Methodology and evaluation of digital assets reconstruction of cultural heritage with visitor participation in museum

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Abstract

On the basis of hardware conditions, the 3D digitization of cultural heritage entities still requires a lot of human resources. In a short period of time, it is difficult to obtain a large number of 3D models of cultural heritage with conservation and communication value under the current mainstream production process. The ability of smartphones in photography and video has been enhanced by the mutual emphasis of manufacturers and consumers, and it is gradually becoming possible to generate reliable 3D models from the photos taken by them. In addition, the images generated by the large number of visitors taking pictures of objects and other content in museums provide a large amount of potential data for the digitization of cultural heritage. This work aims to examine the reliability of 3D entities of cultural heritage generated using images of cultural objects recorded by visitors in museums through mobile camera devices such as smartphones and to verify the value of the application of the models. The method can provide a way to quickly record large amounts of data for cultural heritage conservation with sufficient accuracy and ease of use, making it a potential alternative to traditional methods that rely on specialized personnel and specialized equipment, such as photogrammetry or laser scanning with specialized equipment.

Author keywords

Digital assets; 3D reconstruction; Cultural heritage; Mobile devices.

Introduction

Background

In the digital era, the primary work of systematically constructing digital resources of cultural heritage is to carry out the digitization project of cultural relics and realize the transformation of cultural relics from material form to digital form. Three-dimensional digitization has become a common practice in cultural heritage conservation, but there are still some problems. On the one hand, the equipment used for digitization of cultural relics, such as laser scanners or camera arrays, is mostly expensive and requires specification of the operation, which requires a certain amount of money and human resources. On the other hand, because the workload of digitizing cultural relics is large and difficult, the staff needs to have basic operational knowledge and experience in data acquisition and processing. Therefore, the work is usually done by cultural and museum institutions or professional teams. Cultural and museum institutions usually use professional recording equipment and follow standardized operating procedures to complete the digitization of cultural relics. Both the data kept within the institution and the models open for public viewing have high-quality information recorded in terms of form and color.

Today, the improvement of digitization technology has made digitization significantly less difficult. Structured light (Rocchini, 2001), encoded light methods, and photogrammetry are all mainstream methods for 3D scanning. Among them, photogrammetry, with the optimization of algorithms and the improvement of the performance of image acquisition equipment, has had the effect of significantly reducing the cost of both acquisition and computing (Pavlidis, 2007). Individual use of camera equipment, with software such as RealityCapture or Metashape and other related processing software, allows you to do the three-dimensional digitization of real entities. Even ordinary people can go digital by using their smartphones (Boboc, 2019). This undoubtedly reduces the resources and learning costs of the process of digitizing the real world in 3D, making everyone a mover of 3D information in the physical world and a producer of assets in the digital world. Among the models in the public 3D content center sketchfab, the model assets under the "Cultural Heritage and History" tab are both produced by professional cultural and historical institutions and also by users themselves. The majority of them are produced using multi-image generation methods.

Even in the three-dimensional technology is so convenient now, there are still a large number of cultural relics in cultural and museum institutions have not been established a digital model file, but also can not get a large number of preservation, dissemination value of cultural heritage digital model in a short period of time. This is both because the calculation and processing of data requires considerable computing power and time, and at the same time requires considerable human resources to complete the image acquisition work used to generate the model. At the same time, as mobile camera tools are widely used by museum visitors, more and more "wild digital images" of cultural heritage are being produced (Makantasis, 2016). Widely uploaded to online platforms such as social media or stored on users' devices, they are not considered valid data for the preservation of cultural heritage, but constitute potential content for its digitization. With the help of device updates, visitors have generally become capable of digitizing cultural heritage at the two-dimensional level. Although they are still not widely practiced at the three-dimensional level, an opportunity does exist to enable every visitor to the museum to participate in the preservation of cultural heritage. This enriches the museum experience while saving institutions significant human resources costs and enabling the rapid reconstruction of digital assets (Mingyao Ai, 2014).

Purpose

This research aims to check the reliability of 3D entities of cultural heritage generated using images of artifacts recorded by visitors in museums through mobile camera devices such as smartphones and to verify the value of the application of the models. The main focus is to compare models generated through multiple devices (smartphones, cameras) and methods (structured light, encoded light, photogrammetry), demonstrating that phones are quite effective as data acquisition devices for photogrammetry for 3D reconstruction of tangible cultural heritage, providing morphometric data comparable to laser scanning results and easier-to-use color information.

Based on this, a participatory approach can be designed to help subjects or visitors complete the photography of the collected objects more efficiently and with high quality, and a real-time visual participation system is used to complete the guidance of the visitors' photography and provide real-time feedback of the results. Finally, the quality of the obtained model results is checked.

Methodology

The study is divided into two main phases, and each phase contains a variety of practical and testing steps.

