Virtual reconstruction from scan to VR of architecture and landscape of a monumental park

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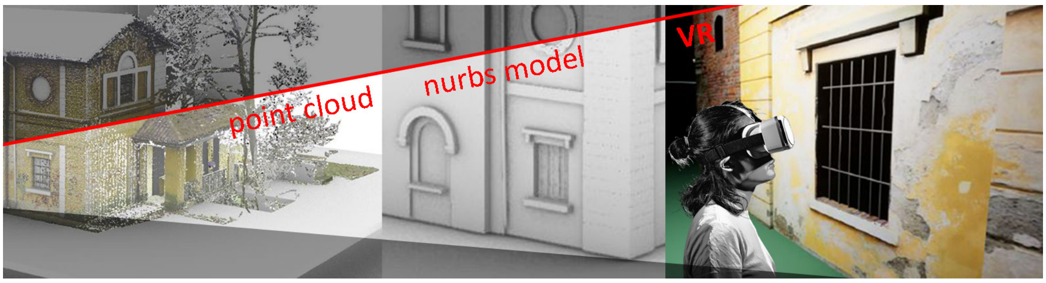
Abstract

The Monza Park, with its more than 7 square meters of green area divided between lawn and woods, its 110,000 tall trees, its 13 farmhouses, 3 historic villas, 13 m of fences and 90,000 visitors on spring Sundays, represents an irreplaceable source of wellness and sustainability for those who live near it. The pandemic situation of the 20s and 21s by reducing the movements and the possibility of coexistence of a large public in an open space has suggested the possibility of new forms of use and interaction of the same, even remotely, reproducing Virtual and Augmented Reality experiences. With this paper, the authors intend to illustrate a workflow from Scan to VR and AR applications, taking advantage of the opportunity to explore digital acquisitions and additional materials available and functional to convey the values and importance of open space and historical monuments immersed in them. The VR/AR experiences have been structured for navigation from the scale of architectural detail to the environmental one, which effectively ensures the fruition of one of the most significant and large historical walled parks in Europe. An unprecedented and still unique park made up of woods, meadows, cultivated fields, the Lambro, the farmhouses and villas, the mills inserted in an apparently natural but carefully designed environment.

Keywords
Active/passive sensor, laser scanning, photogrammetry, cultural heritage, AR/VR

Topics
Simulating / experimenting / visualizing



From left to right: point cloud, Nurbs and VR model with an accurate texture. (author's elaboration).

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Introduction

In the last years, thanks to the development of more and more powerful hardware technologies and software, able to exploit both the computational skills and the image processing, the dissemination through digital tools in the Heritage field have been developing in an increasingly extensive way [Joannides 2017]. In the field of digital culture related to heritage, the strands are intertwined concerting experiences that can bring to common factor historical, architectural and cultural issues declined through new experiences of storytelling mediated by the experiences of Virtual, Augmented or Mixed Reality [Russo 2021; Teruggi, Fassi 2021; Jouan et al. 2022]. The experience of digital fruition, or better, totally viral if not entirely immersive, has become part of museums and institutions, places that open their contents to an increasing number of scholarly enthusiasts or simple users with a thirst for learning [Aiello 2019; Spallone et al. 2022]. However, museum collections or architectural monuments, even complex ones, have had a relevant part in this field for dissemination, maintenance, conservation and restoration needs [Pietroni, Ferdani 2021]. In contrast, the cases of complex monumental environments or open spaces where architecture plays a decisive role equal to nature are not yet conspicuous. There are many research studies about the reconstructions of archaeological parks [Castagnetti 2017], historical complexes [Bolognesi 2019] and small historical settlements typical villages [Kargas 2019]. However, the park and open space virtual reconstruction, precisely because of its intrinsic qualities, has not yet found its maximum expression in virtual use for specific well-being uses. And yet, thanks to TLS surveys or the possibilities offered by photogrammetry, it is possible to obtain representations capable of supporting any analysis for both maintenance and recreational use; it is possible to obtain a digital model of any context by integrating multiple disciplines from the field of digital survey, modelling, representation to recreate even extensive environments usable in immersive environments to grow the paradigms of well-being even in moments where the visit of a natural place may be precluded [Jouan 2021]. For this reason, this study proposes an experiment to create a virtual environment of the park and some of its monumental architectures able to simulate an immersive recreational environment whose characteristics support the research on a double theme. The first is the reproduction of the open space where the buildings are placed on telescopes and perspective views; the second is the virtual reproduction of the buildings themselves. The architectures considered are 4 adjoining complexes that present common architectural characteristics and different uses linked to their location in the perspective corridors of the Park: Villa Mirabello, Villa Mirabellino, Cascina Cattabrega and the Mulino del Cantone. The survey activity of the latter is described, while the workflow describes the passages from the survey to the development of the virtual environment [Lombardia Beni Culturali 2021].

