was at the core of the work. The light and wind provided the

Fig. 15.8 ***Interwoven Motion***, Grizedale Forest, Cumbria, (2004). Copyright © Chris Meigh-Andrews, 2019

source of the images both in terms of the generation of the electrical power which supported the video and electronic apparatus and in terms of the direct physical and visual experience which become part of the work. (Day/night, ambient light and the movement of clouds, and foliage, the changing weather conditions, etc.)

It should also be noted that the work itself, like the image-sequences it produced, was transient. The components which constituted the work were temporarily clamped to a living tree for a period of ten days. The various bits of inexpensive technology—wind turbine, solar panels, video cameras, image switcher, LCD video display, cabling, etc.—were temporary modifications, which, once removed, left no trace. During the period in which the prototype installation was functioning, it was left running night and day for as long as the technical systems remained operational. Designed to be self-powering as long as the weather conditions provided sustaining light and wind, the installation was equipped with two large-capacity rechargeable batteries capable of powering the installation for approximately 72 hours. Located on Forestry Commission land, it was relatively inaccessible except via an unpaved road. From the distance, the solar panels and the wind turbine would certainly have aroused the attention of curious by-passers. However, the casual visitor coming across the installation would find no explanation or context for the piece, what it was, why it

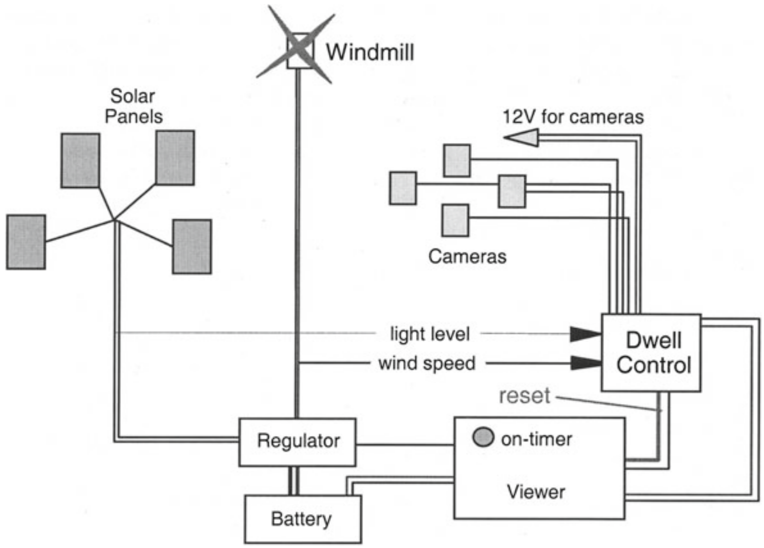

Fig. 15.9 ***Interwoven Motion***, (2004): Outdoor site-specific installation for four cameras, wind turbine and solar panels. Commissioned for "ITEM", Funded by the National Endowment for Science, Technology and the Arts (NESTA) and Arts Council, England for The Foundation for Art and Creative Technology (FACT) Liverpool, with support from Grizedale Arts, Wind and Sun Ltd. and the Forestry Commission. Consulting Engineer, Dr. John Calderbank. Copyright © Chris Meigh-Andrews, 2019

was there, or what purpose it might have. Visitors were free to respond (or not) and to offer up their own explanation for its existence.

The location of the prototype outdoor video piece at Lawson Park was significant, as the site was on land once owned by John Ruskin, the influential Victorian English writer and critic. Ruskin's passionate enthusiasm for the landscape of this area is well-documented, not least in his published lectures and prolific diaries. His detailed and evocative descriptions of the ceaselessly changing views of the "Old Man" above Coniston Water and of the cloud formations and vivid skies provided me with a compelling sense of this dynamic landscape—and provided me with a title for the work:

> *From the west the wind blows fiercely towards you out of the blue sky. Under the blue space is a flattened dome of earth-cloud clinging to, and altogether masquing the form of, the mountain, known as the Old Man of Coniston. The top of that dome of cloud is two thousand eight hundred feet above the sea, the mountain two thousand six hundred, the cloud lying two hundred feet deep on it. Behind it, westward and seaward, all's clear; but when the wind out of that blue clearness comes over the ridge of the earth-cloud, at that moment and that line, its own moisture congeals into these white—I believe, ice-clouds; threads, and meshes, and tresses, and tapestries, flying, failing, melting, reappearing; spinning and unspinning themselves, coiling and uncoiling, winding and unwinding, faster than eye or thought can follow: and through all their dazzling maze of frosty filaments shines a painted window in palpitation; its pulses of colour* ***interwoven in motion****, intermittent in fire,—emerald and ruby and pale purple and violet melting into a blue that is not of the sky, but of*

the sunbeam;—purer than the crystal, softer than the rainbow, and brighter than the snow [7].

Ruskin's vivid perception and appreciation of the lakeland landscape provided me with a powerful connection to the cultural history of the site and was an important element within the context of the work, deeply connected to a sense of its location. At that time, I saw this project as the first step towards the goal of creating a landscape installation that was an integral part of the landscape in which it was sited, responding directly to and in relation to its location, which remains an aspiration to this day [8].

15.7 Resurrection

The subsequent invitation to produce and exhibit an installation incorporating renewable energy was once again within a gallery context and I took the opportunity to develop a companion piece to the recently completed *Interwoven Motion*. A description of the elements and structure of the installation may help to visualize the work (Fig. 15.10).

Fig. 15.10 ***Resurrection***, (2005–06): Site-specific installation for solar panels, DVD player and data projector. Commissioned for "Digital Discourse", curated by Vincent Briffa, St. James Cavalier Centre of Creativity, during the Commonwealth Heads of Government Meeting, (CHOGM), Valletta, Malta. Funding from the British Council and support from the University of Central Lancashire. Copyright © Chris Meigh-Andrews, 2019

A dead tree, complete with roots (approximately twenty feet high), was cut in half, the root end mounted in the centre of the floor at one end of a rectangular gallery space. The upturned tree and roots were lit by halogen lamps, casting strong shadows on the opposite gallery wall. Over forty individual miniature solar panels were arranged irregularly on the roots and connected in series, the wires grouped and bundled and flowing down the trunk and in a cluster along the floor towards the centre of the gallery. The clustered cables were connected via a junction box and through a regulator to a twelve volt battery positioned in the centre of the space. The battery was connected in turn to a DC powered DVD player.

The top half of the tree was mounted in the centre of the ceiling pointing downward, its branches reaching down towards the floor with numerous small rectangular sheets of heavy white paper fixed to the branches, arranged to resemble leaves. A data projector mounted on the ceiling at the opposite end of the gallery was fed a continuously cycling pre-recorded video sequence of the original living tree, complete with leaves stirred by a fresh breeze. The sound of the wind in the leaves filled the space and the projected image created a strong silhouette of the upturned tree on the gallery wall.

This new gallery installation, entitled *Resurrection*, drew directly on the experience of building *Interwoven Motion*, bringing both the technological and the natural elements back into the "white cube" gallery space to create a companion piece. The living tree of the Grizedale project was conjured up in a revivified form within the interior of the gallery.

The video images of the fluttering leaves in *Resurrection* presented a record of a previously living existence, recreated via technology. The electrical energy used to bring the resurrected tree back to life was transformed within the gallery space from electricity to light and back again and the shimmering leaves were experienced as both light reflectors and light receptors, the solar panels as both surrogate leaves and transforming technology.

Resurrection was developed from the knowledge gained through the development and making of previous works and shared many of the same conceptual concerns (and components). In retrospect, it was a refinement of my approach to previous gallery-based installations made prior to *Interwoven Motion* because it offered gallery visitors a more pronounced sculptural experience. The technical and functional aspects of the work were more integral to the spatial arrangement of the sculptural components. In this sense, *Resurrection* was more akin to my aspirations with *Mothlight* and *Perpetual Motion* and my earlier non-renewable installations such as *StreamLine* in which I was conscious of the relationship to the architectural space of the gallery and intent on achieving a balance between the metaphorical "function" of the technical components and a perceptual (haptic) experience within the exhibition space.

15.8 Sunbeam

The environmental burden of electronic equipment, in terms of resources, manufacture, energy use and waste has become a matter of concern for artists working with this equipment. Some have developed works that variously recycle old technologies or decline to take their power from the grid. Thus, Chris Meigh-Andrews' SunBeam *uses a solar-tracking array (photovoltaic cells that follow the sun's arc during the day) to power a night-time projection of processed images from NASA's Solar Dynamics Agency, the content and the process matching. The piece appeals to a cultural history of solar energy and the symbolic power of plants, like the daisy and the sunflower, that track diurnal rhythms in their behavior and growth* [9].

I had been fascinated by the large tracking solar array installed adjacent to the School of Dentistry at the University of Central Lancashire in Preston ever since they had been installed in 2009. This solar array was able to track the sun as it moved across the sky during daylight hours, substantially increasing its efficiency [10]. During discussions with Dr. Robert Walsh, director of research at the Jeremiah Horrocks Institute for Astrophysics and Supercomputing who was seeking ways to publicize the institute's work with NASA's Solar Dynamics Observatory, I suggested that we harness the energy from the solar array to produce a series of evening projections of the high-definition images of the sun produced by the observatory. My proposal was to draw energy collected during the day to project images of the sun back onto the surface of the array itself in a reversal of the process. Tests during the development stage of the project revealed that this would require covering the panels with a reflective material during the evening to provide an image of sufficient brightness to be visible. The project would also require a high-powered data projector and local police clearance to allow the images to be projected from the building across a busy road from the array. For the screen, I ordered a custom-made PVC sheet large enough to cover the surface of one of the two solar panels and this was installed using a large hydraulic lift. At dusk on the evening of each event, the covered solar array was rotated to face the university building directly across the road in which a Christie high-definition video projector was installed on the third floor. Edited time-lapse high-definition video sequences were projected onto the array on four consecutive nights, drawing considerable crowds and providing a spectacular demonstration of the power and majesty of the sun and of the university's collaborative research initiatives (Fig. 15.11).

My own aspirations for this work extended beyond this and were related to ideas and concerns that link it to my previous renewable energy installation projects. As Charlie Gere, professor of media theory and history at the Lancaster Institute for the Contemporary Arts at the University of Lancaster, has observed, *SunBeam* brought me closer to my conceptual goal of producing a technological artwork which attempts to integrate the source of its energy with the images it presents, to celebrate the harmonious relationship between light, energy and the fluid nature of matter in general:

In SunBeam *Meigh-Andrews now perhaps realises what the earlier works hinted at, an artwork which both represents the prodigious energy of the sun and performs its effects by*

Fig. 15.11 ***SunBeam***, (2011): Site-specific digital projection event. (Tracking Solar array, data projector.) Produced in collaboration with the Jeremiah Horrocks Institute for Astrophysics and Supercomputing, UCLan and the Solar Dynamics Observatory, (NASA). Scientific Advisor: Dr. Robert Walsh, with assistance from Dr. Stephane Regnier, David Henckel and Michael Dorricott. With support from Astley Hire. Video editing of solar sequences: Cinzia Cremona. Copyright © Chris Meigh-Andrews, 2019

> *using that energy to make the representation possible…That the energy harvested during the day can then be used to make an artwork possible beautifully encapsulates (Georges) Bataille's notion of art as a form of general economy exemplified in the sun itself. The system that harnesses the sun's extraordinary power for straightforward and restricted uses, such as supplying energy to the university and to the national grid, is 'detourned' to produce a work of art, or in other words something useless according to the restricted economy of reciprocity and exchange. This is, perhaps, the very definition of art itself.* [11]

15.9 Aeolian Processes

Aeolian Processes I and II (Fig. 15.13) were unusual within my body of work in that renewable energy was harnessed to produce sound and neither installation included any visual imagery [12]. However, both works followed my general approach of seeking to produce a series of visual connections enabling the functioning of the work to be decoded by following the operation of the elements from which the work is constituted; hence the subtitle of the 2nd version of this work "Box Revealing

Fig. 15.12 ***SunBeam***. Installing the temporary screen on the solar tracker, UCLan, Preston, May, 2011. Copyright © Chris Meigh-Andrews, 2019

the Sounds of its Own Making", which makes a reference (and homage) to Robert Morris' 1961 sculpture [13].

Both installations had a definite physical presence and the various technical components that produced the sounds were all visible and involved elements of movement and change. As with all the installations discussed in this chapter, I was interested in making a temporary sculptural object in which the visitor engages with the functioning and operation of the work in order to make sense of it. With *Aeolian Processes,* I aspired to make something which was simple, direct and compatible with the landscape ethos of its location. Both installations were comprised of similar elements and operations, although *Aeolian Processes II* is a refinement and development of the earlier work.

Aeolian Processes I was commissioned for a group exhibition to be sited in a large urban park, and consisted of a large wind chime suspended within the interior of a glasshouse which was being continuously activated by the breeze from a small domestic fan. A microphone placed close to the wind chimes picked up the sounds which were then amplified, electronically manipulated and relayed to an outdoor speaker installed on the roof of the glasshouse. All the electrical components were powered via solar panels which were also installed on the roof.

Aeolian Processes II (Box Revealing the Sound of its Own Making) used the same basic configuration of components as the previous version, but given that the work

Fig. 15.13 ***Aeolian Processes I*** (2013): Outdoor solar-powered sound installation, commissioned for "Art in Your Park", Highfields Park, Nottingham, curated by Theresa Caruana, with funding from Arts Council, England. ***Aeolian Processes II (Box Revealing the Sound of its Own Making)*** (2014), "La Lune: Energy Producing Art", Long Reef, New South Wales. Curated by Allan Giddy with funding from the Environmental Research Initiative for Art, College of Fine Arts, University of New South Wales, Australia. Copyright © Chris Meigh-Andrews, 2019

was commissioned for a sculpture trail intended to be viewed after dark, the interior of the glasshouse was illuminated. As the work required a more substantial power supply, the solar panels were located on a separate structure which was positioned adjacent to the glasshouse. The electronics were also refined; an echo device was incorporated into the sound processing and an improved amplification of the wind chimes enabled the sound to be heard from a greater distance.

In 2015, I began developing a series of small-scale sculptural installations under the generic title of "Impossible Objects", motivated by an interest in making works which would not require a specific commission, purpose, venue or dedicated gallery space, and with no major funding. Although these pieces have much in common with earlier works discussed in this chapter in that they often incorporate or feature renewable energy components in order to make connections to the theme of flow, they are also more directly centred on notions of "process" as a central concern. They are "Impossible Objects" not because they cannot exist (as they clearly do), but because they make use of or refer to a process that contains a contradiction or presents an "impossible" idea. They are representations of a state or situation that cannot be achieved, except through the processes and agency of art. In this respect, I have been influenced in part by the *Mono-ha* works of the Korean artist Lee Ufan, in which there is an encounter between different materials—"a relationship of tension" in which the work is the site of the encounter. In common with my approach to my large-scale installations, all of these "Impossible Objects" are hybrid installation/sculptures made using domestic technology; temporary assemblages are made using readily available materials and equipment. Most involve moving images and some have sound. Although there are at the point of writing five in the series, only two are relevant to the themes in this chapter.

15.10 Impossible Objects

Intended to fit onto a tabletop, *Impossible Object Number 1* consists of a symmetrical arrangement of two solar panels top lit by two anglepoise lamps (Fig. 15.14). The panels provide a continuous charge to a 12 V battery which provides the electrical energy to drive a small electric motor geared to turn a crank operating a miniature music box mechanism which repeatedly plays the first few bars of the tune from (John) Lennon's "Imagine". The work employs a similar ironic reference to that of my earlier large-scale installations *Mothlight* and *Mothlight II,* i.e. the notion that solar energy (or more accurately renewable energy as a whole) will solve the current environmental crises. Although the work is perhaps more directly critical when compared to the earlier works, it is also more whimsical.

Similarly, *Impossible Object Number 2* (Fig. 15.15) continues this more directly cynical perspective with respect to the misplaced optimism regarding the role of renewables to "save the planet". Physically, the work is more of a sculpture than an

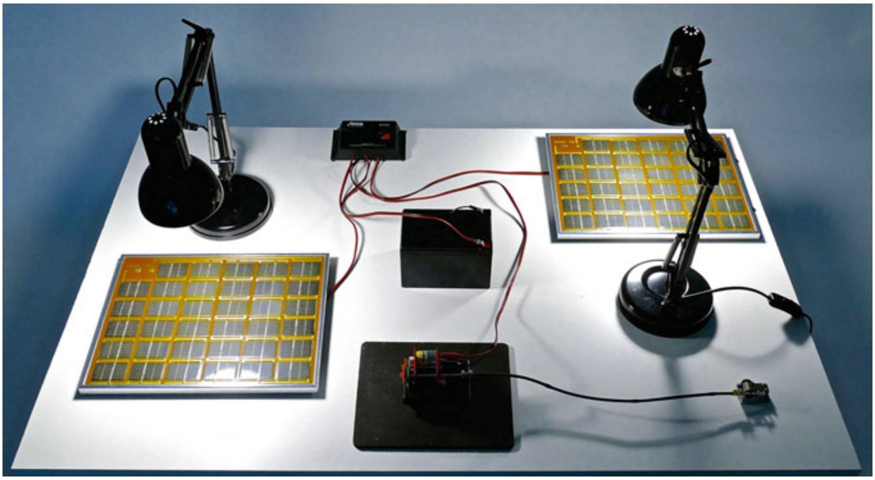

Fig. 15.14 ***Impossible Object Number 1: Imagine (No Pollution)*** (2016–17). Anglepoise lamps, solar panels, battery, electric motor, music box. Funding: First Site Collectors Group Bursary, (2015).

Fig. 15.15 ***Impossible Object Number 2: Blue Sky Thinking*** (2018–19). LCD screen, media player, wind turbine, battery and electric fan. Copyright © Chris Meigh-Andrews, 2019

installation. A black 92 cm × 3 cm × 8 cm wooden beam leans against a gallery wall at a 45 degree angle, with one end sitting on the floor. At the bottom end nearest the floor, a compact domestic electric fan creates the air current to turn a toy wind turbine connected to a battery powering a media player connected to a miniature LCD video monitor, which is arranged so that it must be viewed through a magnifying glass. The monitor displays an endlessly cycling video sequence of a full-size wind turbine. The video presented on the screen was recorded using a rotating mount locked to the speed of the turbine rotors, so that the surrounding landscape appears to rotate while the turbine blades remain static. As with all the other installations discussed in this chapter, both works are conspicuously plugged into the gallery's mains power supply.

These two small-scale sculptures clearly draw on the ideas, techniques and approach of the earlier installations, and although they are less ambitious in scale and execution, they were intended to be more direct in their intention and content. They might be understood as maquettes, as it would be conceivable to create larger versions of both of these pieces, and at a larger size they might be more challenging to experience in a gallery or outdoor setting and perhaps even more effective. Certain elements would need to be reconfigured and the formal arrangements would require revising and modifying, and in an upscaled format both of these "sculptures" would almost certainly, in my view become "installations".

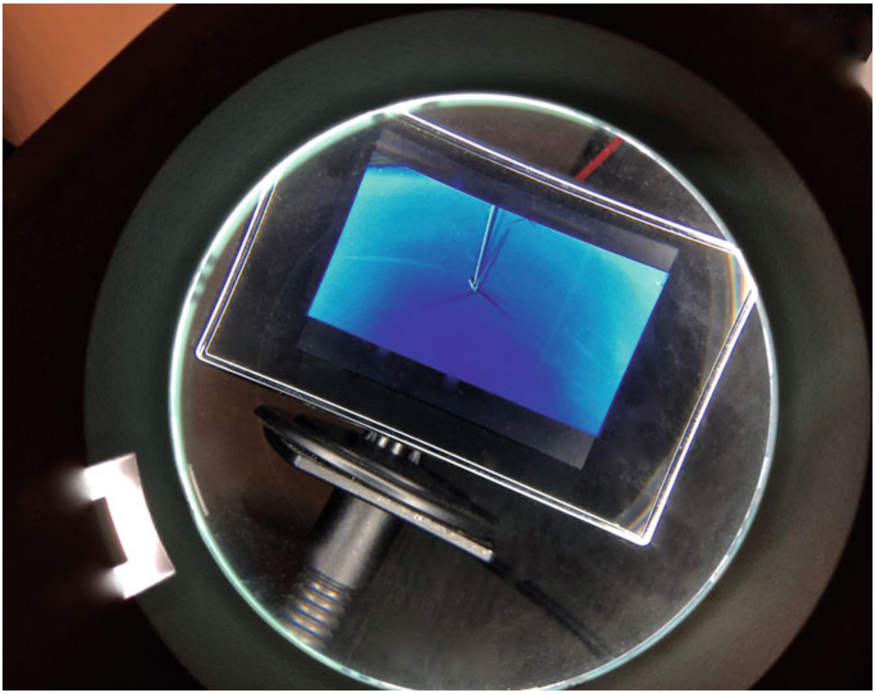

Fig. 15.16 ***Impossible Object Number 2: Blue Sky Thinking*** (2018-19), detail. Copyright © Chris Meigh-Andrews, 2019

15.11 Conclusions

Although all of the works discussed in this chapter inevitably have a level of critical engagement with the impending current environmental crises, and is therefore relevant to any reading of the work, in very few cases was this aspect my sole motivation or even my central concern. The photovoltaic panels and wind turbines in my installations and sculptures have been employed for their ability to transform or transduce energy from one form to another; from light or flowing air into electrical energy. In all of these installations, I have attempted to create or make reference to the flowing movement of matter and its parallel to the fluid movement of time. In relation to this, I wanted to find ways to create an awareness of the process of perception that takes place in the mind of the viewer while she/he actively engages with the work and participates in its potential to exist and/or function.

It seems as if there is something to be said about the terms I have used to describe the various works. I have written about "installations" because I feel that most of the work I have developed that makes use of or features renewable energy systems are works which require the visitor or viewer to engage in a kind of perceptual action—reading or following a line of thinking and making links and connections between elements to reach a conclusion or arrive at an understanding. This could be seen as a kind of narrative activity or at least a time-based process of reading and making connections. A sculpture, on the other hand, requires that it is seen and understood—or at least perceived "all at once" as an object, and then perhaps unravelled and deconstructed, after the initial encounter.

At the point of writing this, I have tentative plans for further work to extend or continue my line of enquiry which may perhaps result in new or further successful developments. However, I believe the context of this work has changed considerably since I began making installations which included renewable energy components. The environmental issues have been brought into much sharper focus, as there is a far greater public awareness of the danger to the environment posed by the use of fossil fuels. For example, in my earliest work visitors were not always able to immediately recognize the function of the solar panels as transducers of electrical energy, but now these objects are so commonplace that they are not perceived as remarkable or intriguing and their potential as a symbolic or poetic device has been considerably eroded. This shift in consciousness makes the environmental dimension of the work too dominant, and weakens its impact and potential, and this requires that I either accept this and move on, or try to discover a new level of signification and relevance for them in my future work.

References

1. Faull, L.: Digital meditation: imagine technology as art. Back/Slash, Castlefield Gallery, Manchester, Sept–Nov (1996)
2. Bohm, D.: Wholeness and the Implicate Order. Routledge and Kegan Paul, London (1980)
3. Leoni, C.: Flash Art (Italy), Summer (1998, translated from Italian by Cremona, C.)
4. Dziekan, V.: Distributed aesthetics and the tele-image. Remote, Plimsol Gallery, Centre for the Arts, Hobart, Australia, June (2006)
5. In this aspiration I have drawn on two seminal artist's films, both made in the 1970's: Michael Snow's*La Region Centrale* and Chris Welsby's *Seven Days*
6. Panorama, a feasibility study, Meigh-Andrews, Elwes & Calderbank, Arts Council of Great Britain (1993)
7. Ruskin, J.: Lecture (1876)
8. Gilman, C.: Interwoven motion: steps towards a semi-permanent outdoor, self-powered video installation in research. In: Gilman, C. (ed.) The Itemisation of Creative Knowledge. FACT and Liverpool University Press (2006)
9. Cubitt, S.: Angelic ecologies. Millennium Film J. **58** (Fall, 2013)
10. https://www.uclan.ac.uk/news/assets/annual_review_2011.pdf. Accessed 29 May 2019
11. http://clok.uclan.ac.uk/4903/1/Sunbeam%2C%20Gere.pdf. Accessed 31 May 2019
12. Although I have worked predominantly with video, I have made other sound installations, notably "For John Cage" (2001), "End Repeat", The Center for Contemporary Art, Tallinn, (http://www.meighandrews.com/installations/1996-2001/for-john-cage) and "Impossible Object Number 1" (2016)
13. Morris, R.: Box with the sound of its own making. https://www.metmuseum.org/art/collection/search/689665. Consulted 07 June 2019

Chapter 16
From Digital Nature Hybrids to Digital Naturalists: Reviving Nature Connections Through Arts, Technology and Outdoor Activities

L. Edwards, A. Darby, and C. Dean

Abstract This work considers how the arts and technology in combination can stimulate connections in heritage gardens, and also nurture care for non-human nature. The chapter divides into two overlapping parts. The first part describes and critiques the design of Digital Nature Hybrid artifacts for interpreting gardens and exploring nature. The second part builds on the first by showing how the challenges presented by the Digital Nature Hybrids stimulated the design of Digital Naturalist workshops. It shows the value of combining arts, digital technologies and outdoor activities to support active engagements with non-human nature and to inspire the development of knowledge and skills needed to attend to natural environments. Research through design underpins the way of working and the project uses a critical approach toward technology, to guide the design decisions. One of the insights is the value that adopting this critical approach has in shaping both processes and designs.

