Research on Three-Dimensional Reconstruction and Augmented Reality Demonstration for Foshan Ceramics

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***Abstract*—In this paper, regarding to the fragility and surface erosion problems of Foshan ceramics, we discussed the methodology and technology of 3D reconstruction and virtual demonstration for Foshan ceramic object and cultural relics. We adopted Reverse Engineering technology to rebuild the shape of object by capturing point-cloud data from different angle, encapsulating and fitting these data into triangular mesh model. We then utilized Augmented Reality to achieve the virtual demonstration of ceramic object, which integrated the 3D reconstructed model with real environment from digital camera. To get a better interaction experience, we have developed a demonstration system with osgART and its scene graph, which can position ceramic object by a mark, transform digital model by mouse and menu, and display brief information. The developed technology and methods can be used in digital preservation of ceramic cultural relic and product design, evaluation or demonstration**

Keywords-three-dimensional reconstruction; augmented reality; Ceramics; virtual; demonstration

I. INTRODUCTION

China is the land of porcelain, the ceramic art and articles are the important parts of the Chinese traditional culture. The city of Foshan in Guangdong Province has gotten the fame of the key southern city of the ceramic culture. Foshan traditional ceramic, called Shiwan ceramic or Shiwan doll (Figure 1), has rich sources of subject matter, unity of form and spirit, and superb vividness. Its craftsman's technique has a variety of techniques and its artworks have characteristics of thick sidewall and glaze layer, and greasy enamel by furnace transmutation with heaviness, simple and mottled elegance [1].

Because of the fragility of ceramic cultural relics, and other problems such as surface erosion attacked by acid rain, the digital technology was put forward to protect the ceramic objects and cultural relics. The shapes of Shiwan doll are very complicated and contain many complex surfaces, which cannot be simply expressed by the mathematical equation like the curve of cylinder or sphere. Therefore, it is very difficult to directly reconstruct these ceramic objects using three-dimensional (3D) software such as SolidWorks, UG, 3Dmax, Maya and so on with high accuracy [2]. Consequently, the methodology of Reverse Engineering (RE) was adapted to reconstruct 3D ceramic objects in our work. Furthermore, the obtained data are utilized by Augmented Reality (AR) technique for demonstration and integrated display with real environment.

FIGURE I. CERAMIC FIGURE OF LAO ZI CREATED BY ZHONG RURONG

II. 3D RECONSTRUCTION BASED ON RE

A. *Study on the Methodology of Reconstruction*

Reverse Engineering (RE), also called as back engineering, is to reconstruct CAD model according to the data measured from the existent real product or physical model [3]. This model can be used for multiple purposes such as analysis, modification, manufacturing, inspection so on. RE includes two important aspects (Figure 2): one is datum acquisition from the objects, and the other is the reconstruction of curved surface.

The surface data acquisition methods of real objects can be divided into two types: contact and non-contact type. The contact measurement method is a trigger type which is based on the principle of force deformation, and the three-Coordinate-Measuring Machine (CMM) is the typical equipment. Though having the advantage of high accuracy, it needs point by point measurement with very low speed. The main methods of non-contact type consist of laser triangulation measurement method, laser distance method, optical interference method, image analysis method and so on [4]. It has the characteristics of fast acquisition speed, higher accuracy and great price advantage, which has the most extensive RE application.