Mulino del Cantone digital survey

The *Mulino del Cantone* is located along the Lambro river inside the Park of Monza (MB). Built from 1840 onwards based on Giacomo Tazzini's design, it seems to have been an adaptation of a pre-existing building that contained a medieval brick tower from the 12th century [Pelissetti 2009]. The small tower (about 20m high on a rectangular plan of about 3mx6m) with Ghibellines battlements and a small, mullioned window is incorporated in the northwest corner of the mill. It is probably the only rest of the ancient Monza defensive line connected to the pre-existing and nearby Villa Mirabello. The original structure of the mill consists of masonry pillars, plastered solid brick masonry, a wooden beam floor and a pitched roof. It has two levels, and the mill took up the ground floor parallel to the river course. The derivation canal (Roggia al Lambro) runs in the centre of the rectangular building between two lateral blocks (on the east and west sides), connected to the south by a neoclassical façade. An arcade (about 4mx16m) on coupled columns surmounted by an entablature with metopes and triglyphs and a tympanum formed by a radial spire hid the wheels of the mills driven by the passage of water.

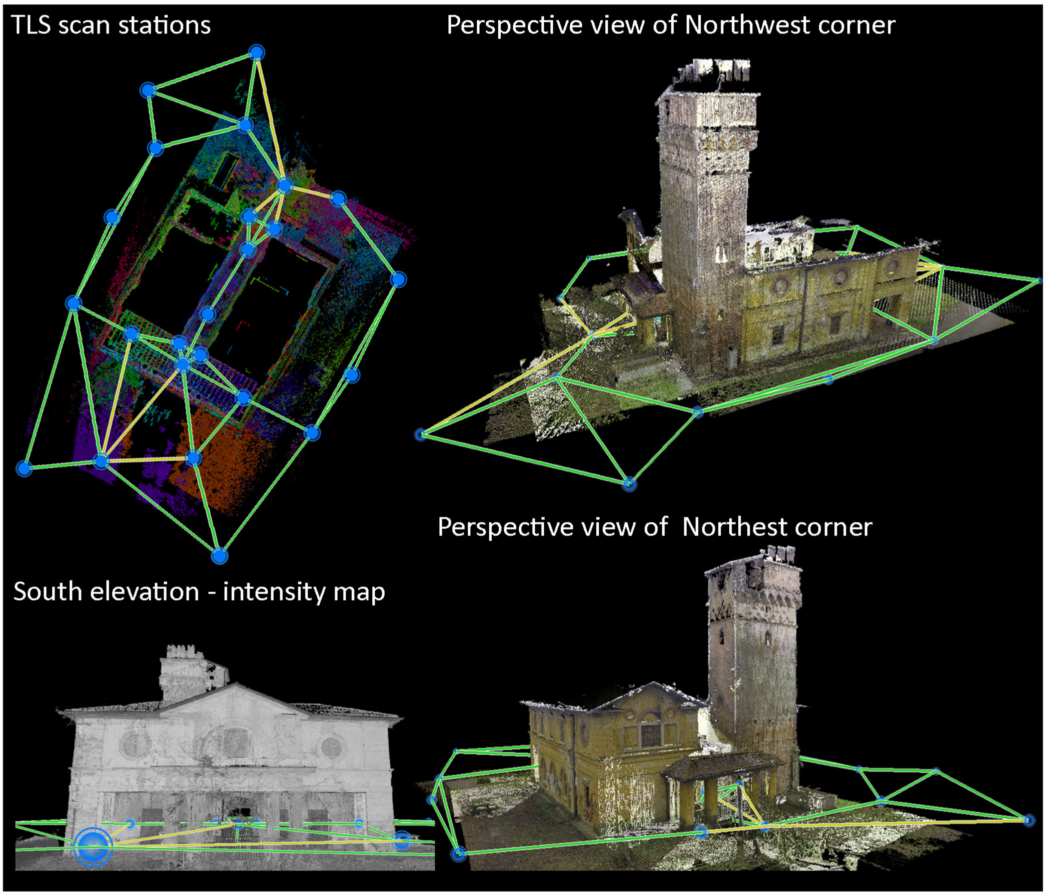

Fig. 01. Map of the scan stations and views of the mil total point cloud model (author's elaboration).

A Terrestrial Laser Scanner (TLS) survey was carried out to get the complete geometry of the building. The used Leica RTC360 is equipped with five cameras to track the scan stations and reconstruct the scanner trajectory with the Visual Inertial System (VIS). The integration of the IMU platform and the VIS allows a raw, real-time, on-site registration of the different scans. In addition, the instrument is equipped with 3 HDR cameras with five bracketing exposures for the simultaneous acquisition of 360° spherical panoramas, which are then used to colour the single point cloud (RGB values).

Setting the resolution of the individual scans to a value of 6 mm at 10 m, 25 scans were carried out using TLS: 20 to represent the external perimeter and 5 for the internal tunnel where the canal passed. Taking advantage of the VIS technology, which makes it possible to check on-site that the overlap among the scans is always greater than or equal to 50%, it was decided to acquire the data in target-less mode. The raw registration of the scans was then optimised using a cloud-to-cloud alignment algorithm within the Cyclone REGISTER 360 software, taking care to eliminate all vegetation around the main mill building.