Keywords Digital nature · Digital Naturalist · Digital design · Digital Nature Hybrids · Design lens · Research through design · Technicity · Focal things · Focal practice · Commoditization · Instrumentalism · Non-human nature · Cultural horizon · Hegemonic structures

Received on September 13, 2019. Revised on September 30, 2019. This work was funded by EPSRC's Digital Economy programme (RCUK Grant EP/G037582/1), EPSRC, an EPSRC Senior Fellowship (Grant EP/P002285/1, The Role of Digital Technology in Understanding, Mitigating and Adapting to Environmental Change) and an ESRC Impact Acceleration Account award (for Digital Naturalists: The Lost Sounds).

L. Edwards (✉)
School of Computing and Communication, Lancaster University, Lancaster, UK
e-mail: liz.edwards@lancaster.ac.uk

A. Darby
Lancaster Institute for Contemporary Arts, Lancaster University, Lancaster, UK

C. Dean
Edge Hill University, Ormskirk, UK

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_16

16.1 Introduction

Digital and other technologies play an increasing role in human life and have become the dominant paradigm in the industrialized world. Technologies shape our movement and interactions, for example, the way we walk through streets, head down, checking our phones. Each technology favors particular senses and pushes and pulls at them for attention. The values and assumptions that are built into technologies are osmosed into society and become accepted as norms by both individuals and wider society, hence shaping the cultural horizon. Once they have been normalized, technologies reproduce themselves because people take them for granted and are conditioned to notice and value the benefits they bring.

Despite widespread acknowledgement of technology's contributions, many writers over the decades, from Simmel [1, 2] and Marcuse [3] to Feenberg [4–6] and Kahn [7, 8] have expressed concern at the effect of technology on humans and non-human nature. Some draw attention to the impact of technicity (the prevalence of and reliance upon technology) on the human psyche, others draw attention to the framing of the world that prevails in this paradigm. Common themes are alienation from the self, from others and from the natural world, and a tendency to perceive every thing and every person as a resource to be harnessed and operationalized, and an inability to see this happening from within the system.

The implications are particularly evident in human relationships with the natural world. People spend more time in communion with their digital devices and less time in nature, leading to a loss of familiarity, awareness and care for the natural environment. As people's care for a place dwindles, protection of that environment declines, and people care even less, leading to an exponential cycle of deterioration.

Fortunately, the cycle can be broken, and the cultural horizon can be shifted, for the benefit of humans and non-humans. Feenberg [4–6] argues that technical codes can be reshaped through a democratic, participatory approach. His work builds on Marcuse's [3] which looks to artists to critique and confront systems and structures.

This chapter discusses digital designs which draw on these ideas, embracing criticism of technologies in order to design differently. The aim of these designs is to revive nature connections and re-energize the culture of amateur naturalists, to ensure that the detailed local knowledge needed to safeguard environments and biodiversity is not lost forever. The designs range from Digital Nature Hybrids intended to stimulate senses and raise awareness of gardens and plant heritage to workshops that meld arts, computing and nature encounters to raise levels of engagement and connection to the natural world. These workshops bring together experts from the different domains, and each iteration responds to location, participants and inputs from the particular partners. Beyond the individual workshop, the project's aim is to strengthen a collaborative community of artists, designers, technologists, environmentalists and educators to excite people about exploring their local area and the wildlife around them.

16.2 Background

The Industrial Revolution caused major changes to the economy and society that cascaded down to individuals' everyday life. People moved from the countryside into cities, becoming geographically separated from the natural world. The character of work changed. Agricultural work had flexed in time with natural rhythms of the day, across the seasons, but machine processes exerted a fixed, relentlessly unwavering pattern, increasingly uncoupled from rhythms in the natural world. Previously people made whole things, from start to finish, but the compartmentalized structures necessitated by machine processes fragmented production, which meant workers carried out discrete, repetitive tasks. Workers no longer saw the workflow from the start to finish and this had consequences. They lost the autonomy to manage their time, they became deskilled, and as a result, were less invested in the production process.

Simmel contended that workers experienced a sense of disconnection in work that affected their identity and extended to their sense of self. The intensity of industrial life distracted and bombarded humans [1] to the point where they had no mental space for reflection and they withdrew emotionally from work and other aspects of life, including the natural world. The narrative of disconnection was later revisited by Marcuse [3] in "One Dimensional Man", which described how technological structures overwhelmed life, to the point where anything that did not fit the dominant technological worldview was squeezed out. In this setting, every thing and every person came to be viewed as a resource to be harnessed and operationalized. This created a situation where people were unwittingly trapped and consumed in their never-ending pursuit of a lifestyle, associated with technological progress, which was promoted through advertising and marketing.

Some, like Heidegger [9, 10], have asserted that technology has a particular character that determines these behaviors and it is so pervasive that retreat from technology is the only way to halt disconnection from the natural world, alienation from one's self and damage to the psyche. Heidegger argues that technology induces a mindset in which everything is seen as "standing reserve", a resource to be consumed, and the essence of things is lost or diminished by this mentality. This perspective implies technology is an external force that acts independently of society to determine particular behavior and values. It has since been shown that technology isn't acting alone in determining behavior but is heavily influenced by society [4–6]. Crucially this led to the possibility that digital technologies could be imbued with a different set of values, prompting alternative behaviors.

This chapter discusses research that explores the use of a critical approach to the design of digital technology for interpretation of gardens and the natural world in support of connection to place and non-human aspects of nature. In Marcuse's critique of technological society [3], he framed artists as outsiders, with the distance and perspective necessary to uncover and challenge the pervading conditions that limit human life. Some fields of art and design have become part of the (hegemonic) structures that perpetuate the cycles of desire that Marcuse criticized, exemplified by "affirmative design", which serves the needs of industry without challenging its structures [11, 12]. Critical design, by contrast, asks questions about society, its values and structures and critiques culture through the medium of design. This role has traditionally been the domain of art, so it has been argued that this pushes design toward artistic practice [12]. Dunne and Raby have been drivers of critical design, through projects such as Foragers, which asks questions about humans' futures in the time of food shortage and overpopulation [13]. In recent years speculative design and more specifically design fiction, which challenge the status quo or ask "what if" questions about potential futures that have gained traction.

This chapter describes work that is derived from the same theoretical roots as critical design but diverges in approach. Where critical design critiques society and speculates on futures through designed artifacts, the work discussed in this chapter attempts to design differently, within the parameters of the current world, by using a design lens that keeps the perceived problematic aspects of technology to the fore, while making conscious efforts to address these problems. This approach focuses on the implications of design process as well as design outputs.

The remainder of the chapter discusses practice-based research conducted by the author that explores the use of a critical approach to the design of technology in the context of environmental communication. The research which began as the lead author's thesis research [14] in 2013, and is ongoing as post-doctoral research, can be divided into three phases: a short initial phase of exploration and prototyping; a five-year collaboration with a team of gardeners at a National Trust property in Nottinghamshire; and development of thesis findings as a research strand within a program researching digital technologies and environmental change. The final phase has a primary focus on Morecambe Bay, Lancashire but its reach has expanded across North West England. The research marries the lead author's background as a Secondary School Geography teacher and a Higher Education researcher, lecturer and multimedia designer.

16.3 The Design Lens

The design lens draws on recurrent discourse found in critiques of technology, as well as themes that are specific to particular theorists. Some of the original arguments were made prior to the ubiquitous presence of digital technologies, though they retain their relevance. Describing all the design principles and the theories that underpin them is beyond the scope of this chapter, but the following example shows the development of the design lens.

16.3.1 Technologies, Things, People and Context

One of the starting points is that technologies differ substantially in character from non-technological "things." Devices, (Bormann's term for technologies) [15–17], are designed to be ubiquitous, so they can easily be used anywhere. The assets they provide are foregrounded, while the controlling mechanisms are hidden away. Without much thought or effort, they become absorbed into the background of our lives. The freedom devices bring comes with a hidden cost. Devices are (intentionally) detached from their context, in order that they can be used anywhere, by anyone but this means they are not rooted in a culture and its values [15–18]. Technological devices are a means of accessing/unlocking resources, be they reserves of fuel or information and as a consequence, they frame everything as a commodity to be consumed. Heidegger calls this “standing reserve” [9] and he believed that this lens prevents us from seeing things in their own right.

By contrast, it is argued that (non-technological, handmade) “things” provoke a different response, because a thing is of its world and is connected to that world by a myriad of social, historical and material threads. Things are indebted to the people, place, environment, history, culture, knowledge and traditions that brought them into being and continue to sustain their life [19, 20]. When humans encounter a thing, they are momentarily “interrupted” by it. They pause to notice and reflect on it and the world that brought it into being. They see the thing in and of itself [20]. Where technology’s lens reveals everything to be a raw material to be harnessed by humankind, in an ongoing, never-ending process, things illuminate the world that surrounds them. Things are seen through their use, but technologies ultimately disappear in their use [19]. Spinosa and Dreyfus [21] suggest that if technical devices could behave more like other “things”, humans could be drawn into a positive relationship without themselves being turned into a standing reserve and losing their capacity to be world disclosers. World disclosers [22] is a term used by Heidegger to describe how things in the world become meaningful through everyday human practices. Equipment has a purpose and when someone uses the equipment for the given purpose, it gives an identity to that person [23]. Hence peoples’ identities and sense of self are tied to things and practices.

16.3.2 Focal Things and Focal Practices

This connects to the concept of focal things and focal practices [15, 16]. The term derives from the word “focus”, which formerly referred a hearth or fireplace, which Borgmann used to illustrate the concept [15]. In the past, a fire was the focal point in a home, and people were brought together around it. It was the focus around which families gathered, shared news, told stories, played games and connected with one another. Maintaining the fire took effort, exertion and learned skills, from cutting and collecting the wood, to cleaning the hearth and setting the fire. The fire and its activities create sensory experiences, from the smells of the burning wood to the feeling of creeping warmth around a room or muscles fatigued from using an ax to split logs. Focal things like fires form a point of convergence for family and community life, and a social world revolves around them. The world is increasingly revealed, as the focal practice is habituated.

This is contrasted with technologies which require minimal effort, skill and engagement [15, 16]. Switching on a central heating system does not provide the same level of engagement and heat distributed through radiators allows a family to spread out across different rooms. Central heating gives the liberation of privacy and instant heat, at a cost.

16.3.3 Commoditization

Feenberg [4, 5] suggests that there are ways to challenge the tendency toward technological de-worlding that results in wholesale commoditization. Rather than stripping away to reduce something to a raw material (termed Primary Instrumentalization), he advocates incorporation of the social into the technical so that technologies reveal more than commodity. Secondary Instrumentalization integrates the social environment, through systemizations that disclose connections to the world, and valuative mediations that provide space for societal values to inform designs.

In pre-industrial times when things were made in the place where they were used, the production networks were short and local cultural values and priorities were integrated and carried through production. In more recent times, technical networks involved in making digital devices are longer, often spanning the globe, and so the societal and cultural meanings and values that ground things and give them meaning beyond that of commodity may be lost along the way [5]. That said, longer production networks potentially involve more people and present increased opportunities for social interventions [5].

Feenberg argues that more voices are needed in the design process to represent a greater range of values and counter the control exerted through technical systems, a concept he called democratic rationality [4, 5]. From this perspective, technologies need to be open enough that they can be shaped or reconfigured by users to reflect their priorities. In this way the social is inevitably part of the design.

16.4 Using the Critical Lens to Establish Design Guidelines

Turning theory into practical guides to shape design is subjective because different designers will interpret and emphasize the theory in different ways. This subsection presents some selected design guides from the author's interpretation of the theory above.

Technological devices require little effort and skill so *designs should be effortful and encourage skill development.*

Traditionally technology designers have determined what a design is and how it is used. This potentially reinforces power inequalities and excludes the input of users who will be affected by design choices. So, technologies *should be flexible enough for wider society and users to influence and reshape designs.*

Technologies slip into the background offering easy access to commodity which means there is no pause for interruption and reflection, so we lose sight of things, their world and ourselves. Consequently, *designs or design process should create pauses and interruptions that nudge people into noticing things afresh and attending to them with more intent.*

Digital technologies don't require deep engagement or connection to community or place so *digital technologies should support focal practices and integrate social dimensions.*

Technologies have been criticized for creating distance and abstraction. *To counter this, designs should be rooted in context by, for example, medium, materials, processes and values. In order for a design to connect to its world, production networks need to be short to stay close to local culture and values.*

Sensory stimuli connect people to the world of a thing. Smell, touch and taste are particularly associated with the immediate body space surrounding a person, so they are associated with immediacy and intimate connection. In contrast, visual stimuli are believed to create a sense of distance, between the seer and the seen [24]. Hence *designs should encourage more intimate experiences and activate multiple sensory receptors.*

16.5 Artifacts

These and other criteria informed the design of a series of objects for personal use and for interpretation of a public garden, including the *Nature Meditation Egg*, the *Rhubaphone* and *Audio Apples* [14, 25–28].

The *Nature Meditation Egg* (Fig. 16.1) was the first artifact made within the initial exploration and prototyping phase. It was designed for personal use by the lead author to explore the relationship between theory and practice in her role as designer–researcher. The *Nature Meditation Egg* was designed to encourage its user to notice the natural world. This involved the user audio recording the non-human

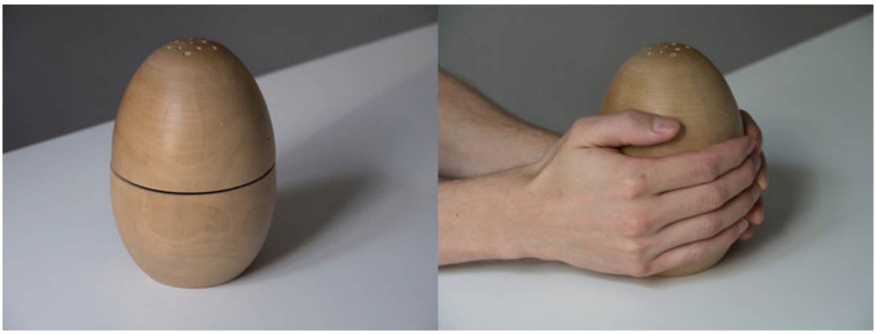

Fig. 16.1 Nature Meditation Egg. Image copyright © J. Lindley 2015 and reproduced by permission

world on a walk in their local area. During meditation, the user would hold an egg-shaped wooden object which contained a sensor, microprocessor and audio player. When held with focus for a period of time, the audio from the walk would begin to play. The aims were to stimulate memories of the outdoor experience with the audio, and through the act of recording and listening draw attention to the natural world at a fine level of detail. The wooden egg was turned from local wood by a local joiner, though the digital components were manufactured elsewhere.

The *Rhubaphone* and *Audio Apples* were made as digital hybrid interpretation for a public walled kitchen garden, to encourage people to notice it in new ways and support connection to place. The *Rhubaphone* (Fig. 16.2) was created to bring to attention the individual cultivars in the National Rhubarb Collection, grown in the garden. The *Rhubaphone* held stems of rhubarb side by side so that differences in size and color were more obvious. Holding a stem activated an audio recording about that variety, its history and cultural significance made by the Head Gardener. The smell of the cut rhubarb and touch of the stem added extra sensory layers to the experience.

The *Audio Apples* took people into an Apple orchard, that held part of the Regional apple tree collection, but the design also spoke to the past and present of the garden, through audio stories, diary entries, audio recollections and poems recorded by gardeners and volunteers (Fig. 16.3). The wooden *Audio Apples* hung from branches encouraging visitors to step off the path to reach and pluck them from the tree. Once plucked the different voices of gardeners and volunteers "spoke" to the visitors, through a variety of different kinds of recordings, intended to light a spark in the listener.

The *Rhubaphone* and *Audio Apples* used wood from the site and the apples were turned by a member of the team. The heritage of the garden was incorporated through motifs that referenced the garden's past. The design process was shaped to fit the working patterns in the garden and seasonal shifts within the garden. The iterative design process involved feedback and reflections from the *Gardens team*, and later in the collaboration, a volunteer learned to maintain the digital interpretation artifacts

Fig. 16.2 The Rhubaphone in use. (Left) Image copyright © A. Johnson 2015 and reproduced by permission. Rhubarb cultivars. (Right) Image copyright © L. Edwards 2019

Fig. 16.3 Audio Apples in use. (Left) Audio Apples in the orchard. (Right) Image copyright © L. Edwards 2015

and ultimately began to develop content and new ideas. Hence ownership over the artifacts started to shift from researcher–designer to the *Gardens team*. The software used was open source so that code wasn't locked down and could be adjusted or completely rewritten. Content was stored on SD cards that were familiar to people from everyday use in cameras and phones. This meant people working in the garden could control content with only limited technical expertise. Where possible components were used that could be replaced to extend the life of the design or uncoupled by the team to create new designs. However, through the iterative design process it was found that pre-made boards incorporating microprocessors and sensors were more robust and easier for laypeople to manage. The design and development of these interpretation artifacts is expanded upon in Edwards [14].

16.6 Reflections on the Digital Nature Hybrid Designs

Responses to the interpretation and its impact on visitors, volunteers and staff were collected through interviews, field notes and observations. The lead author (in her role as designer–researcher) made notes reflecting on design iterations as part of a research through design [29, 30] approach. She participated in the life of the garden and documented and reflected on experiences, conversation and observations in relation to the underpinning theory and practice in notes, audio recording and images made on site, or after visits. The effectiveness of the designs, in conforming to design criteria was evaluated with reference to these reflections as well as theory-driven thematic analysis of interviews with the *Gardens team* and visitors.

The digital interpretation was positively received. Many visitors commented that they had not previously realized there was more than one variety of rhubarb or they hadn't thought about rhubarb varieties. One of the gardeners said that the process of creating the *Audio Apples* helped the team realize the value of their stories, and also let them see how their colleagues experienced the garden. Both *Audio Apples* and

Rhubaphone prompted a pause in people's passage through the garden, where they stopped and attended to the installations.

The multisensory digital artifacts used touch, smell and sound to encourage a sense of intimacy with the artifact and place. The design criteria resulted in a particular aesthetic, that emphasized materials from the site. It produced technologies rooted in place and not easily used elsewhere. For example, the *Rhubaphone* incorporated heritage varieties only grown in the garden. Once cut, the rhubarb would begin to wilt and over time it would be unusable. This meant the *Rhubaphone* could only be used properly within the range of the garden, a characteristic that prioritizes the local and particular.

Overall, the designs cohered with the design lens and had strong contextual relevance. The design processes were a product of place, fitting daily and seasonal patterns in the garden, and respecting the routines and practices of the team. At some points during the collaboration, design and maintenance activities were carried out in a shed in the garden in order to stay connected to the place and enable ongoing input from gardeners and volunteers. This was a response to Feenberg's comments about the benefits of short production networks [5].

Material, software and technological choices were made with the gardeners and volunteers in mind. The question of what would be compatible with their working practices and what they might be able to use independently was kept in the foreground when making design decisions. This enabled a transition toward designs that were initiated by the team, though the team members who managed the digital interpretation artifacts felt more time was needed to build skills to gain more control of the software. The fact the designs were open meant their content could be driven by the team from the ground up, so that their priorities were centered. Stories and content could emerge from the garden.

The interfaces and interactions were described as "fun" and "novel" and they interrupted users, as intended, triggering memories and prompting questions. The use of "actual rhubarb" brought the *Rhubaphone* to life.

16.6.1 Challenges Arising Through Use of the Critical Lens

Although the unfamiliarity of the interfaces caused people to pay attention, it also created barriers to use. The *Audio Apples* definitely didn't slip easily and effortlessly into the background and this was off-putting for some visitors and therefore potentially problematic for the organization.

The technologies were designed to reveal the world of the garden, its values socially, historically and culturally but there were tensions as the interactive installations could be critiqued as turning the things in the garden into commodities to be consumed by visitors. This conflicts with the aims of the design lens.

The digital interpretation artifacts responded to many of the criteria drawn from the theoretical lens, but they didn't achieve some of the objectives in relation to nurturing connection to place. The digital interactions created a pause, but often this was fleeting and superficial and didn't require enough active engagement from participants to really prompt reflection on place. They didn't offer many opportunities for the kinds of extended, embodied engagements that create sensory surprises and experiences which change relationship to place and build emotional connection.

16.6.2 Response to the Challenges Arising Through Use of the Critical Lens

The *Nature Meditation Egg* was designed by its user (the lead author) and the process of designing, creating and using the egg added to a richer understanding of place. The relationship to place was stimulated by the act of design. The process required effort, skill acquisition and significant time spent in a natural environment, which are some of the characteristics of focal practices.

These insights from the *Nature Meditation Egg* about how the creative process prompted reflection and seeded rich emotional relationships to the land influenced the next phase of work. The realization that the act of designing the artifacts unlocked understanding of place resonated with Heidegger's writings about the nature of humans as world disclosers, who illuminate worlds through practices and make visible the conditions on which things in the world depend. Making artifacts or stories in the garden required the creator to give time to the process and attend to the place. It involved sensory and experiential engagements that prompted emotional connections and a relationship to place. It isn't possible to control placemaking because relationships to place are individual and intangible but there is an argument that some conditions are conducive to nurturing connection. Active engagement appeared to play a significant role, and this insight echoes findings from earlier environmental education projects like *Ambient Wood* [31].

Reflecting on the initial *Digital Nature Hybrid* artifacts drove a new research phase about how digital technologies might support active engagement and exploration toward greater awareness of and connection to non-human nature and environments. This led to the inception of the *Digital Naturalist* program, which began in the public garden where the original work took place but has subsequently been further developed in a range of settings.

16.7 Digital Naturalists

The *Digital Naturalist* program comprises a series of workshops that combine arts activities, with digital making, computer programming, nature walks and fieldwork activities to reveal new perspectives on a place and rekindle naturalist skills. Currently, there are two workshops in the *Digital Naturalist* program, *Digital Boggarts* and *The Lost Sounds*. The program builds on the insights gained from the *Digital*

Nature Hybrid artifacts. The pilot project (*Digital Boggarts*) which began in 2016 extended the collaborative work with the National Trust gardeners and with writers who had developed content for the *Audio Apples*. The second project (*The Lost Sounds*) has run in multiple locations across the North West and Midlands with a variety of audiences.

16.7.1 Background

The number of amateur naturalists has declined with successive generations [32] and children spend less time playing outside ranging across smaller territories than in previous generations [33]. Consequently, less than a quarter of children regularly use their "local patch of nature", which is half the number in their parents' generation [34]. The *Digital Naturalists* workshops were designed to explore how digital technologies might be used to stimulate more sustained and effortful interactions in natural environments, with particular attention to sensory awareness. The workshops slow people down in order that they spend time in a place, while the activities aim to tune people into noticing details. The nature walks are led by local experts from environmental organizations in order to raise awareness of local groups. Participants may be more likely to get involved with these groups, as a member or volunteer, if they have made personal contact with someone in the organization.

In the program, digital technologies are used to help people experience the natural world afresh by revealing things that may be otherwise hidden and by supporting the acquisition of traditional skills that bring a new perspective on the natural world. The aim is to inspire a new generation of amateur naturalists and citizens who have increased awareness of their local environments.

Thinking through making is used to focus attention, consolidate knowledge and reflect on a place. The modular structure enables the workshops to be adapted for the specific contexts and audiences. Versions of the workshops have been created for formal and informal education and public engagement settings.

As the workshops have progressed, the importance of sharing the knowledge and products resulting from the workshop, through an exhibition, has become more apparent. The exhibition extends the reach of the program to the wider community beyond workshop attendees and also presents opportunities for workshop participants to act as/or be experts.

16.7.2 Digital Boggarts

Boggarts are folkloric creatures, like hobgoblins, that are often associated with a particular location, for example, the Farndale Hob from North Yorkshire [35]. In effect they are spirits of a place. Traditional tales about Boggarts can be found across the United Kingdom making them a useful conduit for talking about place, nature and history across the country. The pilot project, *Digital Boggarts*, drew attention to microclimates and planting within a public garden, and the spirit or feel of the place experienced as a result of these factors (Fig. 16.4).

The project/workshop offered an opportunity to explore a small part of the garden in detail and build an intimate personal relationship with it. This study of a garden at micro level threw into relief the contrasting character, (or spirit) of differing areas within the garden to make these places present to the workshop participant. The Digital Boggart was a manifestation of the kind of creature that might live in that microclimate, a response to the question "Who would live in a place like this?"

