Application of 3D Printing Industrial Robot in Ceramic Relic Protection and Repair

Jia-zheng ZHU
Nanjing Normal University, Nanjing, Jiangsu, China

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Abstract. The restoration of historical artifacts of ceramics has always been an urgent problem to be solved by the cultural relics community. With the popularization and development of 3D technology and 3D printing industrial robots, it has the characteristics of non-contact scanning and high adaptability. In the process of copying and repairing cultural relics, it has many advantages that cannot be compensated in the traditional process. This paper focuses on the process and method of applying 3D printing industrial robots to the restoration of such cultural relics. After a brief introduction to the 3D printing process, the application of the restoration of cultural relics is divided into three aspects: three-dimensional scanning, reverse modeling, database establishment and cultural relics derivatives, which explains the practicality, efficiency and convenience of it. An example demonstrates the process of combining 3D printing technology with traditional processes to further enhance the protection of cultural relics.

Introduction

Most of the cultural relics have high historical value, artistic value and the characteristics of non-regeneration, but at the same time there is damage caused by fragile, oxidized and other factors [1]. Therefore, the protection and restoration of cultural relics has always been an important part of the collection of cultural relics, especially the museums that collect all kinds of precious cultural relics. Many technologies in the traditional repair process need to be implemented on the cultural relics, which increases the possibility of secondary damage to cultural relics. Therefore, 3D technology and 3D printing industrial robots have been widely used in the restoration of cultural relics due to their high precision, flexible use and non-contact scanning.

In cooperation with Nanjing Museum, 3D printing of industrial robots is used for the repair of ceramic damaged cultural relics, including reverse modeling of broken pieces, generation of robot motion sequence, control of feed pressure tank, temperature control sintering of printing parts and post-processing to carry out the exploration and application of ceramic relics restoration. Through the exchanges with the Nanjing Museum of Cultural Relics Science and Technology, a preliminary cooperation intention was reached.

On the basis of the 3D printing industrial robot system, for the restoration of ceramics artifacts in the museum, the pressure of the feeding tank is controlled to meet the requirements of the viscosity
and fluidity of the printing materials. After obtaining the copy of the cultural relics, the surface is colored and Finishing, and complete the replica of the artifact. 3D printing technology can not only play a role in the reproduction of cultural relics, but also can make up for the shortcomings that cannot be avoided by traditional techniques. With its high efficiency, precision and non-destructive characteristics, it can play a huge role in the field of cultural relics restoration.

3D Printing Technology

3D printing is a manufacturing method that is completely different from the processing method for removing materials in the conventional process. It directly manufactures a three-dimensional physical model manufacturing method that is completely consistent with the three-dimensional CAD digital model by adding materials, usually in a layer-by-layer manufacturing manner.

3D printing has four major advantages: Firstly, 3D printing is direct digital manufacturing. The product is directly produced by 3D CAD digital model which greatly reduces the cost and efficiency of production. Secondly, 3D printing is completely customizable and unique. Its product design is diversified and the cost is almost unchanged. Thirdly, before the production of the finished product, only the data needs to be transmitted, which greatly facilitates the characteristics of the cultural relics that are not easy to handle. Fourthly, we can maximize the characteristics of printed materials, improve the utilization of special materials and avoid waste in the field of cultural relics repair.

The mainstream 3D printing process can be divided into the following categories: SLA, LOM, SLS, FDM, 3DP, etc. These molding methods have their own advantages and disadvantages, and the molding method used for restoration of cultural relics should be determined on a case-by-case basis. At the same time, the 3D printing robot we applied also solves the defect of small print size of ordinary printers.

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Three-Dimensional Scanning

The non-contact measurement is realized by the laser scanning device to convert the stereoscopic information of the physical object to be repaired into a digital signal that can be directly processed in the computer, and the efficiency and precision thereof are extremely high. The reconstruction of the three-dimensional model of the geometric model can be realized by using the CAD/CAM software to receive the stereoscopic size data obtained by the scanning.

In this paper, the scanner is a very common photo-type white light scanner. When using the camera to capture the flash to illuminate the object, the scanner can receive the reflection from the surface of the object due to the curvature of the surface and the distance. The information of the scanned object carried by the returned light, the reflected light changes with the movement of the scanner, and the recognition software captures these changes in real time for data analysis and processing. The flash has a frequency of up to 16 Hz and an accuracy of 0.035 mm. In addition, the scanner can capture the texture and color data of the target object at the same time.

![Figure 2. 3D scanning, modeling and printing.](image)

Reverse Modeling and Artifact Restoration

Through the computer CAD system, it is possible to adjust and modify the three-dimensional size data of the scanned artifacts, and then send them to a professional manufacturer or print them on the
rapid prototyping equipment. Therefore, if there is damage to the surface to be repaired or there are holes or missing parts, the reverse design software can be used to properly process the data. Reverse reconstruction of scanned images is also a particularly critical part of artifact restoration.

![Figure 3. Example of reverse modeling.](image1)

![Figure 4. Replicated artifacts.](image2)

The work of reverse modeling is mainly divided into two aspects, one is spatial position reconstruction. And the other is surface reconstruction, which is the appearance texture reconstruction. For the former, there are quite a few techniques that can be solved, and the latter, the appearance texture reconstruction, is also an important part of reverse modeling.

Aiming at the problems of appearance texture reconstruction, this paper proposes a set of fast, complete, high-quality texture reconstruction methods, which provides good basic data for three-dimensional reproduction, digital protection of digital objects and digital museum display[2]. The methods are mainly reflected in three aspects:

Firstly, in order to make the texture image more clear, a high-resolution SLR camera is used as the acquisition device.