Figure 01 shows the location map of the scans and the overall model of the mill without plants and vegetation used to optimise the global alignment. The cloud-to-cloud alignment of the group of scans is characterised by a final average deviation of about 4 mm, with a maximum value of 8 mm for a single pair of scans and an average overlap between the connected gripping stations of about 52%. Moreover, a small terrestrial photogrammetric survey campaign of the four main external facades was conducted using a Canon EOS 6D Mark II (Full-Frame CMOS sensor, 6240x4160 px, pixel size 5.75 µm) with a 24mm fixed lens. A total of 58 images were captured with an estimated average baseline of 3.20m. The acquired data were processed according to the classic photogrammetric pipeline: image orientation (internal and external), calibration optimisation (Tie Point filtering), scale, dense cloud elaboration (image matching), polygonal model and orthoimages.

Fig. 02. West facade. The coloured point cloud, orthoimage, and false-colour point cloud from left to right (author's elaboration).

Fig. 03. South facade. Orthoimage, coloured and false-colour point cloud from left to right (author's elaboration).

The photogrammetric project was scaled and referenced using the TLS survey. Finally, orthoimages of the four main fronts were extracted with a 5 mm GSD. Figg. 02, 03, shows different representation modes of the facades, using different TLS point cloud rendering and/or photogrammetric orthoimages. Previous research by the authors has focused on integrating active and passive sensor datasets. For the presented case study, TLS data integration into the photogrammetric project allowed to complete the representation of the highest areas (such as the medieval tower) that are difficult to detect with terrestrial acquisitions. This approach ensures an accurate alignment between TLS and photogrammetric point cloud, as is possible to appreciate from figures 02, 03, where the different datasets are integrated.