At first a wilder setting might seem more suitable than a formal, managed public heritage garden, but many people in the UK have access to a private or communal garden or yard, and gardens are often the most immediate point of contact with non-human nature. The public garden was far larger than a domestic garden but the scale made it easier to identify different microclimates. One of the aims was that participants might start to notice the microclimates and the spirit of different areas within their own gardens or communal spaces. Another aim was to encourage new visitors to the public garden.

Twelve children aged 9–10 from a primary school located close to the public garden took part in the 1.5-day workshop, some was delivered in school, while the major part was delivered in the garden. In school, prior to the garden visit, the children learned to program Micro:bit computers to sense temperature, humidity and direction. The day in the garden began with a guided walk and mapping activity, led by gardeners. This was followed by time exploring the garden with sensors to identify microclimates.

Using information collected in the garden as inspiration, the children worked in groups with a writer to make a fictional story about a Boggart that lived in an area of the garden. They performed the story in the garden and made an audio recording. The children created Boggart creatures from clay, beans, seeds and materials found in the garden, so that the character was rooted in the garden. Each Boggart was given a digital dimension in the form of a Near Field Communication (NFC) tag embedded

Fig. 16.4 Images from the Digital Boggarts workshop: sensing humidity, story making and a Digital Boggart incorporating Near Field Communication tag. Image copyright © A. Darby 2019

in its body. When the Boggarts were placed on top of upturned flower pots (that housed hidden NFC readers and speakers), the story created by the group played aloud. In effect, the children created a piece of artistic digital interpretation inspired by their experiences and exploration in the garden. Interpretation is commonly used within museums, heritage sites and cultural organizations as a kind of communication that happens in conjunction with direct, firsthand visitor experience. Traditionally, it presented the voice of the expert, in a range of forms but there has been a move toward a more collaborative approach to include more voices alongside that of the trained, experienced interpreter [36, 37]. The idea behind this is the inclusion of excluded histories and the recognition of multiple perspectives on place. Back at school the children made a display of their interactive *Digital Boggarts* to share stories of the garden with their wider community.

16.7.3 The Lost Sounds

The Lost Sounds encourages people to pay attention to the birds in a place through their calls and songs (Fig. 16.5). The name has a twofold meaning. It refers first to the increasing number of birds on the International Union for Conservation of Nature “Red List” of species at risk of extinction. In 2015, 67 of 244 species were on the Red List, compared with 52 species, 6 years before in 2009 [38, 39]. This includes birds such as the Curlew, Nightingale, Merlin and Mistle Thrush. As their numbers decline, their songs and calls are lost to our localities and over time they fade from consciousness. *The Lost Sounds* is as much about the lost skill of recognizing birdcalls and the songs that are “lost to us” (as the number of amateur naturalists decline) as it is about the loss of particular species.

Fig. 16.5 The Lost Sounds interactive birdcall prints. (Left) Image copyright © L. Edwards 2019. The Lost Sounds mini exhibition. (Right) Image copyright National Trust Images 2019 and reproduced by permission

The Lost Sounds [40] has been run in formal education settings at primary schools and a nursery and informal education settings including community festivals and events run in partnership with environmental organizations/charities.

It was originally designed for children in Year 5 targeting Key Stage 2 learning outcomes in computing, art and design, design technology, music and science. It has since been adapted for children in Year 3 and 4, nursery children and family groups. It is also being reconfigured for after school Code Clubs as a way of blending natural history and environmental science into the program. We anticipate compatibility between the structure of Code Clubs and Digital Naturalist workshops that may inspire the development of additional workshops.

The workshop has a similar structure to the *Digital Boggarts*, involving time spent outside, combined with arts and technology. Specifically, the project includes a guided nature walk, birdwatching, sound recording and editing, listening skills, printmaking, circuit building and computer programming with Scratch running on Raspberry Pi. As before, the aim is to build naturalist skills including careful observation and listening. The full workshop takes 2 or 3 days but shortened one-day and drop-in versions of the workshop have been run in settings where the longer format is unfeasible. This necessitates a smaller range of activities, but the workshop always involves art with technology.

Ideally the workshop begins with a guided walk led by a bird expert or expert in the local environment, but in extreme weather timings may shift. Participants watch for birds with binoculars and take turns with a shotgun microphone and digital audio recorder to listen and make recordings at intervals on the walk. The aim is to use the digital equipment to tune people into their environment and make them more aware of the birdcalls around them. The directional capability of shotgun microphones helps participants to isolate the calls of individual birds, but they don't require the same degree of precision as parabolic microphones. Sight is the dominant sense for most humans [24, 41–43] while sound is omnidirectional and dynamic making it less precise and harder to locate without a visual cue. Locating sound can require practice and effort. Using the microphone gives the holder a temporary "superpower" of enhanced hearing that makes it easier to notice sounds that are initially unfamiliar. As one becomes able to identify individual calls, it is easier to pick them out without the microphone.

After the walk participants draw one of the birds found in the area from pictures, sometimes a bird they have seen or heard. The aim is to look carefully and closely observe the detail of the bird. The drawings (etched into foam) are turned into prints, made with conductive ink. In shorter workshops, participants are taught to recognize selected calls and then pin their print to an interactive sound sculpture, which plays the call of the bird when the print is touched.

In the full workshop, participants either edit their own recordings or the ones made available under a Creative Commons license. They make a circuit with a capacitance sensor attached to the input and output pins of a Raspberry Pi computer and learn to program it to play appropriate calls when prints are touched.

After these workshops, the participants' prints and edited audio are transferred to an installation comprising: Bare Conductive Touch Boards, speakers and fabric print of a location visited during the workshop. The installation acts as a mini exhibition of the outputs of *The Lost Sounds* workshop and it encourages involvement from the wider community beyond workshop participants, (for example, parents and other pupils in a school, or National Trust visitors or local residents). The interactive soundscape installation has been designed in a form that is easy for external partners to manage.

16.8 Reflections on Digital Naturalists

Both strands of the *Digital Naturalist* program, *Digital Boggarts* and *The Lost Sounds* have been well received by participants, host organizations, teachers and parents in all settings. Focused time spent in place, and time spent reflecting on non-human nature is built into the design of the program, so this inevitably results in a more significant experience for participants than that created by digital nature interpretations alone.

The combination of arts, computing and outdoor experiences is particularly potent because the digital technologies like the audio recorders enable the participant to experience the environment differently and reveal things that it would otherwise be harder to sense. The digital technologies don't supplant the traditional noticing skills but awaken them, whether that is noticing sunny and shady parts of a garden or using directional microphones to pick out the sounds of individual birdcalls. The digital technologies are intended to encourage people to spend time outside in a focused way. This doesn't have the value of habitual focal practices, but it does require effort while also contributing to skill acquisition that can change a person's relationship to a place and potentially their relationship to technologies.

Creative practices require different kinds of engagement. The drawing encourages the participant to look carefully and notice the difference and the printmaking asks people to think about the character and signs that communicate the essence of a bird species. To write the *Boggart* stories, people have to think imaginatively about the space which goes beyond recalling facts. The story outcomes may start from jumping off points in a world that is close to the reality of the garden and then shift into realms of fantasy, but both have an impact on the memory of the children and the connections they make to the garden. A translation occurs as the participants turn what has been shared with them into something that they own, and that process involves the investment of the participants.

The layered activities provide different hooks for individuals. Some respond to the making activities, while others are drawn to computing, but the combination is intended to make each activity more appealing to a wider audience. The intention is to consider how this interdisciplinary approach affects perceptions, particularly of technology, computing and environment.

One of the most significant outcomes has been the impact of the sound installation that creates a mini exhibition of project work. These have been left in schools or National Trust properties for days or weeks after a workshop to open the project out to wider audiences who did not participate directly in the workshops. In schools, teachers and children talked about the pride of showing their creations to others and sharing the birdcalls they had learned. The fact that the fabric image was of the place where they had spent time outside birdwatching and recording also made it more meaningful. Showing the work to others in the community, for example, at Community Days can start conversations about birds in the area and how to get involved with projects to protect their habitat.

The role of environmental and creative experts is also a key feature of the workshop design. Local environment experts reveal what is hidden or unnoticed and when this is paired well with technologies that also make the invisible visible (or audible), they complement each other powerfully. Creative experts like writers or printmakers introduce ways of seeing that may also unlock new dimensions of non-human worlds. These inspire the active engagements that build care for the non-human world. The creative activities create a space for conversations and questions about ecology and action. Beyond the participants, the workshops bring together organizations and individuals with different competencies who have an interest in the environment, and this has the potential to strengthen networks and seed collaborative action.

The design criteria used at the outset emphasized that the designs should fit the place in which they will be situated. In the earlier *Digital Nature Hybrid* interpretation, this included using materials from the site and designing artifacts with the local team. This presents a challenge for the *Digital Naturalists* workshops because they move from place to place. For example, the materials for the exhibition stand cannot come from the location unless the stand is continually remade.

Nevertheless, the *Digital Naturalist* workshops have been designed to give prominence to place and to respect individual contexts. For example, the *Digital Boggarts* incorporate materials from the garden in which the *Boggarts* "live". The fabric backdrop for the *Lost Sounds* is reprinted with a site-specific photo for new workshop locations. Working with experts from a site and planning the activities with partners who know the location well is another way of ensuring that care for the place is embedded, and that the use of digital technology is appropriate. The combination of arts, outdoor activities and computing is important because at different times each pulls place into focus. That means there is a tension when the shortened versions of the workshops are run because an element is lost that may weaken the connection to place. However, the shortened workshops have prompted bookings for the longer workshops.

One of the ways that *Digital Naturalists* responds well to the original design lens is that the workshops encourage attention, endeavor and the development of skills. The commitment required in time and effort makes these engagements potentially more meaningful than the brief encounters with the *Digital Nature Hybrid* interpretation. In both cases, the participant's intent and motivation will affect their experiences.

16.9 Conclusions

Technology has been criticized because of its instrumentalizing tendency, and the implications of that tendency, for example, the increasing separation of humans from non-human nature that results in a lack of care that puts the environment under threat. It also includes the impact on humans' sense of self and well-being. By responding to the criticism directed at technologies through design criteria that referenced the criticism directly, the projects aimed to refocus and reshape priorities and design processes. The simple act of setting the criteria was important for foregrounding the questions, "How are we using digital technologies?" and "What impact is this having on humans and non-humans?"

One of the significant impacts of this lens was the cascade created by prioritizing individual places and rejecting the idea that "one size fits all." Attending to place meant the design process had to respect local ways of working including the rhythms of the place, for example, seasonal and daily working patterns. This in turn influenced digital technology choices and other material decisions which ultimately influenced physical designs and sensory interactions. By attending to place within the design process, the designer–researcher (lead author) became more connected to the places in which she designed. This led to the insight that making in a place and in response to a place could foster a connection and a realization which drove the second phase of research.

The initial *Digital Nature Hybrid* designs went some way to revealing places and showing non-human nature in a new light. It demonstrated how digital technologies could be rooted in context and culture and how they could amplify particular sensory stimuli to resonate with the sense of place. This in itself had value, for designers, organization and visitors.

However, the engagements with the *Digital Nature Hybrids* were brief and too superficial to prompt significant change or connection, unless the people concerned were already primed for change or connection. Analyzing the limitations of the *Digital Nature Hybrids* with respect to the design criteria showed that effort, focus, skill and social connection that made focal things and practices meaningful were less present in the *Rhubaphone* and *Audio Apples* and so the question of how to build in these attributes became central to the second phase.

The subsequent projects created deeper, richer encounters with natural environments and showed the power of combining artistic activities with technological activities. The activities required participants to use their technologically amplified senses and creative skills to attend to and reflect on the world.

Using technologies to kindle traditional skills and practices shows one way that technologies might contribute to re-energizing the culture of amateur naturalists and nurture care for non-human nature.

Acknowledgements The work would not have been possible without partners and participants in schools, arts and environmental organizations. I would particularly like to thank the gardeners and volunteer gardeners at National Trust who contributed to this work.

References

1. Simmel, G.: The Metropolis and Mental Life. Blackwell Publishing, Oxford (2004)
2. Frisby, D., Simmel, G.: Key Sociologists, 2nd edn. Routledge, London and New York (2002)
3. Marcuse, H.: One Dimensional Man: Studies in the Ideology of Advanced Industrial Society. Routledge & K. Paul, London (1964)
4. Feenberg, A.: Transforming Technology: A Critical Theory Revisited. Oxford University Press, New York (2002)
5. Feenberg, A.: Between Reason and Experience: Essays in Technology and Modernity. MIT Press, Cambridge, MA (2010)
6. Feenberg, A.: Critical Theory of Technology. Oxford University Press, New York (1991)
7. Kahn, P.H.: Technological Nature: Adaptation and the Future of Human Life. MIT Press, Cambridge, MA (2011)
8. Kahn Jr., P.H., Severson, R.J., Ruckert, J.H.: The human relation with nature and technological nature. Curr. Dir. Psychol. Sci. **18**(1), 37–42 (2009)
9. Heidegger, M.: The Question Concerning Technology, and Other Essays. Harper & Row, New York (1977)
10. Heidegger, M.: Only a god can save us: the Spiegel interview (1966). In: Sheehan, T. (ed.) Heidegger: The Man and the Thinker, pp. 45–68. Routledge, London and New York (2017)
11. Dunne, A., Raby, F.: Critical design FAQ [Online]. http://dunneandraby.co.uk/content/bydandr/13/0
12. Gonsher, L.: Beyond Design Thinking: An Incomplete Design Taxonomy [Online]. http://www.cd-cf.org/articles/beyond-design-thinking/
13. Dunne, A., Raby, F.: Designs for an overpopulated planet: Foragers (2009) [Online]. http://dunneandraby.co.uk/content/projects/510/0
14. Edwards, E.: Designing contextually relevant digital interpretation for a public garden, HighWire Centre for Doctoral Training, Dept. Computing and Communications, Lancaster University, UK (2019)
15. Borgmann, A.: Technology and the Character of Contemporary Life. University of Chicago Press, Chicago (1984)
16. Borgmann, A.: The moral complexion of consumption. J. Consum. Res. **26**(4), 418–422 (2000)
17. Borgmann, A.: Orientation in technology. Philos. Today **16**(2), 135–147 (1972)
18. Borgmann, A.: Reality and technology. Camb. J. Econ. **34**(1), 27–35 (2010)
19. Edwards, J.C.: The thinging of the thing: the ethic of conditionality in Heidegger's later work. A Companion to Heidegger, pp. 456–467 (2005)
20. Heidegger, M.: Building dwelling thinking. Poetry, Language, Thought, vol. 154 (1971)
21. Dreyus, H.L., Spinosa, C.: Highway bridges and feasts: Heidegger and Borgmann on how to affirm technology. Man World **30**(2), 159–178 (1997)
22. Heidegger, M.: Being and time. A Revised Edition of the Stambaugh Translation. Suny Press (2010). First published (1927)
23. Spinosa, C., Flores, F., Dreyfus, H.L.: Entrepreneurship, Democratic Action, and the Cultivation of Solidarity: Disclosing New Worlds. MIT Press, Cambridge, MA (1997)
24. Rodaway, P.: Sensuous Geographies: Body, Sense and Place. Routledge, London and New York (2002)
25. Edwards, E., Coulton, P., Darby, A., Chiasson, M.: Planting and tending digital-nature hybrids in a walled kitchen garden. Des. Issues **33**(3), 65–78 (Summer, 2017)
26. Edwards, L., Coulton, P., Chiasson, M.: The inclusions afforded by a value-led design process for technology-nature hybrids in a walled kitchen garden. In: Proceedings of 11th European Academy of Design Conference, Paris, France (2015)
27. Edwards, L., Coulton, P., Chiasson, M.: Walking off the garden path: a design journey. In: Proceedings of Research Through Design Conference, Cambridge, UK (2015)
28. Edwards, E., Coulton, P., Chiasson, M., Darby, A.: Growing an interpretation ecology in a walled kitchen garden. In: Proceedings of the 2014 Companion Publication on Designing Interactive Systems. ACM, Vancouver, Canada, pp. 65–68 (2014)

29. Frayling, C.: Research in art and design. R. College Art Res. Pap. **1**(1) (1993/94) [Online]. http://researchonline.rca.ac.uk/384/3/frayling_research_in_art_and_design_1993.pdf
30. Durrant, A.C., Vines, J., Wallace, J., Yee, J.S.: Research through design: twenty-first century makers and materialities. Des. Issues **33**(3), 3–10 (Summer, 2017)
31. Rogers, Y., Price, S., Fitzpatrick, G., Fleck, R., Harris, E., Smith, H., Randell, C., Muller, H., O'Malley, H.C., Stanton, D. et al.: Ambient wood: designing new forms of digital augmentation for learning outdoors. In: Proceedings of the 2004 Conference on Interaction Design and Children: Building a Community. ACM, pp. 3–10 (2004)
32. Moss, S.M.: Natural Childhood. National Trust, London (2012)
33. Louv, R.: Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. Algonquin Books, New York (2008)
34. Pretty, J., Angus, C., Bain, M., Barton, J., Gladwell, V., Hine, R., Pilgrim, S., Sandercock, S., Sellens, M.: Nature, childhood, health and life pathways. Interdisciplinary Centre for Environment and Society Occasional Paper 2009-02. University of Essex, UK (2009)
35. The Farndale Hob [Online]. http://www.farndalefamily.co.uk/Other/The%20Farndale%20Hob.htm
36. Silberman, N.A.: Heritage interpretation as public discourse: towards a new paradigm. In: Marie-Theres, A., Bernecker, R., Britta, R. (eds.) Understanding Heritage, pp. 21–33. DeGruyter, Berlin (2013)
37. ICOMOS: The ICOMOS charter for the interpretation and presentation of cultural heritage sites. Technical Report. International Council on Monuments and Sites, Charenton-le-Pont, France (2008) [Online]. http://icip.icomos.org/downloads/ICOMOS_Interpretation_Charter_ENG_04_10_08.pdf
38. Hayhow, D.B., Burns, F., Eaton, M.A., Al Fulaij, N., August, T.A., Babey, L., Bacon, L., Bingham, C., Boswell, J., Boughey, K.L., Brereton, T., et al.: State of Nature 2016. The State of Nature partnership (2016) [Online]. https://www.rspb.org.uk/globalassets/downloads/documents/conservation-projects/state-of-nature/state-of-nature-uk-report-2016.pdf
39. Eaton, M., Aebischer, N., Brown, A., Hearn, R., Lock, L., Musgrove, A., Noble, D., Stroud, D., Gregory, R.: Birds of conservation concern 4: the population status of birds in the UK. Channel islands and Isle of Man. British Birds **108**, 708–746 (2015)
40. Edwards, E.: The Lost Sounds (2019) [Online]. http://www.thelostsounds.org/
41. Tuan, Y-F.: Space and Place: The Perspective of Experience. University of Minnesota Press (1977)
42. Lewis, N.: The climbing body, nature and the experience of modernity. Body Soc. **6**(3–4), 58–80 (2000)
43. Ingold, T.: Culture on the ground: the world perceived through the feet. J. Mater. Cult. **9**(3), 315–340 (2004)

Part VI
The Use of Virtual Reality and Augmented Reality to Extend Creativity, Reach, and Engagement in the Arts

Chapter 17
Virtual Reality Holography—A New Art Form

I. Pioaru

Abstract Virtual reality holography (VRH) is a new art form that synthesizes the qualities of traditional hand drawing with the unique features of holography and virtual reality (VR) art. As a new art-making tool, it offers the possibility to develop artistic ideas and concepts that could not be materialized with any other medium, whilst from a practical point of view it has the unique ability to showcase VR artworks external to VR space, without the need for a headset. Starting with a brief historical overview of holography art and VR art, this chapter presents an exploration of the VRH medium and the artworks which were generated. The various contexts in which these artworks are disseminated are presented, and the dialogues arising from the material specificity of VRH as a new medium are discussed. VRH is envisaged to extend the reach of audience engagement.

Keywords Virtual reality holography · Digital holography · New media · Virtual reality art

17.1 Introduction

Virtual Reality (VR) art-making tools have become increasingly popular amongst artists. However, VR art is still far from ubiquitous, mainly because of the high cost of purchasing a VR system and the space required to run it. At the same time, VR artworks are fundamentally difficult to view or exhibit outside of VR, as they have a functionality that makes them impossible to reproduce in any other medium without losing some of their essential features. For example, 3D printing, due to its particular constraints, only allows for a relatively narrow range of models to be produced [1]. Online galleries which allow the viewer to explore VR projects using a standard monitor, flatten the three-dimensionality of VR artworks, as is the case with any 2D representation of a volume [2].

I. Pioaru (✉)
Wrexham Glyndwr University, Wrexham, UK
e-mail: ioanapioaru@geola.eu

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_17

Digital holography, despite its own limitations, can constitute good support for VR imagery, offering a high fidelity of representation and preserving the most important properties of such imagery.

The advantage of bringing together these relatively new media is that it allows an artwork produced in VR to be displayed and viewed easily in either a public gallery or a private space, by a much larger number of people simultaneously, without the constraint of requiring viewers to wear a cumbersome headset in order to preserve the 3D appearance.

17.2 Overview of Holography as an Artistic Medium

In simple terms, a hologram is a photographic recording of a light field, on either film or glass, resulting in a seemingly 3D image which can be seen with the naked eye. Holography can be either analog, when it captures something which exists in reality, or digital, when it displays computer-generated objects or scenes. Both types of holograms require a special, dedicated illumination system in order to be viewed, in the absence of which they appear as dark, indistinct, flat surfaces. There are a number of techniques and optical illusions which are commonly and mistakenly referred to as 'holography', such as Pepper's Ghost or various stereoscopic and lenticular displays. Although holography practitioners will reject these as mere tricks, the general public is perhaps more familiar with such techniques than with holography itself, due mainly to the fact that they are often employed in funfairs, in theatre and in other on-stage acts. Arguably the most notorious use of Pepper's Ghost was Tupac Shakur's virtual appearance at Coachella Valley Music and Arts Festival, in 2012, alongside Dr. Dre and Snoop Dogg [3].

Although primarily a scientific field, holography has a significant potential for being used as an art medium and, as a consequence, the domain appeals equally to artists and scientists. Since its invention by Denis Gabor in the 1940s, holography has drawn the attention of a number of artists, amongst whom Salvador Dali is perhaps the best known [4]. Many of these artists have dedicated their career to the medium of holography, for example, Margaret Benyon [5] or August Muth [6], whilst others have tried to incorporate it in, or add it to, their existing practice, as in the case of Moysés Baumstein.

Catalogues, photographic documentation and generally any type of literature on holography don't really do justice to a medium that doesn't lend itself easily to 2D reproduction. However, articles on holography written by practicing artists, curators or critics are useful for understanding how holography was, and is, perceived and experienced first-hand.

Two volumes of the *Leonardo* art and science magazine dedicated to holography art [7] comprise numerous interviews and articles where holography art practitioners amongst whom Margaret Benyon, Andrew Pepper and Paula Dawson express their dissatisfaction with how the art world receives their work.

Perhaps the most striking concept that comes from these texts, and others written later, is that holography and the art establishment still don't feel comfortable with one another. The medium of holography has encountered constant criticism and dismissal from the art establishment. The main points made against it being vulgarity of colours, awkwardness of display and lack of a proper critical and conceptual vocabulary. This is revealed by D. Tulla Lightfoot in a study titled '*Contemporary Art World Bias in Regard to Display Holography*' [8], where the author interviews several curators and directors of art galleries in New York, seeking to understand their views on holography art and how they justify the constant rejection of this medium by the establishment. The main conclusion of the study is that major museums and galleries don't necessarily dismiss the medium itself—they base their rejection on the status of the artist, claiming that, if an artist who has previously gained recognition by working with other media decided to take up holography, they, the art venues, would not hesitate to show their work. If this is the case, one might infer that holographers simply face the same problems as any other artist approaching a venue seeking representation; with the added difficulty of having chosen a medium that hasn't really managed to prove its aesthetic or conceptual value, as yet.

Nevertheless, there seems to be an ongoing struggle amongst holography practitioners to be accepted and valued or sometimes even considered by major art venues, in spite of long years of sustained efforts and obvious developments, both in the field of holography as a whole and within the individual practices of different artists. During a presentation at the International Symposium for Display Holography 2018, August Muth, one of the most successful artists working with holography today, confessed that when approaching a gallery to propose a collaboration, he simply steered away from using the word 'hologram' in reference to his artworks. This was to avoid the immediate negative reaction and consequent rejection which are usually triggered by the mere mention of this word.

It must be acknowledged that the medium still has glaring deficiencies and limitations that make holographic artworks unconvincing and could be the reason for recurring negative responses. For example, common limitations mentioned are brightness and colour balance, the complexity of arranging good replay illumination, blurring in the rear of a scene, vertical non-uniformity of colour, digital pixelization and the lack of a good archival quality photographic recording material.

Perhaps one of the reasons why many attempts at making holography art have failed, is that the practice of holography bears no clear line of demarcation for where the science ends and where the art begins or vice versa. In order for a holographic product, and any new media artwork to be successful from both points of view—technical/scientific and artistic—this distinction needs to be acknowledged and embraced.