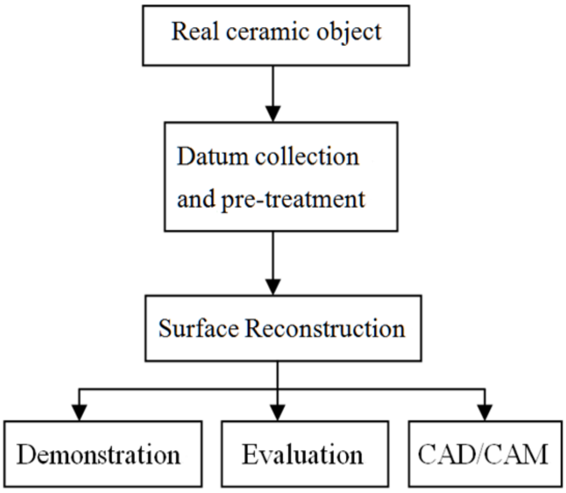


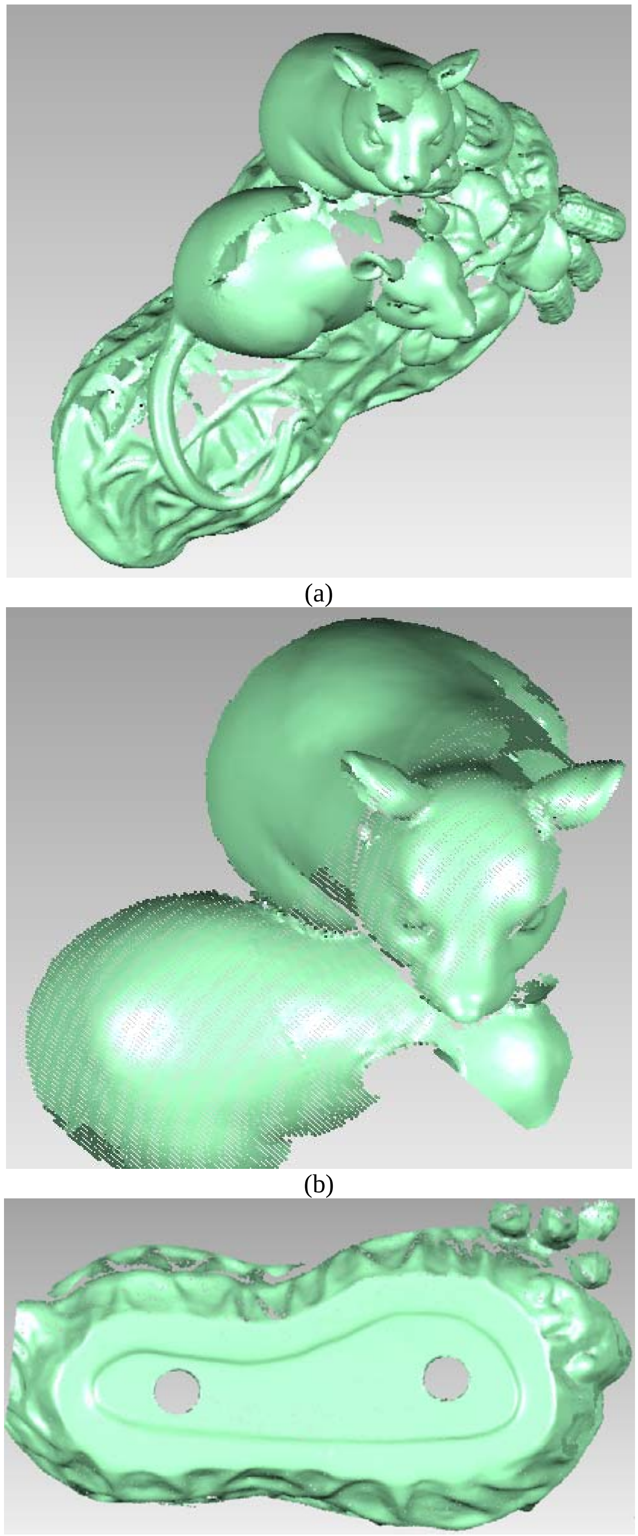
FIGURE II. FLOW CHART OF RE

B. Collection of Point-Cloud Data

In our research, the ceramic objects——Zodiac of rat (Figure 3) was used as examples. Non-contact three-dimensional laser scanning machine was used to collect the data.

FIGURE III. CERAMIC ARTWORK OF RAT ZODIAC

Due to the complexity of these models, it is impossible to accomplish scanning all the surfaces in one step, so the scanning was done by many times. Taking the zodiac of rat as an example, the artwork was firstly overall scanned after being placed in the normal position, shown in Figure 4 (a). Then, the upper surface of the artwork was scanned with its left side down in order to make the top surface towards the laser scanner (Figure 4. (b)). Finally, the rest blocked parts of the object were scanned, and a series of point-cloud data were obtained (Figure 4. (c)).