The park environment reference system and digital reconstruction

The use of data derived from different sources of a digital survey with advanced instrumentation and its transformation for creating a virtual recreational environment capable of increasing the knowledge of the places always requires analysis with respect to the purposes of the representation set as objectives. Added to this consideration are those related to the available instrumentation, in this case, TLS, mobile mapping systems but for reduced environments, instruments for terrestrial photogrammetry, 360° spherical cameras without a total station. This absence has reduced the choice necessary to create long perspective paths connecting one farmhouse to another when not contiguous and the mill itself. The known survey methods for the connection between the different surveys could have been different, for example (fig. 04):
- laser scan survey with long-range mobile mapping tools with the creation of a topographical network to support and use of recognition targets on a single building;
- laser scan survey with aerial photogrammetry using Drones with support of strategic recognition targets;
- video survey with 360 camera for a photogrammetric image processing always for the creation of 3D models with the consequent processing of a consistent set of data for the creation of a cloud of points of vast green areas and trees whose creation of meshes would be useless in a mapping process for VR.
For this reason, having obtained the models of the point cloud survey of the different farmhouses, we proceeded to join on a detailed DTM obtained from the Ministry of the Environment, Land and Sea - National Geoportal - with a 1m x 1m pitch, obtained from a high-resolution LIDAR survey of 2009. The data have an altimetric accuracy corresponding to an error of less than ± 15 cm, and the terrain modelling was found to be the most suitable for the correct location of the architectures. The open-source software used for the first reading of the data (QGIS) allowed exporting data in .dxf format for the NURBS modeller with the possibility to create, modify, analyse and translate curves, surfaces and NURBS solids. The terrain of the Monza Park was then modelled by generating a surface at the scale of detail offered by the DTM, interpolating the points. All the models of the buildings have been realised on point clouds with reference to a local reference system and have been manually placed in the global reference system of the DTM. It is important to pay special attention to the reference system. The reference system for Lombardy is on spindle 32; EPSG 7791. The imported data are in the reference system EPSG 4326, which is the reference system in which they were created and made available. The tool "Shading" allows the creation of a shaded map that provides a three-dimensional appearance to the topographic survey map. The command "Contour lines" was used for the generation of contour lines. The interval between contour lines was set to 1 meter and the option "Produce a 3D vector" was enabled. Then it was necessary to export the "Contour Lines" element in .dxf file format, specifying the geometry type "LineString", including the export data related to the Z dimension and inserting the correct reference system used for the project. The .dxf file relative to the contour lines was imported into the Rhinoceros software, and then the terrain modelling was carried out using the "Patch" command to generate an interpolating surface (fig. 05).

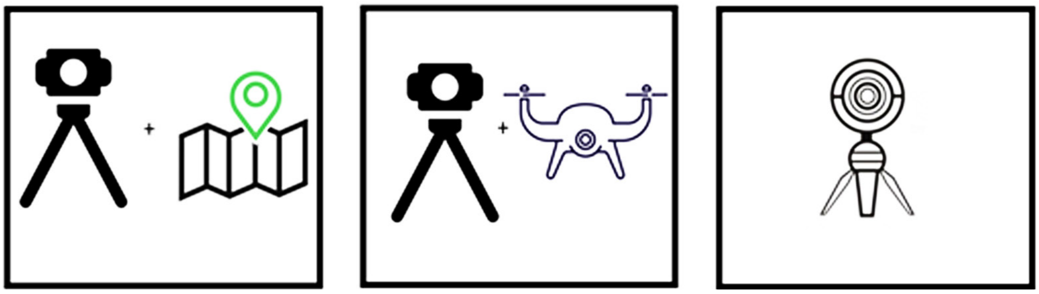

Fig. 04. Three possible survey systems for large and green environments (author's elaboration).