Some of the most successful examples of holographic art come from practitioners who have understood the importance of limiting the role of the artist and that of the scientist in order to allow each of them to contribute optimally in this equation.

A collaborative approach between artists and scientists is needed to enable the two fields to intersect in a successful way that leads to further progress. New media often come with the temptation to use their novelty and specificity as an objective in itself. As a result, practitioners with a background in art are unable to produce artworks of satisfactory technical quality, whilst technicians or scientists with no artistic background, seduced by the visually enticing qualities of the media, produce trivial objects of no real artistic value. When working with a difficult medium such as holography, it is important that both the artists and the scientists understand the limits of their knowledge, and by using each other's expertise and providing constant feedback, work together towards taking the technology to a level that allows it to be acknowledged by the establishment.

17.3 Virtual Reality Art

To clarify the terminology, VR art is a type of artistic content *created* directly inside the VR environment using an application designed specifically for the purpose of art-making, and not computer-generated content *presented* in VR.

VR art-making applications such as Tilt Brush or Gravity Sketch are impressive tools for creating digital 3D imagery, offering great new possibilities for art and the creative industries. They stand out amongst other VR applications due to the fact that they allow users to *generate* virtual reality content, rather than simply *consuming* it. This unprecedented combination of painting and sculpture, not bound to physical laws, with its lack of spatial limits and highly intuitive interface, offers a very satisfying immediacy that materializes gestures instantly.

With its impressive variety of brushes often accompanied by special visual and sound effects, Tilt Brush was designed with the intention of offering the user not just art tool but a fully immersive VR experience, entertaining in and by itself. On the other hand, Gravity Sketch, with its focus on creating geometry in the VR environment, has proved a real game changer by providing a level of editability and precision much superior to Tilt Brush, features which appeal greatly to design-oriented creatives. More recently, the team behind the VR animation tool Tvori aim to create a powerful, immersive and intuitive tool for crafting visual stories, which anyone can use, regardless of their previous experience with either 2D or 3D animation [9].

Currently an increasing number of artists have expressed their interest in this medium and have started adding VR art-making to their 'tool box'. However, because VR art is still in its infancy, and also because of the difficulties associated with showcasing these productions outside of VR space, the works realized in this medium are only accessible to the wider public via online 2D galleries [2].

17.4 The Creation of a New Artistic Medium

The most important achievement of holographic imagery and what truly differentiates it from other media is its capacity to visually expand space without resorting to the traditionally accepted convention of treating a 2D surface as an interface for 3D content. In seeking to redefine maximalism as a type of art which uses a minimum amount of space to deliver a maximum amount of information or content, holography becomes a good example of an efficient use of the 'space of art', in the sense that it employs a flat surface to display a volume, rather than the actual 3D space usually taken up by a physical object or scene.

17.4.1 'Van Gogh by Pioaru'

By using this unique quality of holography in conjunction with VR art, there is an opportunity to not only bridge the gap between the virtual and the real, but also to develop a new form of art that could be unique in itself.

Therefore, a digital hologram was created from a VR artwork. The project was implemented using Google Tilt Brush and an HTC Vive headset and, since it was a reinterpretation of a Van Gogh self-portrait, it was entitled 'Van Gogh by Pioaru'.

In order to transfer a VR project onto a holographic format (and, to my knowledge, the first time anyone had attempted such a transfer), attention was focused principally on the technological aspects of the process, and the choice of subject was a secondary consideration.

Part of the process of transferring the VR project to holography consisted of using the FBX file format for exporting the scene. However, due to various software incompatibilities, only the volumes were imported from TB into 3ds Max, whilst the colour and texture information was lost. This meant that the scene had to be recolored in 3ds Max. In addition, when imported, the brush strokes were reduced to plain, ribbon-like meshes. All this resulted in significant differences between the original VR scene and the final hologram, which was printed using a commercial digital holographic printer from the data set (Fig. 17.1).

17.4.2 'Spectral Figures'

In spite of all technical difficulties, Van Gogh by Pioaru was a promising first step. The artwork was well received at a public demonstration. However, there were some constraints and these were addressed in a follow-on project, 'Spectral Figures' which made adjustments to the limitations of the transfer process. This consisted of a series of black and white portraits of artists and philosophers (Fig. 17.2). These were drawn in black and white in order to reduce the risks associated with recoloring the scene (described in the previous section). In order to maintain a degree of similarity to the models, several photographic portraits of the subjects were imported into Tilt Brush. These were sourced online and taken from different angles, and used as reference images for the artworks, with the objective of building into the models the correct volumetric structure. Thin black strokes were used set against a white background in

Fig. 17.1 A snapshot taken in Tilt Brush (left) and a photograph of the final hologram (right). Copyright © I. Pioaru 2019

Fig. 17.2 'Spectral Figures' series—a collage of snapshots taken in Tilt Brush. Copyright © I. Pioaru 2019

order to simulate the characteristics of drawing on paper. As a consequence, possibly the most striking aspect of the resulting images is that, although effectively they are sculptures, every viewing angle gives the illusion of a 2D line drawing [10].

This decision brought the project a step closer to a preferred artistic media, i.e. drawing, and particularly to 'sculptural drawing'. This is a concept which has been approached in several recent projects and it refers to expanding the characteristics of drawing to create sculptural objects, as part of an exploration of the boundaries between 2D and 3D imagery. Figure 17.3 is a visualization of a project which best illustrates this concept: Insectarium, 2012—a sculptural drawing installation—followed by two close-up photographs (Figs. 17.4 and 17.5) of one of the boxes which make up the installation.

Fig. 17.3 'Insectarium' by Ioana Pioaru—sculptural drawing installation, 2016. Copyright © I. Pioaru 2019

Figs. 17.4 and 17.5 'Insectarium'—sculptural drawing installation, close-up. Copyright © I. Pioaru 2019

The pipeline for creating a hologram from a VR project is relatively straightforward. In order to generate the image data required by the digital holographic printer for a single-parallax hologram, the VR project needs to be exported as a Filmbox (FBX) file—a feature initially implemented into Tilt Brush to allow artists to share their creations online. This is a format that makes it possible for digital content to be manipulated across a variety of digital creation software. The incompatibilities between Tilt Brush and 3ds Max were addressed by simplifying the scene and using a minimum of colours—effectively just black and white. This reduced the time of post-processing significantly, the main remaining task being the setup of the camera for image rendering. This is achieved by programming an automated camera in 3ds Max, a process described by David Brotherton-Ratcliffe and Hans Bjelkhagen in their book 'Ultra-realistic Imaging' [11]. This method produces the required perspective views that can be pixel swapped to generate the data necessary for the digital holographic printer.

The data was sent to Geola for printing on their digital holographic printer and a series of 30 cm × 40 cm colour reflection holograms was produced using a silver halide emulsion. The holograms, when properly illuminated, produce a good impression of the original VR subject (Fig. 17.6).

Digital holograms may generally either be 'Full-Parallax' or 'Single-Parallax'. 'Single-Parallax' holograms are also sometimes referred to as 'Horizontal-Parallax-Only' holograms. In general, the 'Full-Parallax' hologram is to be preferred as it presents the most general and most faithful 3D experience of the original light field to the viewer. The viewer will be able to see both to the left and to the right of an image, as well as properly perceive the image from above and below. The viewer will also be able to approach the image and observe it from close-up; in brief, a

Fig. 17.6 'Spectral figures #4', single-parallax hologram (three photographic views). Copyright © I. Pioaru 2019

full-parallax hologram will relatively faithfully reproduce the original 3D light field from the active side of the hologram.

Single-Parallax or Horizontal-Only Parallax holograms remove the vertical parallax from the light field. As the viewer moves their head up and down, the 3D image will appear to simply tilt up and down. Since human eyes are horizontally separated, this type of hologram still looks very realistic to most people. The tilting of the image is fairly well accepted by the viewer and interpreted as a natural movement of the image itself. The largest drawback with single-parallax holograms is that the viewer cannot approach too closely to the hologram without image distortion becoming excessive.

There are several advantages of the Single-Parallax hologram. The first is the digital image data is usually some hundreds of times smaller than the data required for full parallax holograms. This means that whilst single-parallax holograms can be calculated on a normal laptop or PC, full-parallax holograms often need either a reasonably large network of PCs or a small supercomputer. The second principal advantage of the single-parallax hologram is that it can be illuminated much more easily than the full-parallax hologram leading to brighter images and deeper in-focus scenes.

Nevertheless, full-parallax holograms stand out as being far superior in that they convey the 3D reality of the drawings in a much more efficient and successful manner. The missing vertical parallax is in the single-parallax holograms acts to destroy the illusion of the image integrity that these sculptural drawings seek to embody. The single-parallax holograms are brighter and they can be illuminated by arrays of lights, making them potentially much brighter than the double parallax holograms. However, this does not really compensate for the critical loss of the vertical parallax.

Fully un-apertured double-parallax holograms, giving the maximum field of view, is useful if the hologram is to give the best illusion of reality, printed on Silver Halide material. However, this may inevitably lead to a relatively poor brightness at replay, even when powerful LED lights are used for illumination. Improving this brightness is an important ‘next step’. Potentially, photopolymer could be used instead of Silver Halide, but a few companies are currently offering this choice. Other solutions would be to use more powerful laser diodes for the illumination. The best possible result would be expected if dichromated gelatin glass plates were to be used in the printer.

17.4.3 Tilgate Forest

The starting point of this project was a homonymous ink drawing first created in 2018. This was an opportunity to explore a theme that was different from previous VRH artworks, which had been exclusively portraits. In addition to this, since the landscape is rather underrepresented in holography this choice of theme seemed likely to produce an interesting result.

A photograph of the original was imported into Tilt Brush to use as a reference image (Fig. 17.7).

Fig. 17.7 Tilgate Forest by Ioana Pioaru, original ink on paper drawing, 2018. Copyright © I. Pioaru 2019

Several factors identified in the initial drawing pointed to the possibility of structuring a 3d model of this scene as a *diorama*: the way in which the elements of the composition are clearly individualized, grouped and layered at varying depths; the relative difference in scale of these elements; and the amount of graphic detail used for rendering each layer. Thus, whilst drawing the scene in VR, the composition was distorted by making objects in the distance much smaller and closer to the main viewpoint than they would be in an accurate scale model of the real landscape. Figure 17.8 shows the scene from the main viewpoint and Fig. 17.9 shows what it is as seen from above.

The compressed depth also offered several advantages holographically, primarily that of limiting the angular resolution required to resolve the rearmost parts of the scene. This is a particularly important consideration in light of the fine brush strokes employed. Another advantage is geometric: due to the 'window' nature of a hologram, scene components nearer the glass are viewable from a wider angle of view before being obscured by the edge of the hologram. Thus, compressing the scene makes the compositional layout more robust to viewer movement.

The use of the brushes roughly followed the same method employed for previous projects, in that the sense that the brush used for the white areas had to be different from that used for the black areas.

The resulting 'sculptural drawing' was close enough to the original ink drawing and quite convincing as a 3D depiction of a landscape, in terms of the parallax effect. However, pure black and white images such as 'Spectral Figures' and 'Tilgate Forest' represent particularly challenging subjects for holography, straining its capabilities with respect to brightness and colour balance. Additionally, whilst the maximum angular resolution of digital holography itself is state of the art (thousands of views),

Fig. 17.8 ‘Tilgate Forest’: snapshot taken in Tilt Brush. Copyright © I. Pioaru 2019

Fig. 17.9 ‘Tilgate Forest’: scene viewed from above. Copyright © I. Pioaru 2019

current replay illumination techniques reduce this by an order of magnitude. As a result, although the depth compression used in ‘Tilgate Forest’ was an effective illusion in its own right, it was insufficient to fully mitigate the blurring imposed on the background of the scene. This somewhat compromised the pen-drawing appearance, the very fine brush strokes seemingly blending together to create a charcoal-like effect (Fig. 17.10).

Fig. 17.10 'Tilgate Forest': photograph of the hologram. Copyright © I. Pioaru 2019

17.4.4 Heterotopia

The project titled 'Heterotopia' is also based on an earlier work, a two-colour reduction linocut print, part of a larger series (Fig. 17.11). This combined architectural structures and pseudo-realistic machinery, in the 'techno pop' style characteristic of recent art practice, where the stark, rigid appearance of the machines and buildings contrasts with the rawness and vividness of the colours and the cartoon style. Gravity Sketch seemed much more appropriate a tool, as it offers the features necessary for achieving this type of imagery: the possibility to generate and edit basic shapes and volumes, a certain degree of precision and perhaps most importantly, a grid and world axes/coordinates system that the objects can be aligned to.

As the original artwork was a flat, frontal representation of the architectural/'machinic' structure, adding depth was the first obvious step necessary in the creation of the 3D model of the subject. Consequently, a roof-type surface and a lateral wall were constructed and filled with graphic detail, so that in the hologram, the roof—an element that is not conceptually essential to the composition—would be revealed and concealed by the viewer moving their head up and down. The added lateral wall was intended as a 'transition area' combining architectural features with 'machinic' details (Fig. 17.12).

The post-processing necessary to prepare the data for the holographic printer was different and much more complex than those required by previous projects, and was therefore done in collaboration with Tal Stokes from Geola Technologies, whose knowledge and expertise were essential (Fig. 17.13).

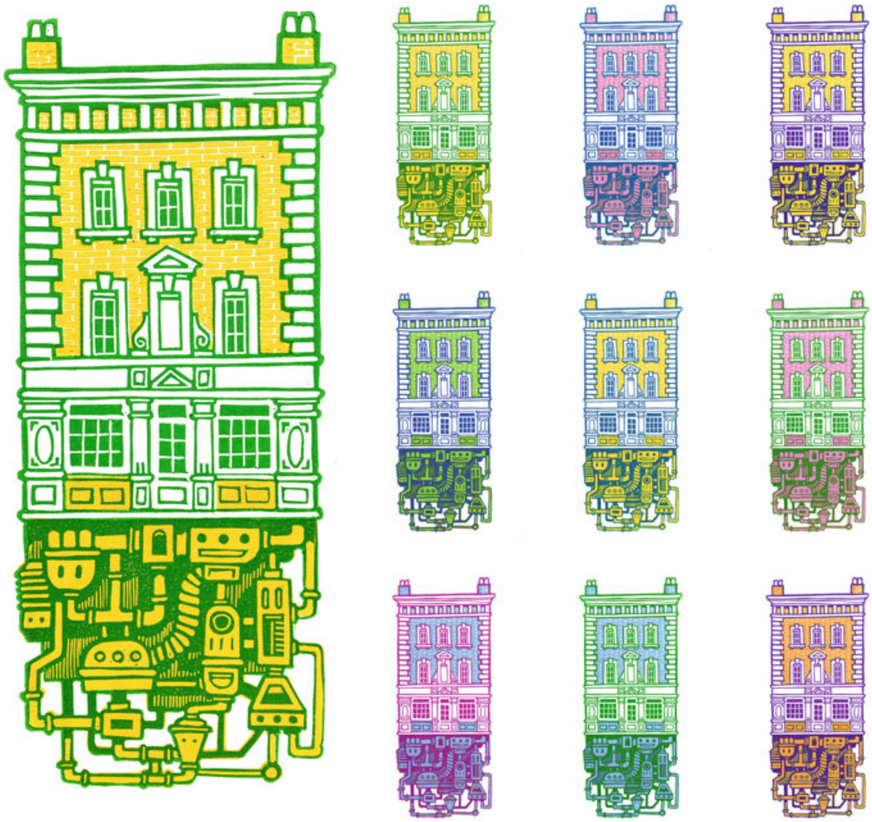

Fig. 17.11 'Heterotopia' series: first print (left) and colour permutations digital mock-up (right). Copyright © I. Pioaru 2019

17.5 Presenting Virtual Reality Holograms to the Public

The 'Van Gogh by Pioaru' hologram was first presented in 2017 at the Cyberworlds International Conference in Chester. During the 2018 Focus Wales Festival, it was on display in one of the exhibitions organized at the Ty Pawb Gallery in Wrexham.

The 'Spectral Figures' VRH series was presented for the first time at the 11th International Symposium for Display Holography which took place in Portugal in 2018. On the same occasion, it was part of the holography exhibition held at the Museum of the City of Aveiro, titled 'Art in Holography: Light, Space and Time' [12]. In 2019, during the Artists' Open House event held within the Dulwich Festival, 'Spectral Figures #1' was exhibited together with some recent artworks made in other media.

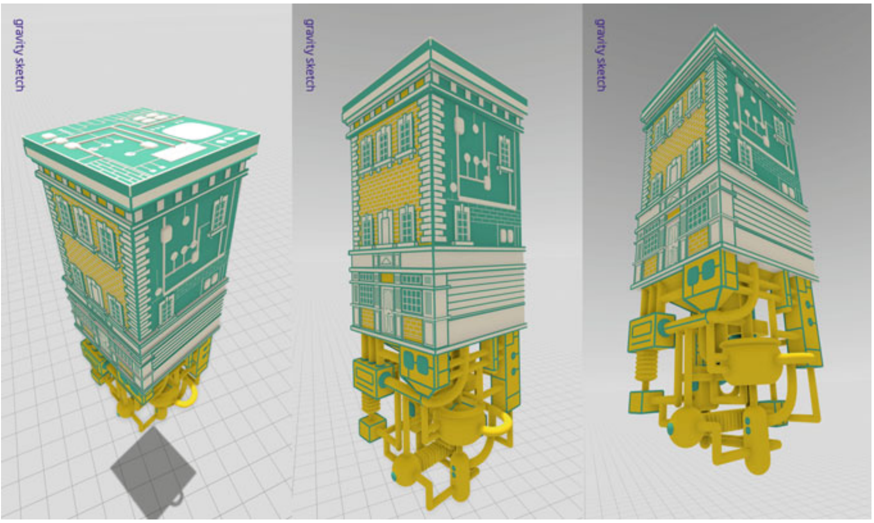

Fig. 17.12 'Heterotopia': collage of three views of the Gravity Sketch model. Copyright © I. Pioaru 2019

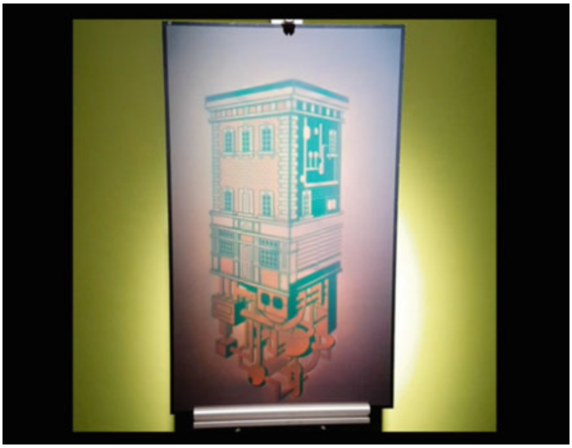

Fig. 17.13 'Heterotopia': photograph of the hologram. Copyright © I. Pioaru 2019

'Tilgate Forest' and 'Heterotopia' were presented at the SPIE Photonics West conference which took place in San Francisco in February 2019, together with one of the pieces from the 'Spectral Figures' series.

On each occasion, the work was well received both by the general public and by artists and scientists attending the events and was deemed highly innovative, particularly the concept and method of combining traditional drawing with the medium of digital holography.

In August 2019, a selection of the VR holograms will be included in a group exhibition which will look at the artistic drive being immersed by the image, organized at the Centre for the Holographic Arts in New York.

17.6 Discussion

For artists and researchers interested in ultra-realistic imagery, it may be important to understand how these relatively new art-making media, holography and virtual reality sculptural drawing, which share the ephemeral nature of their content, can be employed together and how they can highlight and enhance each other's potential.

Major companies developing VR technology are striving to make their devices and products more affordable, lighter, wireless, more intuitive and to offer the possibility to swap between AR and VR. This will inevitably impact on how artists make, experience, and understand art. On the other hand, it may not be necessary to find ways of 'exporting' productions of VR to other platforms, simply because the best way to experience them will be *inside* VR. Nevertheless, due to the challenges and difficulties associated with such ambitious projects, VR technology is still far from ubiquitous.

In this transition period, it is therefore relevant to examine how the intrinsic gap between the virtual and the real can be bridged. As a stage in developing Tilt Brush, Google has recently initiated an Artist in Residence programme [13], emphasizing the importance of an active collaboration between artists and scientists in understanding what steps are necessary to take VR art-making to the next level. Because of this, many artists are expected to use VR as an instrument to develop their practice, and this highlights the need to find ways to exhibit their creations.

VR holography is currently dependent on commercial digital holographic printing services. These services take the processed VR data set and generate the physical hologram. Perhaps the main problem for the practicing VRH artist today is that commercial holographic printers usually print on plastic film. To achieve the flatness required for the display of the artwork, this film must be laminated onto either a plastic or glass sheet using an optical glue. Unfortunately, even if the visual result is usually excellent using this technique, the process itself is associated with poor archival properties. This is a significant problem for the artist and indeed for the wider art collecting industry. The situation is slowly changing in this respect and digital glass hologram printers are starting to appear. In the EU, Geola, in addition to offering large holographic prints (up to 1.5 m $\times$ 1 m) on film now offers a service for printing some types of smaller glass holograms (up to 15 cm $\times$ 15 cm) on photoresist. The Centre for Ultrarealistic Imaging at Glyndwr University in Wales is also planning on recommissioning its large glass printer (capable of printing up to 1.2 m $\times$ 1.2 m) later this year.

Another problem with commercial holographic printing is the availability of small hogel sizes. Currently, Geola offers a 0.8 mm hogel with its film printers although its new glass service can in principle goes down to 100 microns. 'Hogelization' or the visual pixelation caused by larger hogel sizes is a distracting feature in the context of VR holographic art. It is a particular problem with full-parallax holograms where the nature of the image invites the viewer to view the artwork from all distances including from very close proximities. Reducing the hogel size by a factor of two does however increase print time by a factor of 4. And with a 30×40 cm $\times$ 0.8 mm hogel hologram usually printing in around 3–3 h, commercial printers are not keen to reduce the hogel size dramatically. Nevertheless, technology is again coming to the rescue here with the latest generation of digital printers now forecast to offer printing speeds between 120 and 180 hogels per second—a significant improvement over typical current rates of 30 hogels per second.

A further problem encountered with VR full-parallax holography is image brightness. This is usually related to the preferred use of Silver Halide emulsions in the hologram printing industry. Sculptural VR drawings can be particularly susceptible to this brightness problem if there is too much white (or coloured) background and too few black drawing lines.

A way around the brightness issue is to use the technique of drawing with a white pen and a black background. This effectively routes the light energy available from the hologram into the drawing lines. Because the drawing lines usually occupy a much smaller solid angle in total than the background, the relative brightness of the lines can be much higher. Another effect of this technique is that when the hologram is switched on, the only thing which changes is the image lines appearing in front of a black background. This is in contrast to the case of drawing with a 'black' pen. In this case, when the hologram is switched on, the background changes from black to white. A further advantage of this technique is that hogelization should be less perceptible through the bright pen lines when compared to their perceptibility through a white background. 'White' is also the hardest colour to achieve in holography and large areas of white tend to often show up discoloration. Discoloration should be minimized by both the geometry and brightness of the lines.

17.7 Conclusions

The primary conclusion of this paper is that digital full-parallax full-colour holography provides an appropriate and useful means of visualizing 3D art created in VR. Whilst digital holography is not without its problems, it is currently the only medium that affords simultaneous group viewing of 3D virtual works without equipment such as glasses or head-mounted devices. This is an important consideration in the context of an art gallery. The artist should therefore be encouraged to consider its flaws as simply an inherent constraint of the medium and understand how to work with the medium and how to use it to its best effect. In this regard, VR holography is no different from any other medium. Perhaps the principal difference is the highly technical nature of holography and the burden that this places on the artist.

The next step is to present these VRH artworks in the context of an art gallery. Here they could be brought to the attention of a wider audience and also art experts who could assess their relevance within the landscape of contemporary art. Hopefully, the dissemination of VRH artworks would then result in more art practitioners deciding to work with it and finding it stimulating, useful and inspiring.