(c)

FIGURE IV. POINT-CLOUD DATA FROM DIFFERENT SCAN

C. Data Processing

After the objects were scanned, the obtained point-cloud data needs to be post-processed. Here, we use an open-source software, Meshlab, to accomplish these jobs. Meshlab is free and open-source software is developed by the ISTI - CNR research center, which is oriented to the management and processing of unstructured large meshes and provides a set of tools for editing, cleaning, healing, inspecting, rendering and converting these kinds of meshes. Some job such as removing hot pixels (noise) and separated units was done by Meshlab. Cloud-data aligning and merging were also done by coordinate matching, and the completed point model was then obtained. (Figure 5).

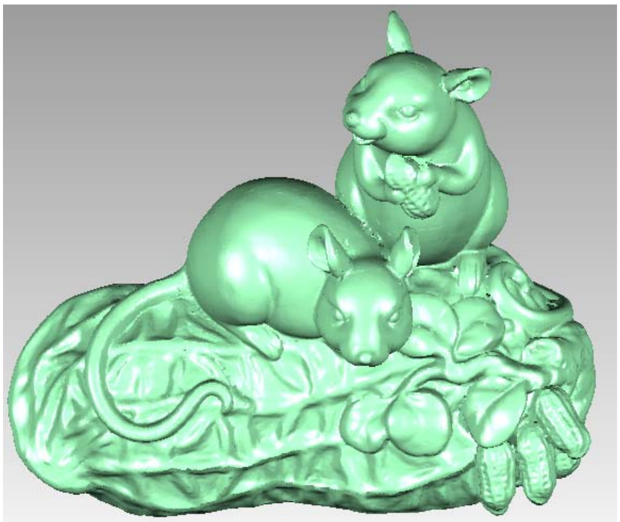


FIGURE V. RESULT OF POINT MODEL AFTER SPLICE

This model still consisted of large number of point-cloud data, which make the size of digital file very large, thus it needed to be optimized to meet the final goal of application. After a reasonable number of point-cloud data is reached, data encapsulated and fitted needs to be done to obtain triangular meshes of the model. 3D reconstruction was finally finished by exporting it into 3D modeling software (Figure 6).

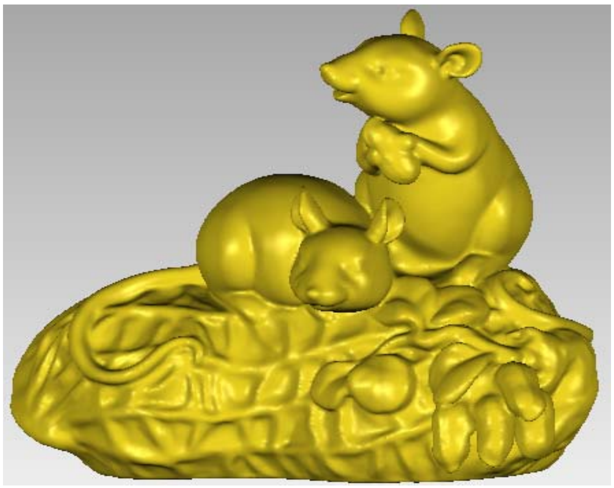


FIGURE VI. RECONSTRUCTED 3D SURFACE MODEL

III. AR SYSTEM FOR CERAMIC OBJECT AND ITS DEMONSTRATION

A. Generation and Conception of the System

In traditional way, ceramic objects and cultural relics are mainly displayed by actual objects, pictures, digital images, sound and so on. The display of actual objects have the limitation of could only be showed inside museums or exhibition halls, which is difficult to expand effectively the spread range and small number of audiences [5]. The display by picture, digital images and sound is not effectively enough for Shiwan ceramic dolls with rich shapes and color feature. It is also a difficult thing to be integrated with all kinds of information concerned with the theme of cultural heritage, which extremely limits the propagation and study of traditional culture. Therefore, we put forward a novel method which utilizing spatial data acquisition and 3D reconstruction technology together with Augmented Reality, one branch of virtual reality technique, to achieve the comprehensive demonstrate of ceramic objects and cultural relics.

Augmented Reality (AR) technique is the scene expansion technique for the human version by integrating the virtual object and real environment. AR technique emphasizes the combination of the virtual and real world, which combines the computer-generated virtual information with the images captured by a camera from the real environment to generate an entirely new scene [6]. In this way, the final result integrates the virtual information and real environment altogether so naturally that the users can regard the virtual objects as one of the real component of surrounding environment in the senses.