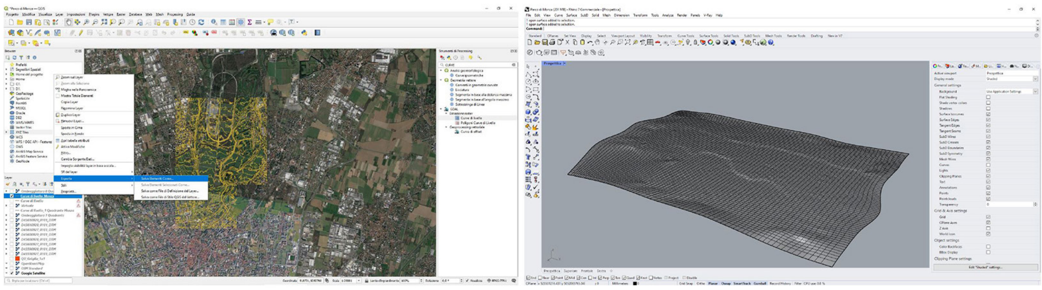

Fig. 05. On the left, the image shows what the vector of contour lines looks like; on the right image of the interpolated surface within the modelling software (author's elaboration).

Texturing for virtual environment

The historical reconstruction of the paths and the green axes of the park has required the management and processing of a large amount of data coming from different sources: TLS point clouds, photographic campaigns, and photogrammetric projects advantageous for the preparation of orthophotos, high-resolution textures for the final digital model. After the procedural step of positioning the buildings inside the park environment in their exact positions, the following phase is the reality-based modelling of the architecture (in this specific case of the mill) using NURBS modeller. Figures 06, 07 show the mill nurbs model generating using the TLS point cloud. The last step is designing the path inside the park (in progress research activity). Although the existing building is built on a previous building, the neoclassical features facilitate the process of modelling using the point cloud, given the simplified forms. However, the presence of the tower but especially the degradation detected on the plaster applied, in this as in the other buildings, complicate the production of a virtual-faithful model for the design of the desired immersive environment and aimed at the recreational experience of users. While the algorithms present in the NURBS modellers give a perfect correspondence of geometric and metric parameters, more complex is the attribution of those notes, textures, and shapes typical of heritage buildings within the platform used to develop immersive reality. Indeed if on the one hand, the growing need to transfer content, both cultural and recreational, pushes towards the use of open platforms for the management of virtual projects, allowing the creation of complex virtual environments such as this, the theme of the reproduction of the elements of coating geometries needs a decided in-depth study. Inside the Unreal Engine platform, the VPL allows a wide range of development of blueprints, useful to increase the experience in terms of movement and fruition. But the rich libraries of materials provided cannot meet the requirements of heritage modelling, which is necessary to increase the levels of immersion and interactivity if not by modifying them and using additional VPL nodes to modify materials in specially added platforms. The texture projection is never metrically accurate using the existing orthoimages. Nor stitching in V-ray nor application as Substance Painter presents sufficient accuracy, giving more the idea of an ancient fact than the realistic representation.

Fig. 06. From the point cloud to the Nurbs Model (author's elaboration).

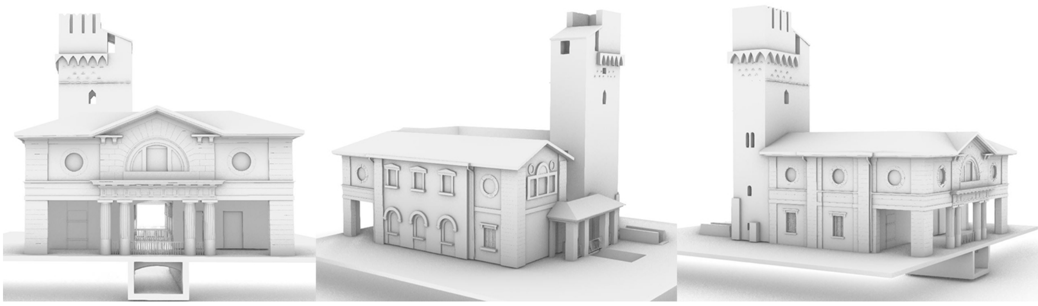

Fig. 07. The Nurbs Model (author's elaboration).