References

1. Fantasygraph, 3 Rules to avoid support structures when 3D printing (2016). https://pinshape.com/blog/dotm-fantasy-graph-3d-printer-support-structures/
2. https://sketchfab.com
3. Dodson, A.: The strange legacy of Tupac's 'hologram' lives on five years after its historic Coachella debut (2017). https://theundefeated.com/features/the-strange-legacy-of-tupacs-hologram-after-coachella/
4. https://spie.org/news/spie-professional-magazine/2014-january/dali-in-holographic-space?SSO=1
5. http://www.members.optusnet.com.au/mbenyon/index.htm
6. http://www.augustmuth.com/new-page
7. Journal edition dedicated to holography, Leonardo **22**(3&4) (1989)
8. Lightfoot, D.T.: Contemporary art world bias in regard to display holography: New York. Leonardo **22**(3&4), 419–423 (1989)
9. Feltham, J.: Tvori's latest update makes VR animation even better (2018). https://uploadvr.com/tvoris-latest-update-makes-vr-animation-even-better/
10. Short video showing the progress of one of the author's drawings in VR. https://www.instagram.com/p/BxRyXLfnN1K/
11. Bjelkhagen, H., Brotherton-Ratcliffe, D.: Ultra-realistic Imaging: Advanced Techniques in Analogue and Digital Colour Holography, pp. 357–368. CRC Press, Taylor & Francis Group, Boca Raton, London, New York (2013)
12. Video by Narcis Rovira of the artworks in the exhibition 'Holography: Light, Space and Time' and the Margaret Benyon retrospective. https://vimeo.com/277902286
13. https://www.tiltbrush.com/air/artists/

Chapter 18
In Darwin's Garden: An Evolutionary Exploration of Augmented Reality in Practice

Alan Summers

Abstract This chapter discusses the rapid developments in augmented reality and mixed reality technologies, from a practitioner's perspective of making the augmented reality sculptural work *In Darwin's Garden*. From its conception in 2012, to its exhibition at *Carbon Meets Silicon II* in 2017, the advances in augmented reality technology led to an interplay between the goal of the creators and the technological realisation of that vision. The art, design and technology involved, generated a reactive process that was mired in external influences as the accessibility to augmented reality became commercially valuable and subsequently restricted. This chapter will be of interest to anyone who wants to understand more about the possibilities, technologies and processes involved in realising mixed reality practice and about the commercial culture that supports it.

Keywords Augmented reality · Sculpture · Extended realities · Transmediation · Embodiment · Virtuality

18.1 Introduction

The artwork *In Darwin's Garden* was developed by the artist Chris Meigh-Andrews with the collaboration and assistance of Rowan Blaik, Head gardener at Down House, and the author, a design educator and researcher at the University of Chester, UK.

Chris Meigh-Andrews' art practice considers the resonance of place, by using moving image to discuss temporality and the relationships to space, of history and natural forces. He produces site-specific installations that examine spatio-temporality using technological devices. *In Darwin's Garden* explores the historical resonance of the old mulberry tree in Charles Darwin's home, Down House in Kent. The tree was there when Charles Darwin lived in the house and as Chris explained in an interview for the *Leonardo Electronic Almanac*:

A. Summers (✉)
University of Chester, Chester, UK
e-mail: a.summers@chester.ac.uk

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_18

> is a living link to the past, and through that connection there is a tangible nexus with the history of ideas, to science, and to the development of theories that have profoundly shaped our sense of what it is to be human [1].

The artwork comprises of two related works where the mulberry tree is central to the viewer's experience. In the first work, the three-dimensional structure and environment are digital; viewed on a screen or recently explored using a virtual reality headset. The second work is a physical sculptural form, with an augmented digital object at its centre.

The digital representation of the tree used in both works was formed from photographic imagery that included a year of time-lapse photography collected from four cameras placed in the garden of Down House. This body of time-lapse photography was the catalyst for the development of a digital 3D form. Chris Meigh-Andrews discussed how "*3D visualisation seemed a natural extension and progression from previous work, and deeply related to the fact that the mulberry tree is itself a growing, living organic structure*" [1].

The mulberry tree is now in decline and requires human intervention through the use of man-made structures to support the weaker branches (Fig. 18.1). *In Darwin's Garden* uses full-size facsimiles of these structures in both forms of the artwork. In the augmented sculptural form, these create a physical space that the digital tree inhabits and the viewer engages with this physical space, exploring the digital form within it. The collaborative challenge was how to implement this augmented reality sculpture, combining both digital and physical elements in order to facilitate an immersive experience for the viewer.

The completely digital form of *In Darwin's Garden* is a three-dimensional structure set in an environment that can be viewed on a web browser, and more latterly this has been explored using a virtual reality headset. Within a web browser, this work is viewed as a window into a digital space, seen as another reality. The viewer can move around this digital space using a keyboard or mouse, but their physical reality is separated through the implicit knowledge that the artwork is a reality contained within the screen. In a virtual reality format, the viewer stands in front of the structure with the real world expunged from their sight. Virtual movement is by a handheld controller but the viewer's body does not move due to hardware and safety restrictions. The virtual reality experience is exactly that, a virtual reality that disappears when the headset is removed and the viewer returns to the real world.

These web and virtual reality (VR) implementations, while effective in their own right, do not offer what the use of augmented reality (AR) brings to the experience. Part intention, part necessity, the AR version of *In Darwin's Garden* brings an embodiment to viewing the artwork that is worthy of independent discussion. The technical journey to this augmented realisation is also of interest as the technology's rapid development posed interesting questions of remediation across realities. This chapter discusses AR and its use within a project that combined physical and digital structures, theoretical notions of digital and physical space and also details of the technical elements of AR for art practice. There is also the relationship between practitioner and technology and the evolution that occurs over time, as both evolve

Fig. 18.1 The mulberry tree. Copyright © C. Meigh-Andrews 2019, reproduced by permission

while developing the project; that is an important thread running through this chapter. My background is in industry and education, with a design practice that researches the understanding of digital space and notions of place, often working with computer animation and game engines. The approach to this collaboration was from the aspect of both designer and researcher into the possibilities of digital realities. The development of AR was, and still is, resolving the design and theoretical language needed to discuss its application. In 2011 Papagiannis likened AR to early cinema

> …in its infancy, when there were as yet no conventions. AR, like cinema when it first emerged, commenced with a focus on the technology with little consideration to content, marked as secondary [2].

The rapid and continued development of AR means it will take time before there are clear artistic conventions, for as Pearson states technologies are "*not developed by the artistic community for artistic purposes but by science and industry to serve the pragmatic or utilitarian needs of society*" [3]. This is reflected in the artistic development of *In Darwin's Garden*, which was at the mercy of commercially focused technological developments. But, as Malina states when discussing art forms enabled by the computer, "*since contemporary culture is being driven by contemporary science and technology, one of the roles of the artist is as "coloniser" of the technology for artistic end*" [4]. Chris Meigh-Andrews stated this was an extension to his previous work—it was definitely an extension to my knowledge of designing commercial applications for digital realities—so with the artistic vision discussed, we set out to explore the possibilities for an augmented sculpture.

18.2 Augmenting Reality

To augment reality is to blend another reality with a person's physical reality, so both realities are perceived as a single seamless environment. In the most common and current context the phrase "augmented reality" is thought of as blending digital imagery with the surrounding environment. It is often discussed as a technological development and not as a theory of blending a different reality with the real world. The most identifiable forms of augmented reality are looking at a mobile phone screen and seeing digital objects blended with the live camera feed, or more recently using smart glasses that directly overlay the digital elements onto the user's field of view. Yet the theoretical concept of augmented reality relates to more than a modern digital development and has a broader historical context in art and design practice. There are studies of artworks from Hellenistic times that superimpose painted realities onto interior walls, in a form designed to create the optical experience of both artwork and real world as a single reality [5]. The scientific development of perspective during the Renaissance led artists to the development of trompe l'oeil, mixing real and painted realities. Neither trompe l'oeil nor digital augmented realities require the viewer to lose their sense of reality; both blur the optical boundaries between what is real and what is not.

Renaissance theories of perspective are important discussions for the future of AR as the Albertian perspectival system that actualised trompe l'oeil is still driving the Cartesian logic of today's computer space and subsequent digital realities. McGuirk and Summers argue that augmented reality technologies bring "*psychological and even philosophical concerns with regard to those [Renaissance] perspectival systems that underpin these technologies*" [6]. And recommend the investigation of other forms of perspective for AR such as ocular, floating-point or multi-perspective forms that are less Western specific. Artists do not rely solely on Renaissance theories of perspective, so it may now be time for the artistic "colonisers" of AR technologies to explore other theories for developing practice and as Papagiannis discusses, not just remediate the current contexts and forms of AR but break out from the current environment AR is discussed in [2].

18.3 Extended Realities

The discussion of augmented reality in its digital form must be understood in the context of other digital realities as technology continues to drive this area forward and create new forms. A catch-all term used for this area is Extended Realities, commonly abbreviated to XR. It refers to all forms of combined real and virtual environments including augmented reality (AR), virtual reality (VR) and mixed reality (MR). If a spectrum is considered, where a real environment and a completely virtual environment are at opposite ends, then the range in between these two endpoints is where realities are mixed in different ratios. This is Milgram's Reality-Virtuality Continuum [7], a concept to aid in the creation of a taxonomy for mixed realities. The possibility is that this range may not be discrete but continuous and it has since been extended in another dimension using mediality. In order to be clear for this discussion, we shall briefly consider what defines virtual, augmented and mixed realities.

Virtual reality is a completely immersive reality that replaces the user's real-world environment with a simulated one. A headset covers the user's eyes, headphones cover their ears, then visual imagery and audio immerse the user in a digital environment. There may also be elements of haptic feedback to enhance the immersion.

Augmented reality, in its digital form, is where the real world is overlaid with computer-generated imagery with the intention to create the illusion of a single seamless environment. In order to avoid limiting AR to specific devices, Azuma [8] stated three characteristics for AR:

1. Combines real and virtual;
2. Interactive in real time;
3. Registered in three dimensions.

These were written before mobile phones became powerful enough to run AR technologies and so were prescient in their thinking.

Mixed reality is where virtual objects can interact with real-world objects in a form where the user can act on either, or both, with them having an appropriate reaction. A mixed reality headset uses sensors to map the real objects and track their movements within the field of view so digital objects can appear attached to real objects. The headset can recognise hand movements and the user can manipulate a digital object as if it were in the real world.

Extended realities will continue to develop and so definitions may be redefined by future technological advances.

18.4 The Drivers Behind the Development of Augmented Reality

Compute-driven augmented reality was first explored in 1968 by Sutherland [9] but remained a specialist area until the early 2000s when increases in processing power in affordable mobile devices enabled AR to become a viable technology with which to engage users. The development of a variety of AR software development kits (SDK's) for mobile devices meant developing AR applications became steadily more accessible to anyone who understood a certain level of coding. Companies released SDK's free to developers, but this meant the developer was locked into that company's technology [10].

An alternative to using an SDK is the use of augmented reality browsers. Developers register with the browser company and can then create AR experiences by uploading digital files to the company's cloud service. The browser will then download these files to a user's device. This business model locks both developer and user to the specific AR company and their browser technology.

The use of AR browser applications has enabled graphic designers to create printed material containing images that play video or show three-dimensional objects when the reader uses the specific browser on their phone. With this development's ease of use, an array of print-based AR advertising was created as a way of attracting attention to products and appealing to mobile user's curiosity to try AR experiences. The monetization of AR as an advertising format instigated the development of an array of applications and SDK's and the developers of mobile devices took note.

Metaio GmbH was an augmented reality development company that started in 2003 and was used in the initial prototypes for *In Darwin's Garden*. They provided an AR web browser and development kit for programming AR applications for computers, web and mobile devices. In May 2015, it was reported that Apple had bought the company [11] and Metaio announced all products and subscriptions were to be discontinued. Developers using Metaio had to find another way to serve augmented reality experiences to their users before the deadline of December 2015. In September 2017 Apple released iOS 11, their mobile operating system for iPhones and iPads, that included support for augmented reality development. Their application programming interface (API), called *ARKit*, allows third-party developers to build augmented reality applications that can take advantage of the device's functionality and processing power. The hardware developers of mobile devices were now directly supporting the development of augmented reality on their products through their operating systems.

18.5 Augmenting Art

In contrast to the evolving monetization of AR, artists recognised the opportunities for their practice. In October 2010 Sander Veenhof and Mark Skwarek created the *WeARinMoMA* exhibition in the Museum of Modern Art (MoMA), New York. This was not an official MoMA exhibition, but as the exhibition's website states an invasion showcasing the "*radical new possibilities and implications Augmented Reality is bringing to the cultural and creative field*" [12]. Using the *Layar* augmented reality browser application [13], an Internet connection and the global positioning system (GPS) on their phones, visitors were able to see digital objects inserted into MoMA's gallery spaces. Since then this form of unauthorised intervention has resulted in a range of dialogues between artists and exhibition spaces, exemplifying the conflict and opposition to traditional conventions both Pearson and Papagiannis discussed [2, 3]. MoMA is still being used in this way with the 2018 *MoMAR project* targeting permanent displays in the museum for AR artwork interventions [14]. On the *WeARinMoMA* website, Veenhof and Skwarek added a cheeky "*PS The MoMA is not involved yet*" [12], and while MoMA has never responded they do now have at least one artwork in their collection that uses AR, Martine Syms, *Incense Sweaters & Ice*, 2017, [15].

18.6 *In Darwin's Garden*: Producing the Digital Environment

Production on *In Darwin's Garden* started with the web-based digital environment, as this was the less experimental production process. It was intended that digital elements from this web format could then be used in the creation of the second format, the augmented reality sculpture. Both artworks could be split into component parts of the tree and the supporting structure. The tree would be digital in both, but the supporting structure would be digital in the web format and physical in the AR format. The relationship between the component parts and their true to life scale to the viewer was deemed crucial to the experience.

> …the old tree is now in its decline, with man-made structures supporting some of its branches. We would like to make full-size facsimiles of these structures to use as a foil to the virtual image of the tree and develop a work that would enable visitors to explore the tree in virtual space and time—Meigh-Andrews [1].

The viewer of either experience should encounter a full-size tree and supporting structure. This should not be a perfect digital representation of the tree in three-dimensional space, as this would not carry the empathic connection of standing next to a living, dying tree. The viewer in this experience has to feel they are up close to a very specific mulberry tree, physically stepping around the framework supporting the old tree, getting close to the trunk and looking up through the canopy to the sky.

At the time production started there was experimental photo software, such as *Photosynth* [16], that could crowdsource photos of a landmark and then build a digital photo cloud simulation of the landmark from them. This approach was a precursor to photogrammetry, now used in the 3D scanning of real objects, where multiple photos are captured and the software extracts information from these to build an exact three-dimensional representation. An exact replication was not the intention for *In Darwin's Garden,* but a representative photographic form where the viewer builds their own mental image of the real tree through the photo cloud approach offered interesting possibilities. This format also had links to David Hockney's two-dimensional photo collages—referred to by the artist as "joiners"—but in a three-dimensional form that would be at the actual scale of the subject matter.

Using 3D modelling software, the tree structure was assembled as a photo cloud comprising of single planar shapes with a photo applied to each. These photo planes were arranged in such a way as to create the abstracted form at the scale of the real tree. The physical framework supporting the tree was modelled so as to link with the tree in a manner representative of the real-world site. The time-lapse images were placed as clouds of photo planes around the structure in locations that were spatially representative of the camera locations (Fig. 18.2).

The main technical consideration for this design approach was the quantity and quality of photographic images, more images equate to a larger file size and an increased download time. The photos included the time-lapse imagery meaning a single photo plane would contain 20 time-lapse photos, played in a looping sequence,

Fig. 18.2 The web-based form of *In Darwin's Garden*. Copyright © A. Summers 2019

and there were 20 photo planes for each of the four cameras. In 2012 the average speed in the UK was around 12.0 Mbit/s so the first version of the application at 86 Mb would take just over 1 min to download. This was considered to be too long.

To reduce file sizes, a consideration of how close a viewer will get to a single image was determined. It was expected that a viewer would be able to walk up to and into the lower areas of the tree structure. This meant that a single image in the lower section of the tree could fill the viewer's screen. Therefore, any image at this lower level must be the same resolution as the screen the viewer is using. A standard resolution, at that time, for playing a standalone application on a computer monitor was 1024 by 768 pixels.

Photo planes in the middle of the tree are at a height above the viewer's eye line so could be a lower resolution, as no single image will ever fill the viewer's screen. The photo planes at the top of the tree were bigger in scale, but fewer in number, in order to create areas of foliage and blue sky. These needed to be at the screen resolution as these would again fill the viewer's screen when looking upwards.

The author's previous design practice had explored the analysis of how trees move in the wind, applied to game environments, where wind and weather affected how a player interacts with an environment. Wind movement was explored for *In Darwin's Garden* using an algorithm to create a random direction and strength of the wind. Photo planes fluttered emulating foliage in the wind and added something to the presence of the tree structure, but it was considered too much of a simulation; ironically it did not feel natural in the digital environment. On testing it was left running over 24 hours, only to discover an issue in the wind algorithm meant that the photo planes moved imperceptibly over time. The whole tree structure would move across the space, effectively walking out of the environment. A key development point was to remember to leave each iteration running for a reasonable length of time, as it might in a gallery situation.

Experimenting with programming the photo planes to face the viewer meant that an element of movement was present but not overpowering. As the viewer moves, the photo planes overlap and intersect while rotating to face the viewer. This kept a sense of physicality and real-world movement within the abstracted foliage.

In its web-based form, *In Darwin's Garden* explores space and temporality surrounding the notion of place. The viewer can see Down House in the background locating them in the space of the garden. Within that space the tree's supportive frame is treated as a physical barrier the viewer must move around, while the photo planes of the tree offer no resistance to movement and the viewer can move through them. The photo planes containing the time-lapse imagery hold the location of the real time-lapse cameras making the viewer spatially aware of the image of the garden space and the real-world tree. This web version was finalised and uploaded to the IDG web site [17] and in August 2012 presented via Leonardo Electronic Almanac's digital media exhibition platform [18].

18.7 Producing the Augmented Reality

18.7.1 Production Process

At this point in production with digital assets assembled, the consideration of how to transfer the conceptual vision to an augmented reality experience began. Transmediation across forms of extended realities is not a direct process, as virtual reality offers complete immersion which brings greater levels of control over the viewer's experience than augmented reality, where the viewer can see their physical surroundings. The transmediation of *In Darwin's Garden* was not a simple transfer of digital assets; it meant overcoming technical issues while working with the dialogue between digital and physical forms, leading artist and designer on an explorative journey into the possibilities of augmented reality. Design enquiry alongside technical investigation is required for each of the component parts in an AR experience and this is a useful way to break down and reflect on the process. Those component parts are

1. Viewing Device: this runs the application and requires a screen and camera.
2. Augmented Reality Application: to be installed on the viewing device.
3. Digital Asset: to be displayed on the viewing device.
4. A Positioning Target: often an image but may also be a physical object or a GPS location that triggers and positions the display of the digital asset.

The principal for an AR application is that when launched it accesses the viewing device's camera, displaying the camera feed on the screen of the device. When the camera is pointed at a target image the application recognises this image and displays the digital object superimposed onto the camera feed. The digital object holds a fixed spatial relationship with the target image, so when the device is moved around the target image, the display shows the viewer to be moving around the digital object.

18.7.2 Viewing Device

The ability to position the work in any indoor or outdoor location was important for the development of *In Darwin's Garden*. In an indoor gallery, a viewing device can be supplied with a preinstalled application. Using a specific device means any application can be fully tested to ensure it works properly. Devices can be updated and interesting developments in technology, such as advances in augmented and mixed reality glasses, can be explored.

In an outdoor context, it is unlikely that a viewing device can be left securely at a site, so the viewing device has to be the mobile phone the viewer is carrying. The application will need to be developed for a range of devices and registered with the appropriate application stores. Downloading the application will be limited by the viewer's network transfer speeds and data allowance so its file size will be a factor in any viewing experience. If a person encounters the work outdoors and is not carrying a suitable device, the engagement with the sculpture will only be through its physical form.

18.7.3 Application Development

To use a pre-existing augmented reality browser would mean any viewer first has to download it from the Internet, then the digital object is downloaded while the browser is running. This is potentially the fastest development process and advantageously uses a proven and tested browser. But it brings in the extra stage for the viewer of dealing with the AR browser and its brand, which can act as a barrier to the process of engaging with the artwork. If an application is built specifically for the work it will contain all the information needed and is the only item to be downloaded. The disadvantage is that the application will need to be developed, tested and certified in order to be distributed by an application store. Also instructions on where and how to download any application must be visible near the installation. Augmented reality applications and SDK's for building applications are constantly being developed and improved upon but a useful starting point is *A Comparative Analysis of Augmented Reality Frameworks Aimed at the Development of Educational Applications* [19].

The decision was made to use the Metaio software tools to develop the augmented reality sculpture. This provided access to *Junaio*, a free mobile AR browser application for iOS and Android devices, along with software development kits for programming, PC, web and mobile augmented reality applications. The *Metaio Cloud* stored content online and the *Metaio Creator* software was a very good drag and drop creation system. Metaio also organised the *insideAR* conferences at the forefront of technological developments in this field. This suite of software gave flexibility in terms of choice of device, application development or a ready to use AR browser, and an offline or cloud-based approach. Metaio also supported the Epson Moverio BT-200 Smart Glasses that contain the processing power of a smartphone and the ability to superimpose the device screen upon the field of view of the user. These offered exciting possibilities for AR experiences so the development of the AR form of *In Darwin's Garden* began using Metaio tools, smart devices and Epson's Moverio glasses.

18.7.4 The Digital Object

There are various forms of digital object that can be displayed using AR; a two-dimensional graphic in vector or raster form, a video file, or a three-dimensional digital object which may be static or animated. Images, text and video are two-dimensional objects that can be mapped directly onto a target object to overlay it, or programmed to appear above it and always face the camera. A digital object might be "smart" meaning it can continually access device functionality, such as GPS location, to provide a constantly updated flow of information.

In 2013, AR advertising was starting to become more commonplace. AR was being used to play videos over car advertisements in magazines and to show digital replicas of the advertised car [20]. Three-dimensional objects can sit directly on or over the target object aligned to face a specific direction and also animated. A major factor in building digital objects to use in AR is file size. The larger the file size, the longer its download will be and the more likely the user will move on before the AR experience gets started. In the web version of *In Darwin's Garden,* the size of the digital asset for the tree was 36 Mb; this meant a minute or more download time over a 3G mobile network. To explore file size options different iterations of the digital asset were created by adapting the number of photo planes, the resolution of the photos and the number of time-lapse images in each animation. The augmented experience required a level of transmediation led by file sizes also considering a viewer's accessibility to an Internet connection, the viewing context in terms of location, and the active engagement with the augmented reality experience.

Firstly, the time lapse images were relocated to be in the tree structure amongst the images of foliage. A physical reason for this was the viewer might not be able to walk across a gallery in order to see the images as in the web version. Importantly they were now embedded in the experience of the tree, like fruit amongst the foliage. The viewer could recognise that some photo planes contain a sequence of landscape images as opposed to images of tree foliage. These became objects that draw the viewer into the digital space, so that they move in the real world around and through the physical framework. An interesting time-lapse image is where a portrait of the artist appears because Chris Meigh-Andrews was working on the camera as it took a photo, this creates the chance that a viewer will encounter the artist within the AR experience.

In the augmented experience, the backdrop photos of the house were removed because they show a fixed landscape behind the digital tree that is not there within the real-world context; this would break the viewer's immersion. Instead the view only holds the digital tree and behind it the viewer's actual location appears, situating this digital form in the real landscape with the support structure. This means other viewers can be seen as part of the view, situating them in both the digital and physical realities, and true to scale against the digital tree (Fig. 18.3).

18.7.5 Target and Positioning

The most basic problem that limits the immersiveness of an augmented reality experience is that of registering the digital asset correctly over the target [8]. Advances in the technology, needed to register a digital file in the correct position and hold it there, have made a huge impact on user immersion in extended realities. Early AR systems relied solely on images, known as fiducial markers, with the developer registering each target image to display an appropriate digital file. The markers placed in the

Fig. 18.3 The augmented digital tree structure seen to scale. Copyright © A. Summers 2019

environment were often black and white block patterns which could be distinguished in terms of direction to the camera and angle of view. These attributes could then be used to place the object on the target image with the correct spatial and perspectival relationship to the camera. Developments in image processing and camera resolution in mobile phones has meant that photographic images can now be used as targets, although contrast and asymmetry in a target image are important in order to calculate direction and angle of view.

Another positioning system used is the device's global positioning system (GPS). This is reliant on the efficiency and stability of the GPS signal and limitations occur for indoor locations where GPS information may be hard to determine. If GPS tracking is unstable then small changes in location can make the digital object appear to jump around in front of the viewer.

Metaio, then subsequently Apple's *ARKit*, can use an object as a target. This requires the AR application to know the shape of the object in order to calculate direction and angle of view. Developers create separate applications dedicated to scanning objects for use as a target.

Advances in environment recognition from camera feeds has resulted in the ability to position a digital file using markerless tracking. With this system, the application recognises the planar surface in the camera view and places the digital file onto this surface. This means there is no need to prepare an environment with markers as the digital file will locate itself and move around on any flat surface in front of the viewer.

The first iterations of *In Darwin's Garden* used the GPS tracking function within the *Metaio* software to align the digital tree form within the physical frame. Using the application outdoors, the digital structure jumped around due to issues of tracking and an inability to receive accurate location information. The sculpture is 5 m by 3.2 m and as the viewer walked around the sculpture, the GPS tracking was inconsistent. When the errors in tracking caused the digital tree to move only a few centimetres this was deemed acceptable, but when the digital tree would suddenly move a number of metres it immediately broke the immersion, as it appeared to jump outside of the physical structure. Further tests in a gallery space found that some devices might not be able to receive any GPS location information. After various tests, it was decided an image-based target was to be used as it was the most stable form of tracking.