B. osgart and its Scene Graph

OsgART is a cross platform development library for the open source C++, which is mainly used for the application development of AR and mixed reality (MR) [7, 8]. It synthesizes the advantages of ARtoolKit and OpenSceneGraph (OSG) and has three main functions of ARToolkit:

- high level integration of video input
- marker-based spatial registration
- photometric registration

It also can apply directly all characteristics of OSG into the development of AR or MR, thus it has the extensive applications as a development tool of AR.

OsgART is based on the concept of OSG scene graph. The scene mainly consists of two different parts: the first part is the real scene which is captured by a digital camera, and the second part is the virtual scene generated by computer program. These two parts are then integrated or augmented into one scene, and the results will be displayed in real time on a screen or helmet display [9]. To get a better understanding of this process, the main structure of osgART scene graph can be represented as following (Figure 7):

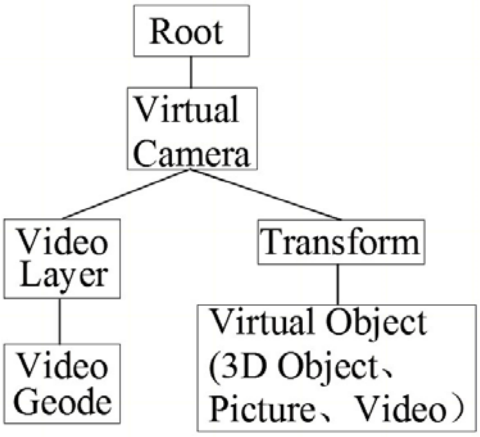


FIGURE VII. MAIN STRUCTURE OF OSGART SCENE GRAPH

C. *Interactive Mode and Real-Time Interaction*

The interactive technique of AR mainly involves three kinds of interactions: the interactions between real object and virtual object, the interactions between the virtual objects, and the interactions between real objects. The quality of the interaction directly influences the displaying of ceramic objects and effect of user's experiences [10]. The interactive modes adopted in this display system include: a) mouse; b) keyboard; c) menu; d) other real objects—marker (target) (Figure 8). They are used to complete the rotation, scaling, moving of object, or altering of material and so on in MFC single document multi-window interface mode.

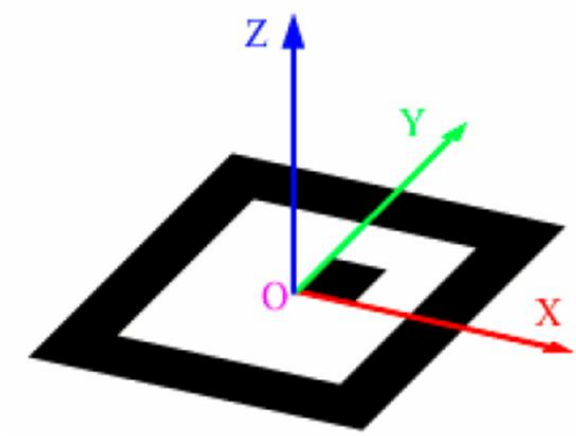


FIGURE VIII. MARKER USED TO POSITION VIRTUAL OBJECT

In mouse interaction mode, one can click to select virtual object, and drag to move or rotate virtual object in a real environment. In keyboard interaction mode, virtual object can be move or rotated by some pre-defined key. One can also transform model by using menu command or altering parameter in control dialogue window.

Perhaps the most natural and easy way to interact with virtual object is to use a Marker (or target). A marker is a special kind of 2-dimensional barcode, which allow the computer to accurately calculate the spatial position of the maker in the real scene through the captured image from camera. After the coordinate information is obtained, the computer can then put the virtual object correctly in relation to the real word. One can manipulate the digital model easily by moving the marker in real environment.