Secondly, using the illumination model based diffuse reflection component, specular reflection component, ambient light component solution algorithm to remove the influence of light attenuation and ambient light in the texture.

Finally, by precisely calibrating the input and output devices, ie the CAD system and the scanner, the scanner captures the color accurately, so it is more realistic in terms of color reproduction and consistency, so that the printer can faithfully represent the color.

After the reverse modeling is completed, the 3D printing robot can be used for 3D printing in the place where the repair is needed. When trimming, bonding, and aging, the secondary damage to the cultural relics can be minimized during the repair process.

### Cultural Relics Replication and Database Establishment

The museum usually contains many cultural relics damaged in the natural environment. Most of these cultural relics are not suitable for exhibition or transportation. The museum will display some replicas of cultural relics in the exhibition for the integrity or educational effect of the exhibition. For viewers to visit [3]. Therefore, some exhibits must be replaced by some copying. However, in order to avoid the viewer’s respect for the authenticity of the cultural relics. Suspect, it is necessary to imitate a replica that is closer to the prototype.

Now through the above-mentioned three-dimensional scanning and modeling process of cultural relics, a 3D printing industrial robot can print an imitation of any size of cultural relics, and then the professional processing has reached the goal of approaching the real thing.

In addition, China's museums currently have less data in the database and are inconvenient to use. [4] Therefore, through 3D technology, under conditions, it should be established for precious, vulnerable and endangered cultural relics, or even any identified cultural relics. 3D data files to be called at any time in the construction of digital museums. In this way, even if some precious cultural relics are destroyed in accidents or disasters, they can still retain their original data and copy and reproduce them through 3D printing technology [5].
Cultural Relics Derivatives

Cultural relics are the continuation of history, the inheritance of culture. And the original cultural relics as the blueprint make the integration of cultural relics into the products, so that the cultural relics derivatives have a rich variety of patterns. At the same time, it is also different from the traditional product's satisfaction with the functionality, incorporating the elements of culture. While satisfying the function, it also satisfies people's demand for appreciation of beauty. The viewer's consumption of derivatives is actually the new way of communication of culture for cultural relics and traditional people. Beijing Pearl Palace Headquarters Headphones and ‘Empire knows’ Tape of the National Palace Museum in Taipei are two best examples.

3D printing dramatically shortens the cycle and efficiency of production, and its advantages are maximized in this personalized and open-designed product. 3D technology can also be used to manufacture complex items without increasing costs. It eliminates the need for direct mold production and eliminates the need for assembly steps, saving a lot of labor and transportation cost.

Application Examples of 3D Printing Industrial Robots in Restoration and Reproduction of Cultural Relics

Taking this partially damaged Guan Gong image as an example. Using the photo-curing printing method, the prototype of the object is first scanned by a camera scanner, and reverse reconstructed by Geomagic Spark software to obtain a complete three-dimensional image. Then 3D printing is performed. Because the copy and repair only need to print the shape, the printed photosensitive resin imitation outer wall is thinner than the original [6]. As shown in the following figure, it is the experimental process of 3D printing in this case of the local damage of Guan Gongxiang cultural relics restoration application, which also includes the part of building the database and using holographic projection to display the museum.

Problems in 3D Printing Industrial Robots in the Protection of Cultural Relics

3D printing technology has many advantages over traditional repair methods, but it still has limitations due to some factors.

Firstly, the protection of cultural relics is more special and more professional than traditional industries, and 3D printing is still a new technology in the application of museum restoration. The
scarcity and cultivation of technicians is the biggest constraint factor. Because of the non-renewability of cultural relics, the requirements for the operation of equipment for the restoration of cultural relics through 3D printing are higher, and there is also a certain knowledge of cultural relic protection. These require new technicians to keep up with 3D printing technology and artifact restoration.

Secondly, due to technical and material factors, 3D printed models generally have a single color and the printed models still need to be professionally colored. In addition, the maximum reduction of cultural relics is a requirement for restoration of cultural relics. Some of the early pottery were mostly made by hand or some other rough way. The surface left many traces of production, and they are generally older things, with many traces of use or erosion. This is demanding on the accuracy of 3D printing.

Thirdly, 3D printing cannot be interrupted, and the process can't be interfered by external factors. Otherwise, a break may cause the printed finished product to be flawed at the break.

In short, in addition to the continuous maturity of technology, to maximize the role of 3D printing in the restoration of cultural relics, we still need continuous research, summary, feedback from professionals, and finally achieve the perfect combination of traditional restoration techniques and modern technology. 3D printing technology is completely integrate into the restoration of cultural relics.

Conclusion

Because China's cultural relics protection regulations require that cultural relics restoration and reproduction work must ensure that cultural relics are carried out under absolutely safe conditions [7]. With the development of 3D technology, it has the characteristics of three-dimensional reconstruction of non-contact scanning, in the reproduction of cultural relics. During the repair process, the risk of secondary damage caused by processes such as overturning and replenishing in the traditional process is avoided. At the same time, 3D printing industrial robots can adapt to the various needs of different materials and cultural relics, which can greatly improve the efficiency of traditional cultural relics restoration. In recent years, it has gradually popularized and better integrated 3D printing technology into cultural relics restoration programs. Therefore, 3D printing technology is very necessary in the field of cultural relics repair. This also requires the accumulation of experiments by many professionals, summing up experience and perfecting this technology.

References