An issue with positioning a large digital object is the tracking of that object when the viewing device moves off the tracking image. As the viewing device pans up the tree structure, the camera loses sight of the target marker and the digital structure would become unstable. This is also an issue where a digital object moves out of the field of view but the user will expect the digital object to still be there upon returning to view that part of the environment. This is commonly referred to as extended tracking and has been important in developing the possibilities for AR for dealing with more than a single digital asset in the user's environment.

During the development of *In Darwin's Garden,* Metaio developed object tracking and provided an application for scanning 3D objects. A problem was the large scale of the physical structure, as this technology was geared towards scanning small objects such as toys. Experiments with scanning a smaller maquette of the physical framework worked at the scale of the maquette but it was found that this could not be scaled up to match the size of the sculpture.

A development with the Metaio software was the ability to upload a digital model of the object that could be used for tracking a real object. This proved successful in recognising the large framework, but only if the whole framework could be seen within the camera view. If the viewer was too close to the physical frame, then the tracking could not recognise a component part in order to position the digital asset. If the viewer could be directed to approach the sculpture from a certain direction, where the camera would have a full view of the structure, then this was a viable method of tracking.

The experimentations in tracking eventually led to the use of a single image marker placed in the centre of the framework as this offered the most consistent stability during the developmental stages of production (Fig. 18.4).

Fig. 18.4 CAD render of the modular framework showing the circular image marker. Copyright © A. Summers 2019

18.8 Exhibiting *In Darwin's Garden*

In 2015 a modular framework for the physical structure was constructed. Five steel units were fabricated to hold a wooden framework together that can support the two "A" frames that lean inwards as if they are supporting the real mulberry tree. The structure had been modelled in CAD, (Fig. 18.4), in order to create the necessary construction diagrams and this also meant an exact digital object file could be extracted to be used for tracking within the Metaio software.

In early November of 2015, the augmented reality sculpture was installed outside the *Chester Contemporary Art Space* for testing. The devices chosen to run the application where iPads and the Epson Moverio BT-200 Smart Glasses. Using a Metaio application, the iPads picked up the structures' shape and the digital tree form would hold within the structure with minor stability issues. Using the Epson Smart glasses, the lower resolution camera feed proved to be able to track the object but only in a good light. When marker-based tracking was used, the tree structure tracked with reasonable stability on both devices. Then in December 2015 Metaio revoked all licences for their software, as they had reportedly been bought by Apple in May of that year [11]. This stopped all applications from working and there was a certain irony that *In Darwin's Garden,* acting as a form of an archive for the dying mulberry tree, had itself become obsolete within 3 years of its conception.

There followed a period of 6 months of testing other SDK's and applications as commercial products competed to fill the gap in the market left by Metaio. The SDK from Vuforia was used to create a marker-based tracking system for *In Darwin's Garden,* but the possibilities of object tracking were not available.

Fig. 18.5 Using the iPad holder to view *In Darwin's Garden*. Copyright © Wrexham Glyndwr University 2019, with permissions

In September 2017, *In Darwin's Garden* was installed as part of the *Carbon Meets Silicon 2* exhibition at the Oriel Sycharth Gallery, Wrexham. For this installation, the smart eye glasses were not used as these could not be secured at the site. Instead iPads were placed in specifically designed plywood holders that slot into charging stations. These holders were robust, having handles at both ends to allow two hands to hold the device (Fig. 18.5). They were designed to give confidence in handling the device and remove the fear of holding, or dropping, an expensive electronic device. This appeared to change the nature of the user interaction as users were more confident holding these larger objects. The users were quick to step into the physical space and interact with the digital elements and each other. The interconnection between the physicality of the real world and the nuances of the digital world appeared to be enhanced by giving the viewer confidence in their handling of the device required to engage with the digital reality.

18.9 Conclusions

Throughout the development of *In Darwin's Garden,* there has been the need to react to the advancements of augmented reality technology, as well as the disappearance of that technology when it became commercially valuable. This shifting dialogue between technology and artwork raises interesting questions of transmediation and archival. Do we keep developing an artwork until the technology facilitates the vision, or accept current technological limitations and compromise that vision? *In Darwin's Garden* is complete, yet for each new installation it is expected that the digital assets will need to be embedded in new devices because of software and hardware developments.

In its gallery iteration, it became apparent that there is an embodiment which occurs between the viewing device and user that facilitates a more complete interaction with *In Darwin's Garden.* This embodiment is inherent in the physicality of holding the plywood iPad holders with both hands and moving around and through the sculpture as these devices appear to push the digital foliage out of the way. This may be in part due to the true to life scale of the digital element that facilitates a tacit understanding within body movement and the path the viewer takes exploring the digital tree. This embodiment between user and viewing device may also be due to the connection we have with our personal smart devices. We are confident in positioning ourselves and our smart device in order to get the best photo. Subsequently, we have a familiarity with the spatial connection between a camera view and targeting objects of interest within it.

The smart glasses used in developing *In Darwin's Garden* were found to have a narrower field of view than human vision, meaning a frame appeared to clip the edges of the digital tree. This broke viewer immersion, as the frame appeared to float at a constant distance away from both viewer and object. As this technology develops to allow wider fields of view this disconnect should reduce, but in this instance these devices did not facilitate a truly immersive experience for the AR sculpture.

In the end it was the physicality of holding a framing device in a form where the user can twist and angle it with their body, hold it out or look in close, adapting the screen view to their preference, that was found to be the most intuitive form for the exploration of an augmented sculpture of this size. Personal smart devices can facilitate this intuitive exploration, so for external installations of *In Darwin's Garden* it will be important for viewers to download the application in order to engage with the experience using a familiar device.

In conclusion, there has been a constant tension between developing the augmented artwork, utilising technological advances and adapting to setbacks as access to technology was withdrawn. With each advance there was a temptation to be led by technology, but the transmediation of the vision, not the application of technology, was the essential driver throughout the development process.

References

1. Dziekan, V.: In Darwin's Garden temporality and sense of place. Live Vis. Leonardo Electron. Alm. **19**(3) (2013)
2. Papagiannis, H.: The role of the artist in evolving AR as a new medium. In: ISMAR-AMH '11: Proceedings of the 2011 IEEE International Symposium on Mixed and Augmented Reality–Arts, Media, and Humanities 2011, pp. 61–65 (2011). https://dl.acm.org/doi/10.1109/ISMAR-AMH.2011.6093658
3. Pearson, J.: The computer: liberator or jailer of the creative spirit. Leonardo **1**(Suppl. Issue), 73–80 (1988)

4. Malina, R.F.: Digital image: digital cinema: the work of art in the age of post-mechanical reproduction. Leonardo **3**(Suppl. Issue), 33–38 (1990)
5. Wyler, S.: Roman replications of Greek art at the Villa della farnesina. Art Hist. **29**(2), 213–232 (2006)
6. Summers, A., McGuirk, T.: Albertian perspective and augmented reality: lessons from Panofsky. In: Proceedings of the Seventh International Conference on 2017 Internet Technologies and Applications (ITA), Wrexham, pp. 355–359 (2017)
7. Milgram, P., Takemura, H., Utsumi, A., Kishino, F.: Augmented reality: a class of displays on the reality-virtuality continuum. Telemanipulator Telepresence Technol. **2351** (1994)
8. Azuma, R.T.: A survey of augmented reality. Presence Teleoper Virtual Env. **6**(4), 355–385 (1997)
9. Sutherland, I.E.: A head-mounted three dimensional display. In: Proceedings of the December 9–11, Fall Joint Computer Conference, Part I, New York, NY, USA, pp. 757–764 (1968)
10. Metaio offers free mobile AR software kit, Worldwide Computer Products News, 9 Dec 2011
11. Apple Buys Metaio, a German augmented-reality software maker, Stock Watch (2015)
12. Augmented reality art exhibition MoMA NYC (guerrilla intervention) [Online]. http://www.sndrv.nl/moma/
13. Van der Klein, R., Boonstra, C., Lens-Fitzgerald, M., Layar, M.: Amsterdam, Blippar (2009)
14. MoMAR. MoMAR [Online]. http://momar.gallery/
15. Syms, M.: Incense Sweaters & Ice (2017)
16. Microsoft Photosynth. Microsoft (2008)
17. Summers, A., Meigh-Andrews, C.: In Darwin's Garden, In Darwin's Garden [Online]. http://www.darwinsgarden.org.uk/
18. LEA Digital Media Exhibition Platform: In Darwin's Garden, Leonardo Electronic Almanac, 1 Aug 2012
19. Herpich, F., Guarese, R., Tarouco, L.: A comparative analysis of augmented reality frameworks aimed at the development of educational applications. Creat. Educ. **08**, 1433–1451 (2017)
20. Nissan augmented reality. Total immersion (2010)

Chapter 19
Creation of Interactive Virtual Reality Scenarios as a Training and Education Tool

Rinat R. Nasyrov and Peter S. Excell

Abstract A novel approach to the creation of realistic training scenarios for safety-critical industrial applications is presented. This is based on virtual reality techniques but extended by the incorporation of a range of options for interactivity, which permit the trainee to take actions in realistic ways in the simulated environment. These actions may include potentially dangerous errors, with realistic consequences simulated, but in complete safety. Any real environment may be simulated both visually and functionally in the virtual environment. An innovative feature is the use of virtual buttons displayed on the image of the user's hand, thus avoiding the need for accessories such as haptic gloves. The system enables trainee specialists to gain realistic operational experience without the anxieties of causing damage in a real environment, but it is also relevant to a wide range of applications where rich interactivity is needed.

Keywords Interactivity · Learning · Safety-critical · Scenarios · Training · Virtual reality

19.1 Introduction

It is probable that the majority of uses of modern Virtual Reality (VR) technologies are for entertainment. However, VR technologies also routinely allow people working in safety-critical industries to undergo training in a realistic environment, without the risk of hazards such as injury or equipment damage. Electrical power distribution is an example of a major safety-critical industry and a need arose to create a virtual training simulator for power substation operators, who have to be ready to react

R. R. Nasyrov
Department of Power Electrical Systems, Institute of EPE, National Research University for Power Engineering "MPEI", Moscow, Russia
e-mail: nasirov.rinat@gmail.com

P. S. Excell (✉)
Wrexham Glyndŵr University, Wrexham, UK
e-mail: p.excell@glyndwr.ac.uk

University of Bradford, Bradford, UK

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_19

rapidly, correctly and safely to a wide range of routine and emergency situations. The work presented here discusses the development of an innovative VR training system for such cases, but the principles established could be used in entertainment or creative applications as well.

The target need arose from an approach by the Russian power industry, for which over 30% of faults and blackouts have historically been caused by errors during switching [1] and hence the improvement of operators' training is a priority: it is probable that the situations in other industries and in other industrialized countries will show significant similarities.

19.2 Limitations of Current Two-Dimensional Simulators

Many simulators exist for training of industrial personnel, but they mainly rely on two-dimensional screen displays. There is no doubt that the underlying algorithms are sophisticated; for the power substation operator case they typically include: control of simulated operation order with both routine and non-routine events; estimation and recording of the operators' decisions made during such simulated events; rapid evaluation of the parameters of the modelled system.

Against this, such simulators have deficiencies, such as: a two-dimensional display of the main control room and substation equipment does not give a realistic scenario to develop skills; routine normal operations tend to be perfunctory and without deep insight for the trainees; navigation around the installation is not a realistic representation of the real situation.

Given the powerful impact of three-dimensional simulations now routinely available for entertainment applications, it was felt that the development of such technology could deliver a major improvement in training simulators. A VR simulator for industrial operatives would be vastly more meaningful, although there would need to be significant improvements in the quality of interaction, in comparison with entertainment-oriented VR devices.

19.3 Three-Dimensional Approaches to Scenario Simulation

19.3.1 3D Technologies

There are two main three-dimensional training technologies: 3D Helmet and 3D CAVE (cave automatic virtual environment). Both of them can be used as forms of VR simulator and both deliver complete immersion in the virtual environment. However, the CAVE demands a relatively large amount of space: it leaves the user unfettered by a headset, but nonetheless has significant deficiencies of realism: in particular, the user only sees a 2D projected image, albeit on a surrounding wall. Thus, if the space is limited or true 3D is essential, the 3D Helmet technology is preferable.

The 3D CAVE consists of a cube-shaped space, normally with a volume of at least 8 m^3, with display screens surrounding the user on all sides [2]. The user may work with virtual objects with hands or a joystick, but it is difficult to display these realistically since the surrounding screens are basically two-dimensional; further, the user's mobility is limited by the cube perimeter. For 3D Helmet VR technology, two small displays are mounted in front of the user's eyes so that they can view the simulated environment [3]. The user then has the opportunity to work with credible 3D representations of virtual objects, either with their hands or a joystick.

19.3.2 Modelling Requirements for Appropriate Environments

A primary need is a 3D model of the environment: this must have a good degree of verisimilitude in both its visual and spatial similarity to the real thing, but it must also have functional similarity in the operation of relevant switches, indicators, etc. The verisimilitude of a 3D model leads the user (operator) to develop the skills of operation of the selected environment during the training, such that after completion they will not need to adapt to the real environment, due to the realism of the VR interaction.

Spatial analogue representations of objects and the environment are very important: operators need to know the time needed to move from one point to another in the space concerned and this can be critical in emergency scenarios. Further, the need for functional similarity in the 3D model is paramount and the model must react to the user's actions in the same way as in the real environment.

19.3.3 Scenarios of Training

The scenarios of training have to include both regular and emergency cases: regular operations refine the skill of routine switching and understanding of the basic operation on the station. Emergency scenarios need to start in the same way as regular training but then there will be the insertion of an emergency at a time and of a nature that must be unpredictable to the trainee, who then has to take correct decisions as fast as possible [4].

The user can choose between training mode and test mode. If they choose training mode, they can select either emergency or regular training and the type of scenario. In test mode, the user does not know what type of training scenario they will encounter: it will be a random choice of the simulator.

19.4 Implementation of Virtual Reality Simulator

A substation of typical Russian design was chosen to be simulated. This contained: six 110 kV overhead line connections; six 35 kV overhead lines and one 35 kV cable line connection; thirty 10 kV cable line connections; outdoor switchgear for 110 kV; outdoor switchgear for 35 kV; indoor switchgear for 10 kV; three three-phase transformers. The area of the prototype was about 18,000 m^2. This diversity of equipment enables many scenarios to be implemented.

The digitalization of the prototype has three main stages, as follows [3]: acquisition of a cloud of object points for the prototype hardware; mesh calculation and optimization; texture calculation and optimization. The object point cloud becomes a skeleton model in the virtual space: the surfaces of the prototype objects are then given appropriate textures and the whole 3D model is optimized.

Creation of training scenarios is a specialized issue dependent on the application. For the substation operator case, the regular scenarios included taking out of, and putting into, service the following: transformers; circuit-breakers; disconnectors; overhead lines. For the emergency cases, the following scenarios were chosen. 1. Taking circuit-breakers out of service due to: emergency powering off of transformer; emergency voltage transformer fuse failure; emergency current transformer explosion. 2. Taking an overhead line out of service due to emergency collapse of column insulation of disconnector. 3. Taking a sulfur hexafluoride circuit-breaker out of service due to emergency gas depressurising. 4. Bringing a disconnector into service due to an emergency earth fault on an overhead line. The totality of these scenarios covers about 90% of typical emergency operations in a substation.

19.5 Technical Description of the Simulator

The game engine part of the simulator is based on Unreal Engine 4 [5] (Epic Games, 2014). A software model of the chosen prototype was written in the C language, enabling the latency to be reduced to less than 10 ms, which is essential for a convincing experience. The VR headset used an umbilical cable to link to the host computer because there is no current wireless link technology that can transmit two channels of HD video plus three channels of gyroscopic information and a USB-3 channel (for the forward-looking camera—see below) with acceptable latency.

There are three main stages of the creation of the training system (Fig. 19.1): preparatory stage, software creation, system operation.

The preparatory stage consists of the selection of the target environment, carrying out 3-D scanning of the real objects in that environment, creation of a library of 3-D models of objects and equipment in the environment, and finally documentation and refinement of the scenarios (Fig. 19.2).

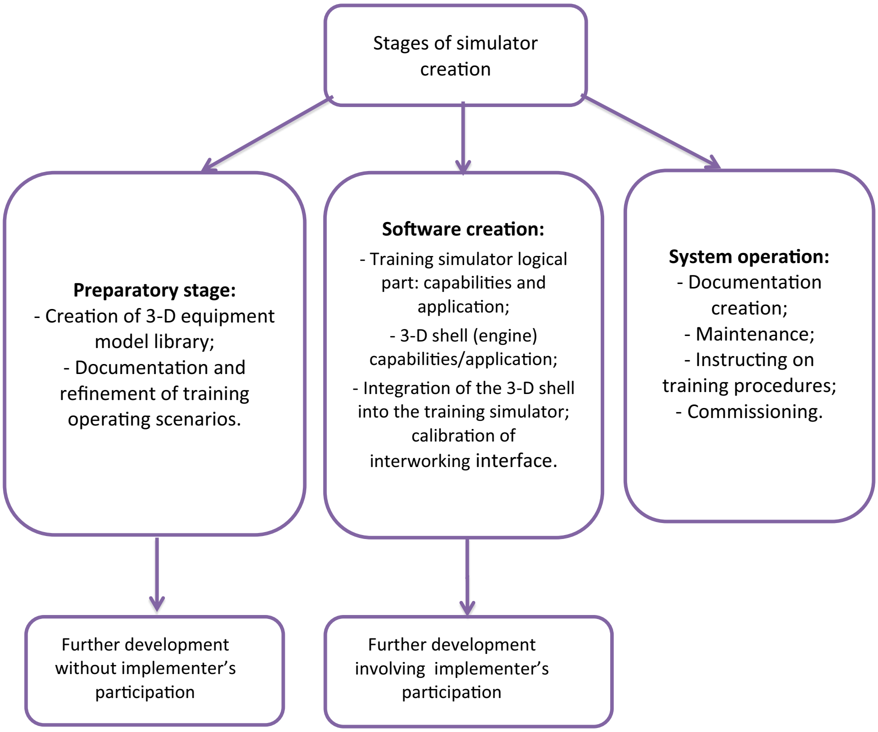

Fig. 19.1 Creation stages of VR training system

To create a functioning simulator, it is necessary to combine the technical functions of the modelled system (the simulator logical part) with the capabilities of modern 3-D shells (graphic engines). The integration of these two subsystems is discussed in Sect. 19.6.1.

19.6 Software Implementations

19.6.1 Functional Simulations and Graphics Engine

In principle, the system consists of two subsystems that constantly interact and exchange information. The first subsystem is the logical part of the simulator: this performs the technical algorithm that describes the real behaviour of the simulated system and its response to operator actions, including button pressing, switch knob turning, cable unplugging and, above all, mistakes.

The second subsystem is a graphical 3-D shell (graphics engine) responsible for the visual presentation of the substation model. The connection between the two

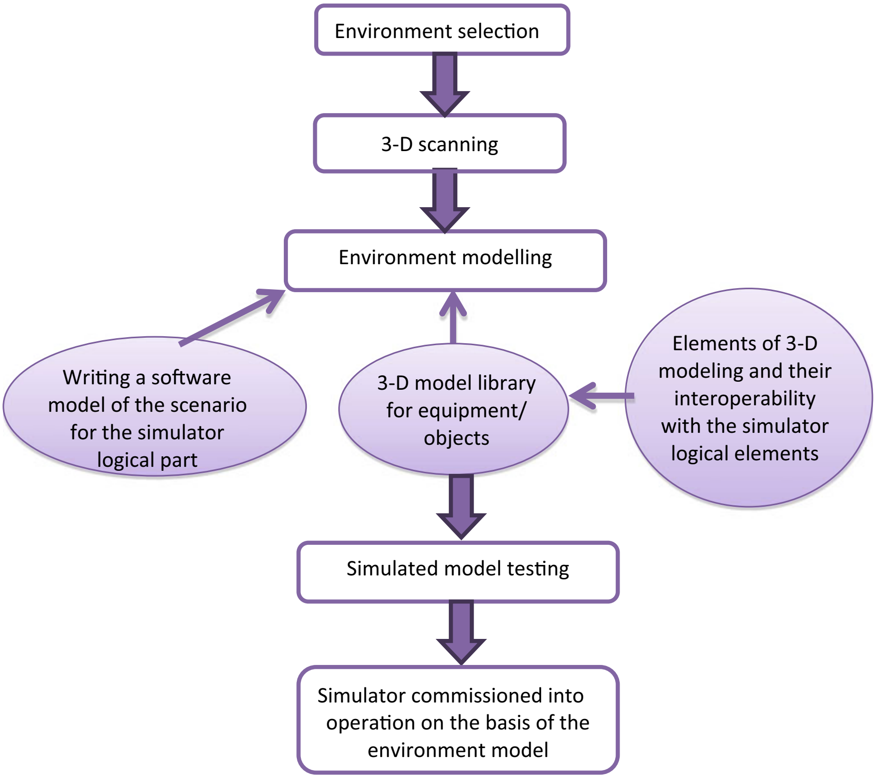

Fig. 19.2 Component preparation for the developed system

subsystems is event-based and is performed through the interaction interface. The protocol is thus that the simulator logical part proceeds to a new state calculation for the system only after receiving the appropriate command from the 3-D shell, this resulting from the user having performed some action that triggers the need for a new response. Following this, the simulator logical part evaluates the action taken and, if it causes a linked visual change in the environment display, sends a command to the 3-D shell to display the corresponding change.

The main training station acts as a server, to perform functions of administration, programming and information storage. The trainee interacts with the 3-D shell using a specific set of controllers connected to their personal computer. There are three options for the sets of controllers, with increasing levels of functionality:

1. Minimum: the user can effect changes in the simulated equipment using a minimum set of peripheral devices—a monitor, keyboard and mouse are needed, connected to a computer.
2. The optimal set of controllers consists of a virtual reality helmet with gyroscopic position sensing and a forward-looking camera to track the position of the user's head, arms and body.

3. Maximum: differs from the optimal by adding an omnidirectional treadmill, which allows the trainee to move around in a virtual environment, ensuring the maximum presence effect, and consequently the effectiveness of training.

19.6.2 Operating Modes

The system can operate in two basic modes: functional preparation mode and training mode. The functional preparation mode consists of environment preparation (see Fig. 19.2): the equipment models are created, connection diagrams loaded and training scenarios are recorded in the corresponding databases on the server.

The training mode is configured for two types of system operation: a multiplayer mode and an individual training mode. A schematic diagram of the operation in multiplayer training mode is shown in Fig. 19.3. In this mode, the personal computers of the staff in training are connected to a single local area network which includes the main training station, which is an automated workstation for the instructor. There are servers for the 3-D shell and simulator logical part at the main training station, providing communication between training stations during group training sessions, as well as a complete database covering training scenarios and the library of equipment in the environment. Administration and programming functions are possible from the main training station. Programming involves entering training scenarios into the simulator logical part using the “Form editor” application, as well as further operational adjustments as required by the scenarios created.

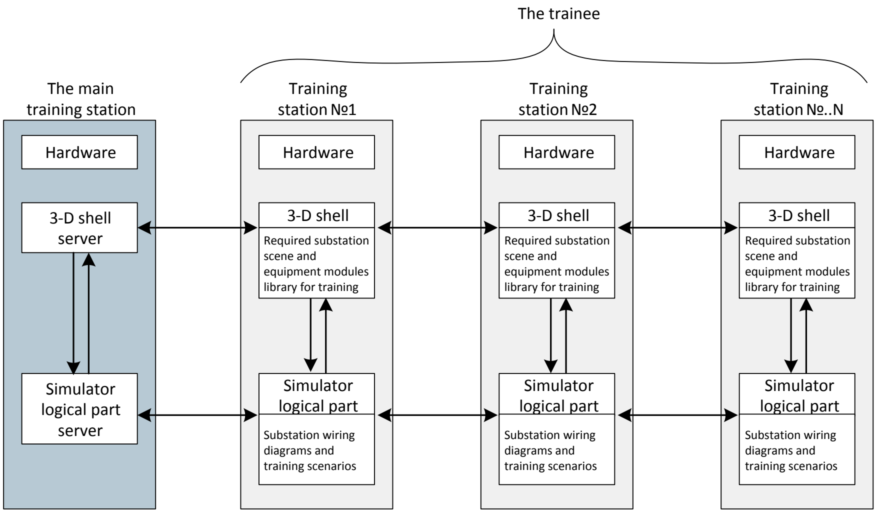

Fig. 19.3 The training mode system structure, when the main training station is a separate supervisor

Basic individual training can be conducted on a dedicated PC: the simulator application is installed at the trainee's workplace; a model file of the trainee's or instructor's choice is then loaded. Depending on the configuration, model files can be located on a workstation or on a server with access to model files using the CIFS protocol.