Digital practices in the Hunan Museum scenario

The first phase of the study was designed to verify the ability of visitors to obtain relatively accurate and usable digital assets in the current real-life museum scenario. The 15 volunteers who participated in this phase need to enter the Hunan Provincial Museum as ordinary visitors, select artifacts displayed in the museum as their digitized objects, and use their mobile devices (cameras or smartphones) to complete the multi-view photography work and finally generate a polygon with color information.

Most of the participants had no experience with or knowledge of polygon modeling and had never been exposed to 3D inverse knowledge like photogrammetry before, so they needed to learn and practice some relevant knowledge and skills in advance before starting the practice, including the following:

1. An explanation of the fundamental principles of photogrammetry to give volunteers an idea of what to expect during the acquisition process.
2. A photogrammetry lecture designed to help participants quickly master the methods and techniques used to generate a set of high-quality images for 3D modeling. Also, participants will be asked to take photos of an object with at least three horizontal tracks and at least 60 photos to make sure there are enough images for model generation.
3. Practical shooting exercises and model generation tests. Participants test their learning by taking pictures of pre-prepared acquisition objects and generating models.

The entire learning process was kept to less than one hour, and most people obtained excellent-quality 3D models after only one practice session. Afterwards, the volunteers started a two-hour tour and photography practice, at the end of which the images were collected and used to generate 3D models, which were then tested and evaluated.

Figure 1. The state of aging of the collected objects in the Hunan Museum.

Usually, the quality inspection of 3D models obtained by reverse scanning is done by matching and comparing them with the original digital model. Since there is no absolutely accurate native digital model of cultural heritage entities, new ways and methods are needed to evaluate the latter models. A cross-sectional comparison of the results of multiple models obtained by different equipment or processes for the same collection object to draw conclusions is the accuracy test method used in this study. The distance difference of the meshes can be used as a basis for judging the accuracy of the reconstructed model shape. In addition to this index, the evaluation of the digital reconstruction model of cultural heritage should also be done in terms of speed, cost, the ability to acquire complex forms, and the ability to acquire color information.

User actions and model generation validation under two scenarios

In the second phase of the experiment, two simple acquisition environments for the multi-view reconstruction method were designed for inexperienced visitors, and the main goal was to avoid the generation of low-quality acquisition images while reducing instructions.

The first scanning space solution consisted of two soft lights, an automatic turntable, and a pre-positioned camera, with the rotation of the turntable set to 18 degrees at a time and the vertical height of the camera set to three positions so that the line from the center of the turntable to the camera was angled at 20, 40, and 60 degrees from the plane of the table. The object is placed on the turntable, which rotates every time the camera shutter is pressed, and the camera position is adjusted upon completion of the turnaround, resulting in 60 images for model generation. Anyone can use the space, and the user can easily get the information they need by pressing the camera's shutter button and changing the height of the camera when the turntable is done turning.

The other space consists of only a light box and a manual turntable. The subject is placed on the turntable, and the user manually controls the turntable and uses phone to take multi-angle shots. Unlike the previous method, the user's cell phone is connected in real time to the computer responsible for model generation in order to visualize which images have been aligned and point cloud data generated, and which locations need to be supplemented with new images.

Figure 2. Two acquisition environments

After a brief evaluation of the experience of the two processes, the quality of the newly produced digital model is verified. Prior to this part of the validation, a high-precision laser 3D data was prepared and compared with the experimentally produced digital model to verify the accuracy of the latter.

Results

Model quality

The quality of the final model was excellent even though there were some limitations in the real museum environment, such as the glass covering the collection, uneven lighting, etc., which created some obstacles to the image acquisition of the visitors. The digital models created from the images captured by the volunteers were not only true to form, but also contained color information with a lot of detail that can be used directly in digital scenes such as digital archives, film and television productions, and online exhibitions.

In the first phase of the experiment, two visitors used a camera and a smartphone as the image acquisition devices to reconstruct the " Bronze square ding (cauldron) with human faces" in 3D to obtain results A and B respectively (Figure 3). After aligning the two, the grid distance between A and B was calculated using A as a reference, and the average value of the mesh distance was about 0.0044, with no obvious error in the shape of the two (Figure 4). The accuracy of the digital shape is still guaranteed even when using a smartphone, which is inferior to a camera in terms of pixels and professional parameters, as the acquisition device. Although not as good as professional cameras in terms of color and grid detail, the more popular mobile devices have greater ability and potential to provide a large and useful digital asset of cultural heritage.

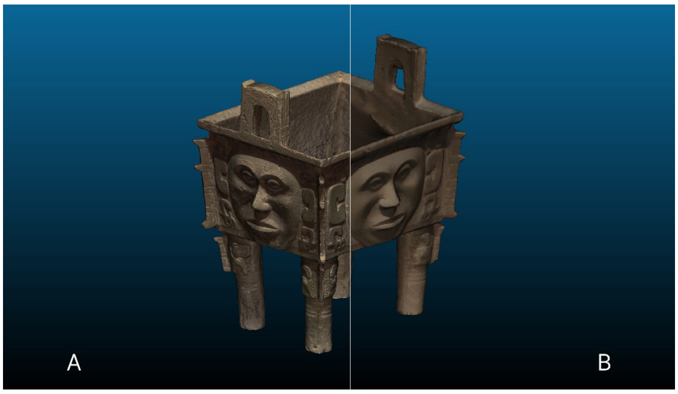

Figure 3. Model results obtained by using a camera and a phone as acquisition devices in the museum.