In order to dynamically carry out the above interaction in the scene in real time, and to display the results of change immediately, the OSG callback functions was used to realize the communication and interaction between multi-windows. A class called CmyCallBack was specially programmed for update callback functions [11]. It is realized by the related member functions of class Matrix and has versatility for different purpose. Its main parts are as follows:

```
class myCallback :public osg::NodeCallback
{
      public:
      virtual void operator()
      (
      osg::Node* node, osg::NodeVisitor* nv
        )
}
void scaleNodeCallback::operator ()
       (
       osg::Node* node, osg::NodeVisitor* nv
         )
       {
          osg::ref_ptr<osg::MatrixTransform>pat=dynamic_ca
st<osg::MatrixTransform*>(node);
            if ( pat )
            {
                ......//Code which need dynamically change placed
here (such as scaling, translation and rotation)

            }
            traverse ( node, nv );
       }
```

D. *AR Demonstration System*

A MFC-based AR system for the display of ceramic objects and cultural relics has been developed according to the methods and technology mentioned above. In this system a window is divided into the left part and right part (Figure 9). The left part is main display area, which displays the AR scene in real time combined with the real environment information collected by camera and computer-generated virtual object which is a 3D reconstructed model by the scanning method mentioned in this paper. A maker is used to align the virtual object correctly with real scene. The ceramic object can be moved or rotated interactively with the marker holding by people. The right part in the window is a parametric control panel, which carry out real-time interactions to the scene and objects by manipulating values of different MFC controls. Some introduction information can also be display on the upper-left part of the window, which can give more useful information about the ceramic object.

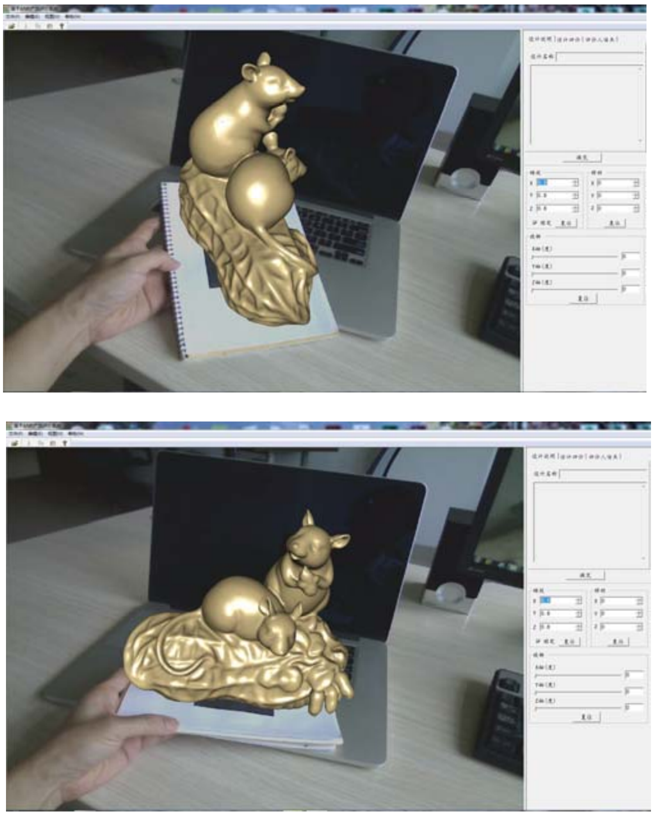


FIGURE IX. AR-BASED DEMONSTRATION SYSTEM FOR CERAMIC OBJECTS

IV. CONCLUSIONS

In order to realize the effective digital protection, promotion and utilization of ceramic cultural relics and products, Foshan ceramic was studied as subject in our research works. The method of RE was used to perform the point-cloud datum gathering, processing and 3D reconstruction of Foshan ceramic cultural relics and objects, so that the digital model was built and digitally processed. The surfaces of ceramics in Foshan are usually quite complex and reflective, so multiple scan were used in our work. The point-cloud data are then be marched and spliced to get a complete model. The AR display system for ceramic relics and objects has been developed based on MFC using osgART and OSG programming. This system can realize the real time interaction, such as scaling, rotation and moving by using target pad, mouse, keyboard and value adjusting, together with the description of the ceramic relics and objects.

From the results shown above, the developed system and methods have found an effective ways for the 3D reconstruction and demonstration for ceramic objects and can be used in digital preservation and digital museum of traditional culture heritages such as Foshan ceramic doll, with which people can view precious cultural relic from any angle in their home through internet. The developed system can also be used in product design, evaluation or demonstration and add comments to the product designs, which would enhance the feeling of reality to the viewer. Beside these applications, it can further be used in advertising and computer games, together with some VR hardware like helmet or gloves.

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