19.7 Creation of Scenarios

Analogous to a computer game, the graphics engine can create an arbitrary environment into which the trainee can enter when using the VR headset. However, as stated above, to reduce latency to less than 10 ms, as is essential for a realistic experience, the use of high-level language and packages was avoided and instead the model was entirely written in the C language. For the prototype that was developed, the client required a realistic model of a high-voltage substation, both the outdoor high-voltage equipment and the indoor control room and low-voltage equipment. All of this had to have simulated functionality, including moving parts, to cover all of the requested training scenarios.

To create the environment model simulating a real example of a substation, about 1200 working hours were required, occupying six people, a modeller (mesh creator), two programmers to create mathematical models, one unifying programmer and two electrical power engineers. The three-dimensional information was derived partly from scale drawings and photographs and partly from three-dimensional laser scans. The results show an excellent degree of verisimilitude (Fig. 19.4). Further images showing the realism that was achieved in modelling of the outdoor hardware are given in Figs. 19.5, 19.6 and 19.7.

The same techniques were used in modelling of the interior of the control room and low-voltage switch room (Figs. 19.8 and 19.9), although much more functional detail had to be included here, such that switches could be turned, buttons could be pressed, lights could come on and even plugs on flexible cables could be pulled out in the virtual environment. Figure 19.10 shows the detail that was incorporated for this purpose: the plugs shown may be pulled out of their sockets in the virtual world and all of the switches, buttons, and lights function in it as well.

For the full VR experience, the equipment shown in Figs. 19.11 and 19.12 is required. The volume of the region that can be accessed is determined by the placing of the motion sensors attached to the tripods, but a cube with 3 m side length is usually adequate, especially if an omnidirectional VR treadmill is available [6]: in fact, the treadmill would allow a smaller volume to be used, e.g. a cube with side length of 2 m.

Figure 19.13 shows the front view of the headset, which has a forward-looking infrared camera attached to its front: this is used to collect the imagery of the user's hand so that the system can determine what the hand is doing and it can also be used to implement some virtual controls on the hand (see below). Figure 19.14 shows the pair of stereoscopic views that are generated in the two eyepieces of the headset,

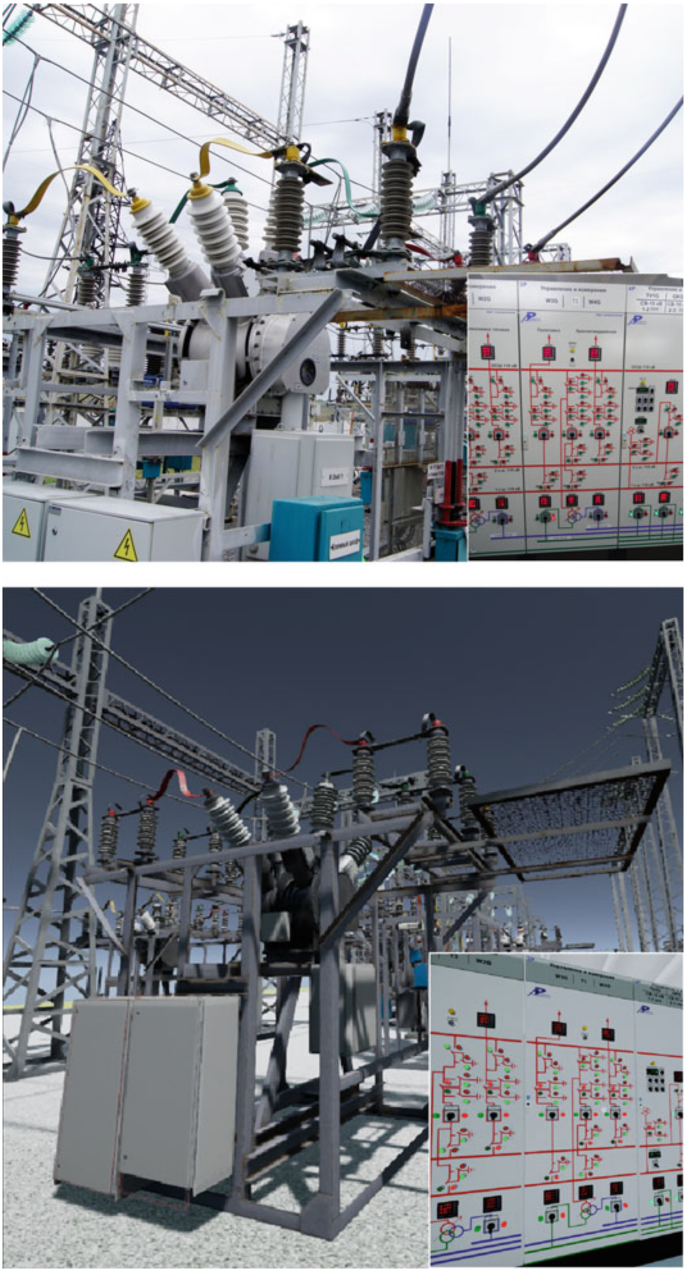

Fig. 19.4 Top: photograph of the real substation that was simulated. Lower: modelled equivalent (differences are mainly due to a slightly different viewing angle)

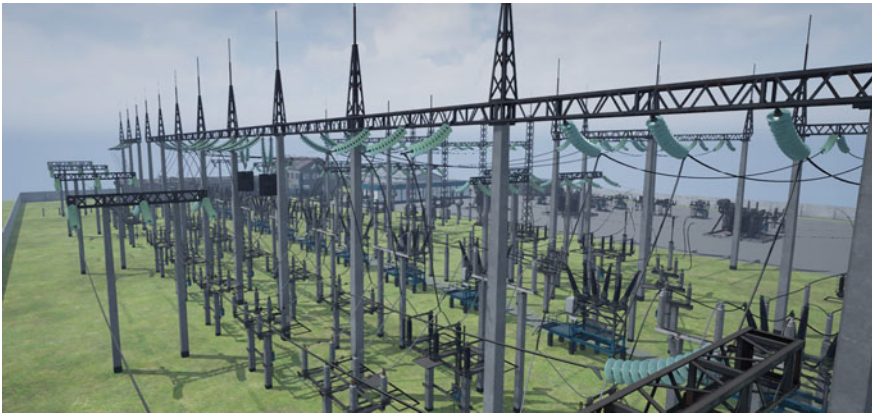

Fig. 19.5 3-D model of 110 kV outdoor switchgear yard

Fig. 19.6 3-D model of a 110 kV sulfur hexafluoride circuit-breaker

including a representation of the user's hand reaching to press a button. Figure 19.15 shows the system in use: the user is wearing the VR headset and reaching out to grasp one of the plugs attached to a flexible cable (Fig. 19.10). The left image shows the view that the user experiences: the virtual image of the hand is shown extracting the plug from its socket in the switchgear.

Figure 19.16 is a diagrammatic recreation of the "virtual buttons" that are made to appear on the left hand of the user in the virtual view. The cube below the wrist

Fig. 19.7 3-D model of a 110 kV disconnector

Fig. 19.8 3-D model of the main control room

is touched when it is desired to change the view significantly, for instance, to move from the control room to the outside switchyard in the combined representation of the substation. The virtual button near the left-hand thumb is used to advance the user's virtual standing position forward in a way rather similar to Google Streetview. The virtual button in the palm of the left hand has been provided for future functionality but is not currently used.

Fig. 19.9 3-D model of 10 kV indoor switchgear group

Fig. 19.10 Detailed 3-D functional model of 10 kV circuit-breaker

There are no virtual controls on the right hand, but the system detects the index finger pointing forward as a tool to press buttons, while a grasping action using all of the fingers is seen as a tool intended to turn a control knob or grasp a plug.

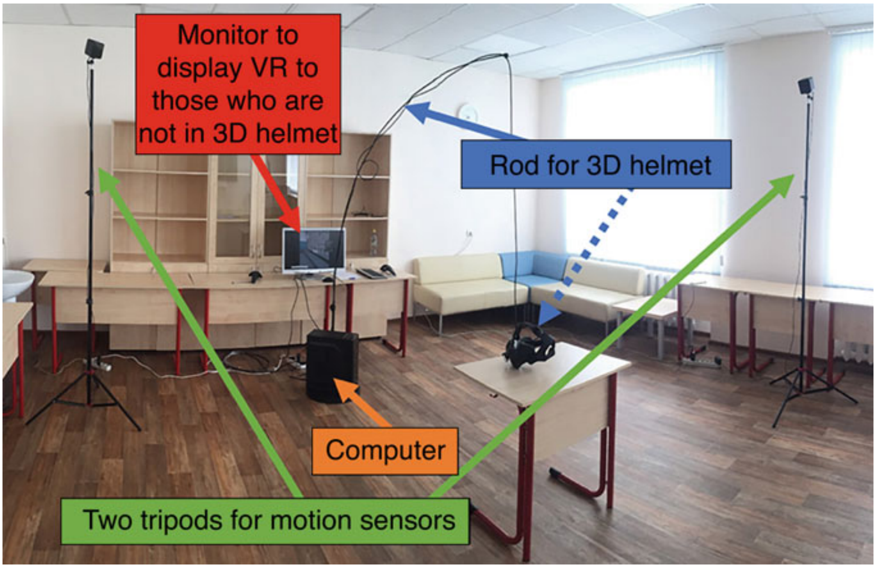

Fig. 19.11 The appearance of the simulator's core elements

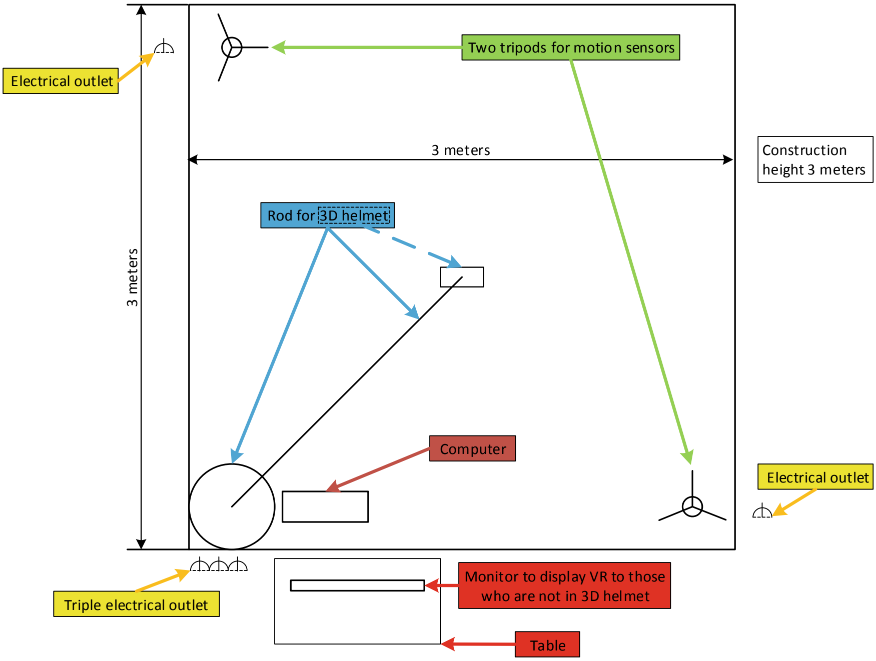

Fig. 19.12 Plan layout of the simulator's elements

Fig. 19.13 Trainee operator interacting with a 3-D model: the forward-looking camera is noticeable. The marker on the index finger was optional in an early version, but not now needed

19.8 Outcomes and Conclusions

A three-dimensional stereoscopic software representation of an industrial installation was created, including a large range of virtual interactive functions.

The implementation was designed to exploit a virtual reality headset with enhanced functionality, including gyroscopes to determine the movement of the headset and a forward-looking infrared camera which was used to detect the position of the hands and fingers of the user, thus avoiding the need for haptic gloves. Further, virtual buttons were located on the hands of the user in the virtual reality space, thus avoiding the need for hardware control buttons. The implementation also prioritized extremely low latency in the display, to give maximum reality in the simulation. To ensure this, the headset was connected to the controlling computer by an umbilical cable, as no standard commercial wireless link would have sufficient capacity and

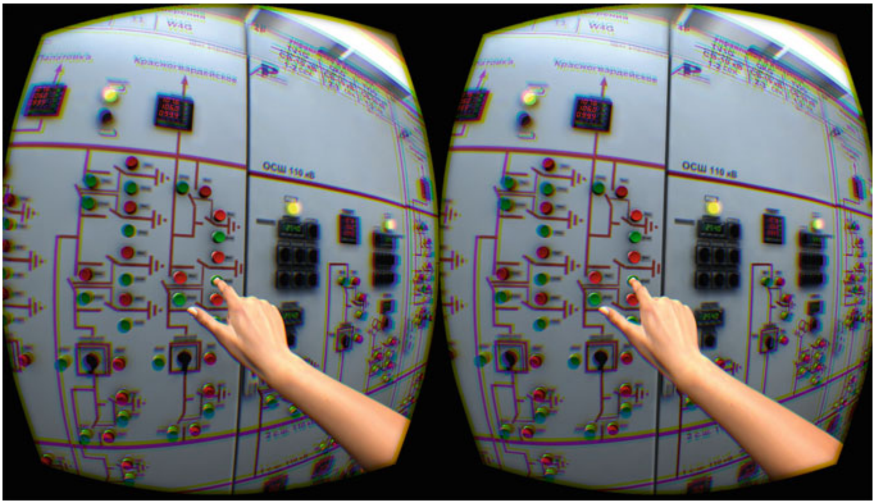

Fig. 19.14 The synthesized stereoscopic view seen by the user shown in Fig. 19.13

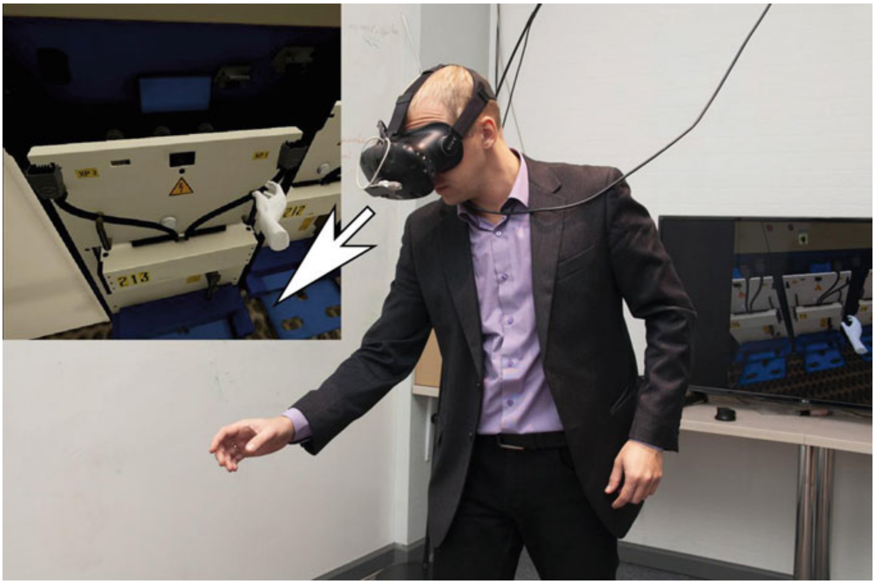

Fig. 19.15 A user interacting with the system. Right: the user is wearing the VR headset and reaching out to grasp one of the plugs in Fig. 19.10. Left: the view that the user experiences: the hand is shown extracting the plug from its socket

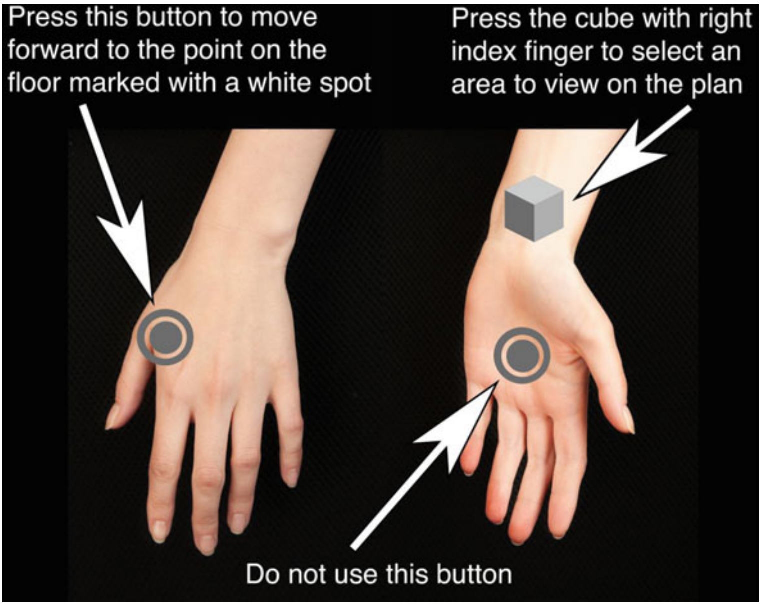

Fig. 19.16 The virtual button controls provided on the image of the left hand, as detected by the forward-looking camera

adequately low latency. In addition, the code representing the simulated environment was written in C to avoid latency issues that could be caused by higher level programming approaches.

The simulated environment in the prototype was an industrial plant (electricity substation), created with great attention to verisimilitude. Excellent realism was achieved and this included functional button switches and electrical connectors, all of which could be operated on by the user's own hands without the need for haptic gloves or other technical adaptations. The industrial environment simulated was dictated by the primary sponsor, but an arbitrary range of alternative environments can be envisaged. A potential disadvantage is the large amount of specialist labour needed to create the simulation: 1200 person-hours in the present case, not including work on assembling the hardware.

The system functioned completely according to specifications and has been adopted for the training of substation operators by a major electrical power distribution company in Russia. A particular advantage of a virtual reality training simulator in an application of this type is the avoidance of any danger resulting from errors made by the operators during their training. The system has been tested with a number of trainee operators and results have been successful, in the sense of perceived realism and relevance of the training. Work is now proceeding to implement other environments.

Acknowledgements and Note The authors are grateful to the PJSC Interregional Distribution Grid Company of Central Russia for funding and technical support to develop the VR simulator.

This chapter is an expanded version of a presentation originally given at the 2018 European Conference on Technology-Enhanced Learning [7].

The copyright of all the images in the figures belongs to R. R. Nasyrov.

References

1. Russkih, A.A., Nasyrov, R.R.: Electrical Safety System, pp. 14–21. PCS, Moscow (2015). ISBN 978-5-905485-81-7
2. Cruz-Neira, C., Sandin, D.J., DeFanti, T.A., Kenyon, R.V., Hart, J.C.: The CAVE: audio visual experience automatic virtual environment. Commun. ACM **35**(6), 64–72 (1992). https://doi.org/10.1145/129888.129892
3. Thompson, J.I.: A three dimensional helmet mounted primary flight reference for paratroopers. Thesis. Jason I. Thompson, Second Lieutenant, USAF. AFIT/GCS/ENG/05-18. Department of The Air Force, Air University, Air Force Institute of Technology (2005)
4. Nasyrov, R.R., Suleimanov, I.R., Churkin, A.I., Pilyugin, A.V., Marchenkov, D.V.: Switching training simulator based on virtual reality. Electrichestvo (Electricity) **3** (2016)
5. Epic Games. Unreal Engine 4. Epic Games Inc, Cary NC, USA (2014). https://www.unrealengine.com/en-US/
6. Leatham, J.: VR omnidirectional treadmills making gains towards full immersion and cardio. VR Fitness Insider website, Boise, ID, USA (2018). https://www.vrfitnessinsider.com/vr-omnidirectional-treadmills-making-gains-towards-full-immersion-and-cardio/
7. Nasyrov, R.R., Excell, P.S.: New approaches to training of power substation operators based on interactive virtual reality. In: Pammer-Schindler, V., Pérez-Sanagustín, M., Drachsler, H., Elferink, R., Scheffel, M. (eds.) Lifelong Technology-Enhanced Learning. EC-TEL 2018. Lecture Notes in Computer Science, vol. 11082. Springer, Cham (2018)

Part VII
The Future of Interdisciplinary Research

Chapter 20
Interdisciplinary Research and Development—Opportunities and Challenges

Rae Earnshaw

Abstract Discipline boundaries have been systematically developed and established over the last century which reflect some of the perceived differences between the science and engineering disciplines and those in the arts and humanities. However, both internal and external factors can result in new disciplines which can arise at the boundaries between existing disciplines, rather than within them, and may combine different aspects of these disciplines. Some of these may be produced by external drivers such as information technology, the Internet and Big Data. It has been argued that innovative and creative approaches that cross disciplinary boundaries are more effective in producing new information and new knowledge. The current scope and priority of interdisciplinary research can be obtained by analyzing the funding programmes of national and international bodies and agencies. Some funding programmes are looking for quicker and more effective solutions for complex grand challenge problems. Analyses of complex information systems may require the crossing of departmental boundaries in order to generate new knowledge. It is recognized that obstacles to effective and sustained interdisciplinary collaborations have the potential to arise unexpectedly. Also, social and cultural factors often come into play when new initiatives are proposed. Mechanisms to grow interdisciplinary research such as internal funding, networking, and training are considered. Potential barriers to progress are also noted. Ongoing issues that remain to be addressed are summarized.

Keywords Discipline domains · Collaboration · Creative approaches · Cultural factors · External drivers · Complex information systems · Research metrics

---

R. Earnshaw (✉)
Department of Computer Science, Faculty of Engineering and Informatics, University of Bradford, Bradford, UK
e-mail: r.a.earnshaw@bradford.ac.uk

St John's College, Durham University, Durham, UK

Faculty of Art, Science and Technology, Wrexham Glyndŵr University, Wrexham, UK

R. Earnshaw et al. (eds.), *Technology, Design and the Arts—Opportunities and Challenges*, Springer Series on Cultural Computing, https://doi.org/10.1007/978-3-030-42097-0_20

20.1 Introduction

In 1959 Snow identified differences between the science and engineering disciplines and those in the arts and humanities [1]. This appeared to be due to a variety of factors including tradition, vocabulary, ways of working, and contributions to society, all of which could be different in different disciplines and circumstances.

Critchley [2] proposed that Snow had diagnosed the emergence of two cultures because of the loss of a common framework of understanding. Scientists and engineers favoured advancement of society through technology and industry, whereas the arts and humanities preferred intellectual and literary endeavour.

However, Gould took an opposing point of view and emphasized the commonalities between science and the humanities [3]. In 1963, Snow appeared to take a more optimistic view about the relationship between science and arts [4].

These views stem from an era when 5% or less of the population participated in higher education, and a faculty member's role was not subject to detailed performance management controls by their institution. The freedom in the academy provided ample opportunity for new ideas to be developed and explored. Research grants were relatively easy to obtain (there were fewer applicants), and there was opportunity for regular publication of research results in refereed journals or monographs. Discipline boundaries had been fairly systematically developed and established over the previous century and these were generally respected. In addition, there was ample new knowledge to be discovered within the existing discipline domains.

This chapter provides a landscape view of interdisciplinary research and development and examines the areas where future progress may be made. The ways in which the creative arts relate to this view are detailed in Sect. 20.6 of this chapter.

20.2 Development of New Disciplines

However, in the last half-century new disciplines have arisen and there has been an acceleration of the pace of change. For example, computer science developed principally out of mathematics in the UK because of the associated interests in numerical analysis and the requirement to use automated methods to perform the required calculations. In the USA, computer science developed principally out of engineering due to the interests in hardware and manufacturing computing devices. However, before they emerged as separate academic disciplines with their own departments and faculty members, they did exist along the boundary of the existing disciplines of mathematics and engineering, respectively. The primary driver for the development of computer science came from outside the academy in the form of the vacuum tube computer (1940) [5], the transistor (1948) [6], and the silicon chip (1961) [7]. National governments appreciated the strategic significance of the technology not just for scientific and business computation but also for their application to a wide variety of disciplines and problems, and so invested significantly in computing facilities for the academy and national research laboratories. Shockley, Bardeen, and Brattain were jointly awarded the Nobel Prize in physics in 1956 [8] for the development of the transistor. Therefore, in its initial stages, computing was seen as part of the natural sciences, at least in its hardware aspects. This is still the case with regard to quantum computing, and publications from this area can appear in the journal Nature [9], whereas those from other areas of computer science do not.

Therefore, new disciplines can arise at the boundaries between existing disciplines, rather than within them, and may combine different aspects of these disciplines. Oceanography is a further example of an interdisciplinary discipline as it covers all aspects with respect to the ocean, which includes its natural components (seawater, living creatures, and the sea bed); its currents and movements (fluid dynamics); and modelling of the overall system (such as by finite element analysis). Similarly, cognitive science draws on interdisciplinary aspects of psychology, linguistics, philosophy, interaction, and computer analysis.

Shneiderman [10] details how innovative and creative approaches that cross disciplinary boundaries are more effective in producing new knowledge. In particular, he advances the case for combining applied and basic research and a new paradigm for interdisciplinary collaboration that puts engineering and design on an equal footing with basic science. Thus even within well-established disciplines there are significant opportunities for new approaches.