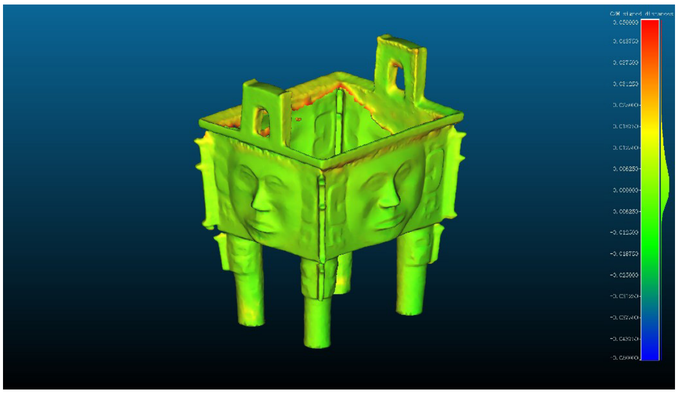

Figure 4. The mesh distance between the model obtained from the phone and the camera in the museum.

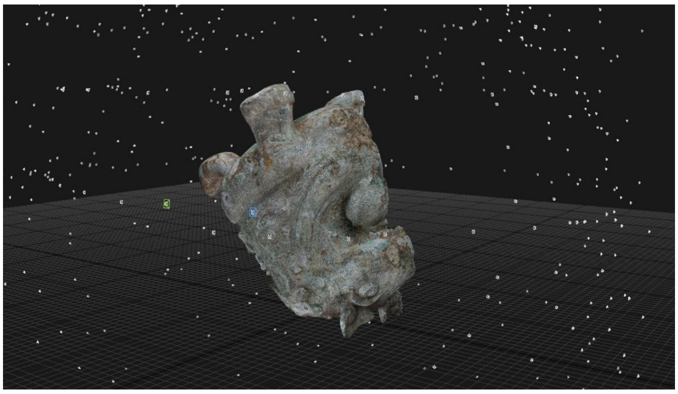

Figure 5. Model results obtained by phone in the laboratory.

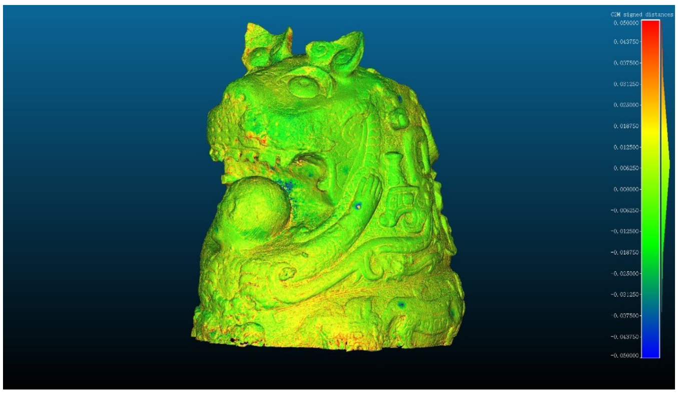

Figure 6. The mesh distance between the model obtained from the phone and the laser scanner in the laboratory.

In a more well-lit and less constrained acquisition environment, with real-time feedback of acquisition information, smartphones can perform 3D reconstruction faster and better, as reflected by a more detailed and color-accurate model mesh (Figure 5). In addition, if redundant image information is provided using different devices, the model quality can be further improved, although the computation time increases.

User experience

Most participants were pleased that they were able to create a digital resource about their cultural heritage and were willing to continue to participate in this work. Most visitors were more comfortable using their mobile devices to reconstruct objects in 3D than to scan them with a simple press of a shutter, although they may be tired of the process or unsure whether their images would produce valid results. In addition, the real-time feedback of scanning results on the screen or the use of AR to guide the user to the best shooting position can calm anxiety and enrich the experience of participating in the digital preservation of cultural heritage.

Conclusions

In summary, visitors can use their own mobile devices to digitize cultural objects, although there are limitations in the current museum environment that affect the quality of the 3D reconstruction results. At the same time, museum institutions can value the ability and willingness of visitors to create cultural heritage image resources, actively provide opportunities for visitors to participate in digitizing cultural heritage, optimize the user experience of creating digital assets through AR and cloud computing, and provide new, fast, and sustainable paths for cultural heritage preservation and digitization.

In the future, the role of visitors in museums will also gradually transform from being educated and entertained to being conservators and builders of cultural heritage. Public participation in cultural heritage conservation is the key to addressing the current crisis in cultural field, and new and proven technologies and products need to be brought to the public in order to awaken more potential forces and tap into hidden resources for this cause.

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