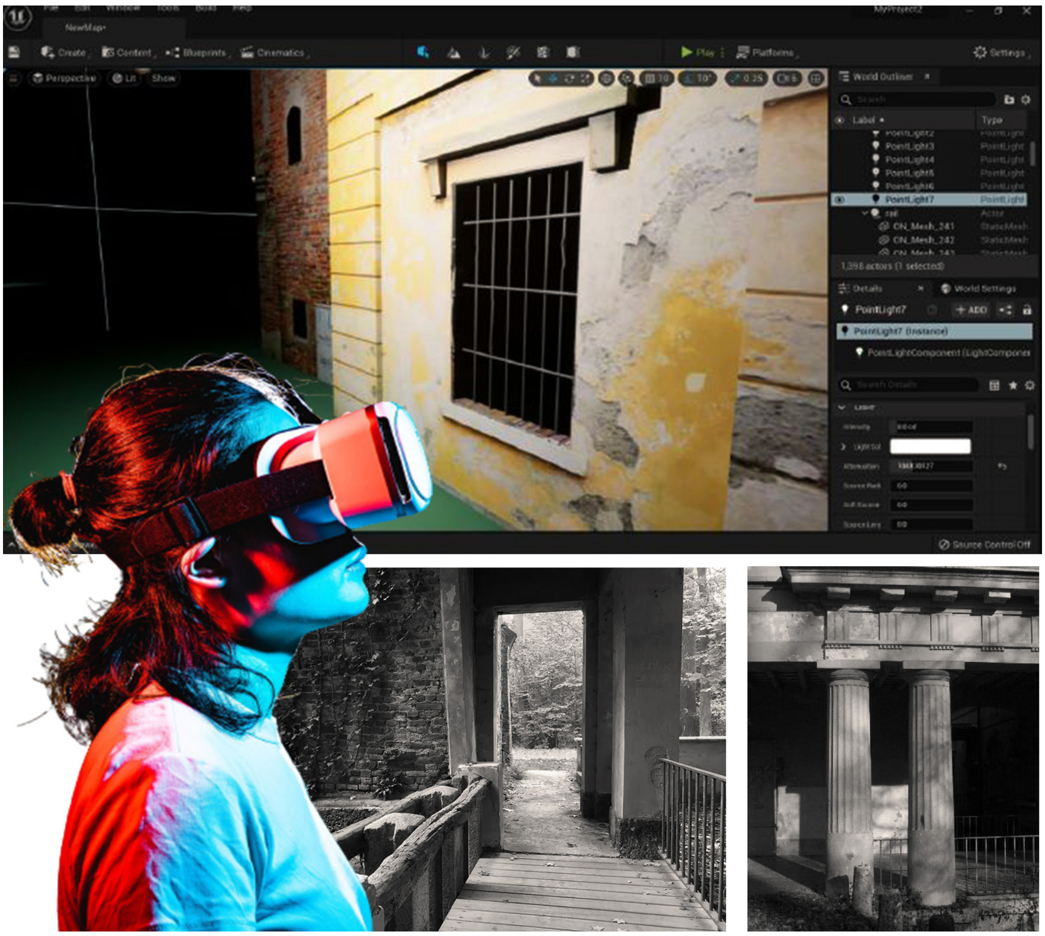

Fig. 08. Images from the VR platform with accurate texturing (author's elaboration).

Conclusion and future works

Research growing regarding the recreating virtual environments topic is multiplying with increasingly complex scenarios. In this summary workflow, we have outlined a scientific modelling and texturing procedure that interfaces with tools for creating virtual environments that are not born with the need for faithful reproduction of the existing but offer different possibilities for its interpretation. However, the virtual environment reproduction for cultural and recreational fruition cannot do without certain adequacy of detail, proper materials and vegetation, which we have not dealt with here. All these parameters become an element of a substantial distinction between the sphere of pure recreational entertainment and the recreational purposes with foundations of knowledge. Future researches have to deepen these themes, experimenting with faster and faster workflows to texturise at best in VR environment without having to deal each time in a specific way with issues regarding the direction of the UV, the scalability of the textures, the use of light on them, difficulties related to file dimension and time for the creation of maps or all those elements that are actually missing in a virtual experience to make it as communicative as a real one.

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