Pressures on funding of universities in recent years have resulted in competition between departments and between institutions. There is competition between departments for students and competition between institutions for research funding and league table positions. It also produced competition between disciplines that resulted in science and engineering arguing that they were better for students and society because they imparted skills and generated jobs, whilst arts and humanities subjects were less useful in these respects. In some cases, it resulted in national bodies advising students against studying arts subjects, which in turn forced some of these academic departments to close because their institutions could no longer afford them if they could not pay their way. Senior academics argued strongly for the value of arts and humanities [11, 12]. However, this overall antipathy between arts and sciences which has been somewhat artificially created has in some cases acted against furthering the important collaborations that are needed. Therefore obstacles to effective and sustained interdisciplinary collaborations have the potential to arise unexpectedly. The participants need to have the perspectives and resources to be able to deal with them.

Further information on the advantages and disadvantages of interdisciplinary research are detailed in [13].

20.3 Acceleration of the Pace of Change

Friedman [14] identifies three principal components that are accelerating change

(i) Market
(ii) Nature
(iii) Technology

The market includes the effects of globalization and political tribalism. Nature includes climate change. Technology includes the Internet and the increasing power and reducing costs of computational facilities. All of these act as powerful forces and they act in parallel. Their combined effect can cause severe disruption. Society needs to be able to adapt and respond to the changes that these forces represent. Many disciplines and applications use the Internet as a delivery service, to access Cloud storage, a computational resource, or a marketing medium, and therefore become subject to its accelerating effects. One Internet year is said to be equivalent to seven calendar years [15]. One effect of the Internet has been to break down traditional barriers. Formerly research teams were co-located with their departments, but today the Internet can be used to facilitate collaboration across departments and countries with equal facility. This can result in a greater sharing of ideas and results. Therefore the potential for interdisciplinary collaboration is substantial, and the Internet can act as an external driver of change in the same way that the silicon chip inaugurated the computer revolution.

Many institutions and organizations are increasingly recognizing the need to analyze large data sets. This can arise in the context of experiments, sensors, simulations, and the user data gathered by social sciences and social media companies. In the academy, such data is often concentrated in a centralized Data Center, with associated expertise on hand to advise on data collection and data analysis. They are often resourced centrally by the academy as they are regarded as an investment to support all disciplines. Such central resources also offer graduate courses (e.g., Masters, Ph.D.) in the various areas of Big Data and its applications. Thus, Data Centers can have the direct effect of encouraging and facilitating cross-disciplinary collaborations. Therefore, the rise of Big Data, rather like the rise of the Internet, has become a significant internal and external driver which forces researchers involved in this area towards interdisciplinary collaborations.

It is clear that interdisciplinary working is not just a matter of the right structures and appropriate facilitation. Social and cultural factors also come into play [16].

20.4 Interdisciplinary Research Funding and Research Priorities

An indication of the scope and priority of interdisciplinary research (IDR) can be obtained by analyzing the funding programmes of national and international bodies and agencies. Included in this analysis are the National Science Foundation (NSF) in the USA, the European Union, and the UK funding agencies.

20.4.1 National Science Foundation (NSF)

NSF states the priority it gives to interdisciplinary research in terms of advancing scientific discovery and extending the fields of knowledge [17–19]. It also supports interdisciplinary training in order to enable the recipients to be able to address current problems in innovative ways [17, 18].

The following challenges were identified [18]:

- Collaboration across people with different backgrounds and cultures
- Extra time needed to build consensus and learning new methods
- Traditions and policies tend to allocate resources to traditional areas
- Professional societies could assist more by active support of interdisciplinarity
- Ensure the peer review process including interdisciplinary researchers.

Potential lessons from industry and national laboratories were as follows [18]:

- Industrial and national laboratories are generally organized to address the problems
- Management is more top-down than in the academy
- There is potential for greater collaboration between the academy and industry.

20.4.2 European Union

A report to the European Union (EU) on interdisciplinary research in the context of ERA and Horizon 2020 identified a number of reasons why this should be a priority. This included the following [20]:

- Faster solutions are needed for grand challenge problems
- Engage in problem-driven approaches
- Exploit disruptive innovation
- Bridge the gap between research communities.

The report also outlined the potential effects of interdisciplinary research [20]:

- Trigger innovation
- Add value to the disciplines
- Solve complex real-life problems
- Bring about discoveries outside traditional disciplines
- Change established research perspectives and paradigms
- Achieve impact.

The following enablers were identified for interdisciplinary research and development [20]:

- Resourcing of people, time, and space
- Providing targeted funding
- Developing interdisciplinary skills and practices
- Triggering of appropriate social and cognitive dynamics between researchers
- Ensuring undergraduate students receive a grounding in different disciplines
- Facilitating an understanding of different scientific vernaculars.

The EU has also explored the reasons for the support of interdisciplinary research in disruptive technologies [21].

20.4.3 UK

Research England was set up as a Council of UK Research and Innovation by the Higher Education and Research Act 2017 [22]. It exists and alongside the other existing Councils (the seven Research Councils [23] and Innovate UK [24]). One of its functions is to evaluate the extent to which interdisciplinary research and development. It includes including cross-disciplinary, multi-disciplinary, interdisciplinary and transdisciplinary activity.

A number of reports on interdisciplinary research (IDR) have been undertaken by various bodies in the UK. Each body has particular interests to do with their mission, so each report is oriented to their objectives. However, taken together the reports

- highlight a range of barriers and incentives for interdisciplinary research (IDR) in the UK
- explore the challenges associated with assessing interdisciplinary research
- provide some real-world examples of 'what works' in supporting an IDR culture in today's higher education research institutions [25].

These are now summarized.

20.4.3.1 The British Academy

The Executive Summary of 'Crossing paths: Interdisciplinary institutions, careers, education and applications' by the British Academy noted the following [26]

- Requests for evidence identified a broad support of interdisciplinary research
- Essential for addressing complex problems and global social challenges
- Enhances understanding of the separate disciplines.

20.4.3.2 Global Research Council

A Survey Report for the Global Research Council (GRC) in 2016 noted the role and importance of IDR, the right conditions for establishing interdisciplinary working; assessment, evaluation, and measurement; careers, training, and recognition; and produced a number of recommendations including the following [27]:

- Better sharing of best practice
- The identification of grand challenge problems
- The provision of funding support over adequate time frames
- The provision of physical and social space
- Fair review processes
- Appropriate end of project evaluation metrics
- Training and capacity building
- Improving awareness of the value and importance of IDR.

20.4.3.3 Review of the UK's Interdisciplinary Research

A review of the UK's interdisciplinary research using a citation-based approach was undertaken for HEFCE and MRC by Elsevier. In order to assess interdisciplinarity, the diversity of article bibliographies was studied in eight comparator countries for the period 2009–13. The principal conclusions were that interdisciplinary activity was growing in the UK; it has an international collaboration component, and the academy was a principal contributor [28]. It also noted a lower citation impact for interdisciplinary research.

20.4.3.4 Landscape Review

A landscape review of interdisciplinary research in the UK identified some potential areas where new stakeholders could promote suitable conditions for interdisciplinary research to develop [29].

20.4.3.5 Case Study Review of English Higher Education Institutions (HEIs)

A Case Study review by Technopolis identified a number of ways of organizing IDR such as [29]

- *Co-location of researchers*
- *Researcher networks across subject areas, departments or faculties*
- *Researcher-led ('bottom-up') and/or strategic institutional ('top-down') approaches*
- *A thematic or generic focus for IDR*
- *Support for high-quality research in general, not specifically for IDR.*

It also suggested ways of growing IDR such as seed corn funding, networking events, improving the skills base by appropriate Masters courses and Ph.D. programmes [29].

20.4.3.6 Team Science in Biomedical Research

A report to the Academy of Medical Sciences in 2016 summarized the characteristics of team science including benefits and challenges, reward and recognition, and career progression [30].

An assessment of progress was done in 2019 [31].

20.4.3.7 Arts and Humanities Research Council

The Global Challenges Research Fund (GCRF) is a 5-year £1.5bn fund and a key component in the delivery of the UK Aid Strategy: tackling global challenges in the national interest. The funding was for 1 December 2018 onwards [32]. The objective includes interdisciplinary research excellence.

20.5 Interdisciplinary Research and Development in the Creative Arts

20.5.1 Introduction

The continued increase of processing power, data storage, telecommunications bandwidth, and display screen resolution provide greater opportunities for handling new types of users and applications. It also increases the ubiquity and facility of computational devices in terms of mobility and user interfaces, whether utilized directly by designers, audiences, users, or embedded in the application environment.

Art and design have a long history in antiquity. They have shaped the values, social structures, communications, and the culture of communities and civilizations. The direct involvement of artists and designers with their creative works has left a legacy enabling subsequent generations to understand more about their skills, their motivations, and their relationship to the wider world, and to see it from a variety of perspectives. This in turn causes the viewers of their works to reflect upon their meaning for today and the lasting value and implications of what has been created.

Some historical examples of art and design were able to use semi-automated methods for creation, particularly where large areas of a canvas or model needed to be filled in. However, it was only with the advent of modern technology that the advantages of harnessing digital techniques were able to be exploited. One of the earliest examples was the Architecture Machine [33] designed and implemented at the Massachusetts Institute of Technology (MIT). The objective was to enable digital technology to assist the user with design tasks, particularly those at large and small scales, where it was known that designers had particular challenges and difficulties. In addition, the computer was able to store data and reproduce designs, thus facilitating the speed-up of the iterative process towards a final design which met the objectives of the designer and the requirements of the client [34]. It also enabled the aesthetics of the design to be seen at the design stage within the wider content of the environment in which it was to be placed. This was subsequently extended using virtual reality technology to enable prospective users of the building to perform 'walk-throughs' within the created space and understand how it would work in practice in terms of logistics, to ensure it was fit for the purpose. Materials and implementation costs could also be optimized at the design stage.

More recent examples of artists and designers interacting with technology include the use of the iPad to produce sketches of scenes which were subsequently grouped into a montage to give a large wall display containing multiple images [35]. Mobile phones with high-resolution screens are being used to produce art works and communicate them via social media networks [36]. Art installations have also harnessed modern technology both to process information and to display it. Such environments have proved useful in engaging users and visitors with real-time images and interactive art.

Collaborative design has enabled the sharing of information across digital networks to produce designed objects in virtual spaces. Augmented and virtual reality techniques can be used to preview designs before they are finalized and implemented. Ancient and modern art and design environments illustrate the design and implementation processes involved, and the opportunities for collaborating and interacting with other artists and designers.

There are also increasing opportunities for artists to use their skills and expertise to illuminate the latest discoveries in science and technology [37, 38]. There is increasing interest in extracting meaning from very large data sets, which in turn requires effective methods of analysis and presentation of the results. Science and technology are also able to contribute increasingly to the arts, either as a component of the artistic output, or part of the methodology used to produce the output. In addition, the traditional boundaries between arts and technology are becoming blurred due to the way computing technology is being embedded into the everyday environment in a seamless way, and the use of social media which enables a greater degree of involvement and sharing by the community. Social media can open up new dimensions of interaction and participation in both the arts and the sciences [34].

20.5.2 Contributions of Technology to the Creative Arts

Technology contributes to the creative arts by providing tools, interfaces, facilities for collaboration, access to data, as well as a range of software for a variety of applications. Such facilities may also include artificial intelligence and machine learning techniques. Telecommunication networks enable artists to participate in communities and collaborate with other artists on joint projects. Exhibitions can be displayed on the Internet and allow local and remote audiences to participate and interact with the project and each other. Such environments can also be used for a variety of applications including simulation, planning, theatre rehearsal, and entertainment, such as computer games [39–42]. Excellent artistic skills are important for the generation of the scenes for effective gameplay.

Artistic works may use digital methods to produce digital art [43]. Computer games may be considered as a particular kind of digital art as they use computer technology and associated software to produce the game.

20.5.3 Contributions of the Creative Arts to Technology

The creative arts have made contributions to Renaissance Teams, the design of technology, and the effective incorporation of technology into the wider environment. Artists have been able to contribute to scientific analysis and enable new results to be produced [44, 45]. Such Renaissance Teams can stimulate creativity and produce new knowledge [46] in way that would be very difficult, if not impossible, for a single artist to do on their own. SciArt is a term used to describe the artistic contributions that can be made to scientific investigations [47].

Technology companies give increasing attention to the aesthetics, usability, and engagement of the devices that they create (e.g., Apple [48, 49]).

An example of the analysis of cultural artefacts by computer is the Digital Michelangelo Project at Stanford University [50, 51]. Its objectives were to advance the technology of 3D scanning and to create a long term digital archive of significant cultural artefacts in Italy. These archives were made generally available over the Internet.

20.6 Methodologies for Identification and Assessment of Research

A number of methods to evaluate research are being used by institutions and national bodies. These include journal quality (such as by impact factor and internationality), paper citation rates, impact factors, H-indices of the individuals and departments, and altmetrics. The UK Research Excellence Framework (REF) also has international representation on its evaluation panels in order to provide externality, and to seek to align internal review processes with externally accepted standards.

A number of difficulties and challenges arise in seeking to extend these methods of assessment within single disciplines to research delivery across a number of disciplines. Identification and assessment of interdisciplinary research are summarized in a consultancy report [52], which noted that different metrics can produce different results [53].

20.7 Conclusions

20.7.1 Ongoing Issues

Although interdisciplinary research has been identified as a priority by NSF, EU, and the UK, and resources have been identified to give grant and infrastructure support, the following ongoing issues remain to be fully addressed

(1) Strong discipline silos are still the norm in higher education and graduate research and there seems to be little inclination to change apart from a relatively small number of institutions such as Arizona State University [54–56] and Pohang University of Science and Technology (Postech) [57].
(2) External examiners who adjudicate on Ph.D. theses would not normally have interdisciplinary experience and expertise sufficient to give an appropriate and fair evaluation of an interdisciplinary thesis.
(3) Graduate students can feel that an interdisciplinary project may be too risky, and also may have an uncertain outcome.
(4) Budget structures in higher education are often ring-fenced around specific disciplines. It can also be difficult to allocate part of the budget across an internal boundary.
(5) Interdisciplinary research appears to be mainly stimulated by external drivers such as information requirements or technology developments. These drivers often require new ways of working. This results in interdisciplinary research operating in reactive mode rather than seeking to advance proactively according to a detailed agenda.

(6) Moving away from a traditional discipline into a new area can still be perceived as risky due to the inertia in the academy, the difficulty of applying research metrics to new areas, and uncertainty about the future of the new discipline.
(7) Increasing competition for grant funding and funding within institutions, can force review bodies to be more conservative and only allocate funding to well-established areas, when such funding is limited.

20.7.2 Enablers for Collaboration Between the Arts and the Sciences

Traversing the boundaries between disciplines can be a challenge. However, recent developments have brought about a number of enablers. Firstly, the Internet has provided a greater ease of communication across disciplines and between researchers. It has also flattened organizational hierarchies to some degree, which in turn has reduced the traditional barriers between existing disciplines. Secondly, the model of Renaissance Teams [58] has proved useful in bringing together interdisciplinary groups of researchers with complementary expertise sets and defined goals. Thirdly, there have been significant successes in the application of information technology to the arts and humanities (for example, in the digitization of ancient manuscripts and artefacts). Fourthly, art and design have been successfully applied in support of the creative processes involved in generating new technology products and services, and in the presentation of scientific results. Fifthly, the increasing amounts of data being generated by research projects have resulted in the establishment of Data Science Centers within the academy, with teams of faculty and researchers brought together from various disciplines. Sixthly, grant funding bodies are increasingly focussing on larger initiatives often traversing different disciplines and countries (e.g., European Union grants) so require personnel to work together on advanced research and development. In addition, creative and artistic cooperation has demonstrated the benefits for all parties. All these factors make interdisciplinarity more the norm for the future and can generate a level of momentum and validity which provide reassurance and support for new researchers who wish to enter the area.

References

1. Snow, C.P.: The Two Cultures. Cambridge University Press, Cambridge, UK (1959)
2. Critchley, S.: Continental Philosophy: A Very Short Introduction, p. 49. Oxford University Press, Oxford, UK (2001)
3. Gould, S.J.: The Hedgehog, the Fox, and the Magister's Pox. Harmony Books, New York City, NY (2003)
4. Snow, C.P.: The Two Cultures: And a Second Look: An Expanded Version of The Two Cultures and the Scientific Revolution. Cambridge University Press, Cambridge, UK (1963)

5. https://www.webopedia.com/DidYouKnow/Hardware_Software/FiveGenerations.asp
6. https://www.cedmagic.com/history/transistor-1947.html
7. http://edition.cnn.com/2004/TECH/12/27/explorers.silicon/index.html
8. https://www.nobelprize.org/prizes/physics/1956/summary/
9. https://www.nature.com/authors/author_resources/about_npg.html
10. Shneiderman, B.: The New ABCs of Research: Achieving Breakthrough Collaborations, p. 336. Oxford University Press, Oxford, UK. ISBN 9780198758839 (2016)
11. https://www.timeshighereducation.com/opinion/a-dangerous-downgrade-undervaluing-the-arts
12. https://www.thebritishacademy.ac.uk/news/diversity-subjects-essential-national-prosperity-post-brexit-warns-british-academy
13. Earnshaw, R.A.: State of the Art in Digital Media and Applications, Chapter 3, pp. 21–28. Springer, Switzerland. ISBN: 978-3-319-61408-3 (2017). For more information see: http://www.springer.com/gb/book/9783319614083
14. Friedman, T.J.: Thank you for Being Late: An Optimists Guide to Thriving in the Age of Accelerations. Penguin, London (2017)
15. Clark. J.: Netscape Time, p. 262, St. Martin's Press, London (1999)
16. Bruns, P.: http://researchdevelopment.byu.edu/wp-content/uploads/2012/12/Full_Report_Creating_Interdisciplinary_Science.pdf
17. https://www.nsf.gov/od/oia/additional_resources/interdisciplinary_research/
18. Committee on Facilitating Interdisciplinary Research, Committee on Science, Engineering, and Public Policy.: Facilitating Interdisciplinary Research, p. 2. National Academies, National Academy Press, Washington (2004). https://www.nap.edu/read/11153/chapter/1#xxvi, https://www.nap.edu/catalog/11153/facilitating-interdisciplinary-research
19. https://www.nsf.gov/od/oia/additional_resources/interdisciplinary_research/definition.jsp
20. https://ec.europa.eu/research/openvision/pdf/rise/allmendinger-interdisciplinarity.pdf
21. https://ec.europa.eu/futurium/en/digital4science/why-should-interdisciplinary-high-risk-research-disruptive-technologies-be-supported
22. https://re.ukri.org/about-us/
23. https://www.ukri.org/about-us/our-councils/
24. https://www.gov.uk/government/organisations/innovate-uk
25. https://re.ukri.org/research/interdisciplinary-research/
26. https://www.thebritishacademy.ac.uk/interdisciplinarity
27. https://www.globalresearchcouncil.org/fileadmin/documents/GRC_Publications/Interdisciplinarity_Report_for_GRC_DJS_Research.pdf
28. https://webarchive.nationalarchives.gov.uk/20170712122715/, http://www.hefce.ac.uk/pubs/rereports/Year/2015/interdisc/
29. https://webarchive.nationalarchives.gov.uk/20170712122426/, http://www.hefce.ac.uk/pubs/rereports/year/2016/interdis/
30. https://acmedsci.ac.uk/policy/policy-projects/team-science
31. https://acmedsci.ac.uk/file-download/52394024
32. https://ahrc.ukri.org/funding/apply-for-funding/archived-opportunities/gcrf-interdisciplinary-research-hubs/
33. Negroponte, N.: Toward a theory of architecture machines. J. Arch. Educ., March (1969)
34. Earnshaw, R.A.: Art. Design and Technology. Springer. ISBN: 978–3-319-58120-0 (2017). https://www.springer.com/gb/book/9783319581200
35. How David Hockney became the World's foremost iPad Painter, Wired. https://www.wired.com/2013/11/hockney/
36. https://en.wikipedia.org/wiki/Coldwar_Steve
37. Miller, A.I.: Colliding Worlds: How Cutting-Edge Science is Redefining Contemporary Art. W. W. Norton and Company (2014)
38. Wilson, S.: Art + Science Now: How Scientific Research and Technological Innovation are becoming key to 21st Century Aesthetics. Thames & Hudson (2012)
39. Virtual Amusement Park (VPARK). http://cordis.europa.eu/project/rcn/46555_en.html

40. Joslin, C., Molet, T., Magnenat-Thalmann, N., Esmerado, J., Thalmann, D., Palmer, I.J., Chilton N., Earnshaw, R.A.: Sharing Attractions on the Net with VPARK. IEEE Comput. Graph. Appl. IEEE Computer Society **21**(1), 61–71 (2001). https://doi.org/10.1109/38.895134
41. Virtual Interactive Studio Television Application using networked graphical supercomputers (VISTA). http://cordis.europa.eu/project/rcn/32297_en.html
42. Flerackers, C., Earnshaw, R.A., Vanischem, G., Van Reeth, F., Alsema, F.: Creating broadcast interactive drama in a networked virtual environment. IEEE Comput. Graphics Appl. **21**(1), 56–60 (2001). https://doi.org/10.1109/38.895133
43. https://en.wikipedia.org/wiki/Digital_art
44. Cox, D.J.: Using the supercomputer to visualize higher dimensions: an artist's contribution to scientific visualization. Leonardo **41**(4), 391–400 (2008)
45. Cox, D.J: Collaborations in art/science: Renaissance teams. J. Biocommun. **18**(2):15–24 (1991). https://www.ncbi.nlm.nih.gov/pubmed/1874707, https://muse.jhu.edu/article/243508, http://www.leonardo.info/isast/articles/popper.html, http://link.springer.com/chapter/10.1007%2F978-3-642-46954-1_28, https://datascience.lanl.gov/data/papers/Pursuing.pdf
46. http://swiki.cs.colorado.edu/CreativeIT/248.print
47. http://cargocollective.com/artscienceclimatechange/SciArt-The-confluence-of-art-and-science-in-conveying-the-uncertaintie
48. Yan, J.: Analysis of apple equipment in the product design thinking. In: International Conference on Advances in Management, Arts and Humanities Science (AMAHS 2016), Atlantis Press, 2016 (Open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/))
49. https://www.fastcompany.com/1665375/the-6-pillars-of-steve-jobss-design-philosophy, https://innovationmanagement.se/2017/06/22/lessons-from-apple-on-why-aesthetic-innovation-is-important/, https://www.cleverism.com/apple-product-design/
50. https://graphics.stanford.edu/papers/dmich-sig00/dmich-sig00-nogamma-comp-low.pdf
51. https://graphics.stanford.edu/projects/mich/
52. https://www.digital-science.com/resources/digital-research-reports/interdisciplinary-research-methodologies-identification-assessment/
53. https://digitalscience.figshare.com/articles/Digital_Research_Report_Interdisciplinary_Research_-_Methodologies_for_Identification_and_Assessment/4270289
54. Crow, M.M., Dabars, W.B.: Designing the New American University, p. 360. Johns Hopkins University Press, Baltimore, MD (2015)
55. https://newamericanuniversity.asu.edu/
56. Crow, M.M., Dabars, W.B.: Interdisciplinarity as a design problem: toward mutual intelligibility among academic disciplines in the American research university. In: O'Rourke, M.R., Crowley, S.J., Eigenbrode, S.D., Wulfhorst, J.D. (eds.) Enhancing Communication and Collaboration in Interdisciplinary Research, pp. 294–322. Sage Publications, Los Angeles (2013). http://methods.sagepub.com/book/enhancing-communication-collaboration-id-research, http://wwwhome.postech.ac.kr/web/eng/ecad_01_11
57. http://wwwhome.postech.ac.kr/web/eng/etc_01?p_p_id=EXT_BBS&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&_EXT_BBS_struts_action=%2Fext%2Fbbs%2Fview_message&_EXT_BBS_messageId=14790
58. Cox, D.J: Collaborations in art/science: Renaissance teams. J. Biocommun. **18**(2), 15–24 (1991). https://www.ncbi.nlm.nih.gov/pubmed/1874707

Further Reading

59. Sharp, P.A., Cooney, C.L., Kastner, M.A., Lees, J., Sassisekharan, R., Yaffe, M.B., Bhatia, S.N., Jacks, T.E., Lauffenburger, D.A., Langer, R., et al.: The Third Revolution: The Convergence of the Life Sciences, Physical Sciences, and Engineering, p. 34. Massachusetts Institute of Technology, Washington, DC (2011)

60. Frodeman, R., Klein, J.T., Mitchum, C.: The Oxford Handbook of Interdisciplinarity. Oxford University Press, New York, USA (2010)
61. Hage, J., Meeus, M.T.H.: Innovation, Science, and Institutional Change Oxford. Oxford University Press, New York (2006)
62. Holley, K.A.: Understanding interdisciplinary challenges and opportunities in higher education. In: Ward, K., Wolf-Wendel, L. (eds.) ASHE Higher Education Report, pp. 1–131. Jossey-Bass; Wiley Periodicals, San Francisco, CA (2009)
63. Klein, J.T.: Creating Interdisciplinary Campus Cultures: A Model for Strength and Sustainability. Jossey-Bass, San Francisco (2010)