Transformational Breathing between Present and Past: Virtual Exhibition System of the Mao-Kung Ting

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Abstract. The Mao-Kung Ting is one of the most precious artifacts in the National Palace Museum. Having five-hundred-character inscription cast inside, the Mao-Kung Ting is regarded as a very important historical document, dating back to 800 B.C.. Motivated by revealing the great nature of the artifact and interpreting it into a meaningful narrative, we have proposed an innovative Virtual Exhibition System to facilitate communication between the Mao-Kung Ting and audiences. Consequently, we develop the Virtual Exhibition system into the following scenarios: “Breathing through the History” and “View-dependent display”.

Keywords: Mao-Kung Ting, de-/weathering simulation technique, view dependent display

1 Introduction

Museums have the generosity of spirit to share exquisite artifacts with the global audiences. With that spirit, the research teams have combined multiple technologies to interpret an invaluable Chinese artifact as an interactive artwork. How to reveal the great nature of the artifact? The Mao-Kung Ting has been selected, as it is a ritual bronze vessel dating back to 800 B.C. Especially, the Mao-Kung Ting has been weathered for thousands of years [1]. For the reasons given above, the team sought to reconstruct a 3D model of Mao-Kung Ting, and develop interactive applications, which are “Breathing through the History” and ”View-dependent display.”

2 Related Wok

2.1 De-/weathering

There are several natural influences that cause real-world surfaces to exhibit dramatic variation over the course of time. Some methods can simulate the de-/weathering effects[2],[3],[4],[5]. To model the de-/weathered appearance of the Mao-Kung Ting model easily and convincingly, we refer to a visual simulation technique called "appearance manifolds" [6].

2.2 Breath-based Biofeedback

Many techniques, such as Optoelectronic Plethysmography, Ultra Wide Band, Respiratory Inductive Plethysmography, and Heart Rate Variability, are available for detecting respiration status[7],[8].Ultra Wide Band (UWB) radar is applied in variety of settings for remote measuring of heart activities and respiration of users [9]. UWB do not need any detectors or markers attached to bodies of users; therefore, we chose that technique in our system.

3 System Architecture

There are two architectures for the Virtual Exhibition System. One supports the scenario "Breathing though the History"; the other supports the scenario "View-dependent display".

3.1 *Breathing through the History*

Breath detection module: The UWB is the major component of the breath detection module. (Fig. 1a)

De-/weathering display module: The process begins with the detection of breath of users, followed by the de-/weathering algorithm activated in the 3D Mao-Kung Ting model. Then, the de-/weathering appearance of the Mao-Kung Ting will change according to the respiration status of the users, and be displayed on the Interactive Multi-resolution Tabletop (i-m-Top) [6].

3.2 *View-dependent display*

The system consists of two major components, described below. (Fig. 1b)

Fig. 1. (a)The architecture has the UWB Breath Detector set underneath the Interactive Multi-resolution Tabletop (i-m-Top). (b) The architecture is composed of a stereo camera and an Interactive Multi-resolution Tabletop system.

1) Interactive Multi-resolution Tabletop: the tabletop system is employed as a display monitor and multimedia server.

2) Stereo Camera System: the device is utilized to detect foreground objects and the positions of the user's head and the handheld device.

4 Implementation

We generate the 3D model firstly, and then the implementation can be divided into the following parts.

4.1 De-/weathering Simulation

First, we had to prepare a weathered material sample and capture its BRDF at a single instant of time. (Fig. 2a) The sample must contain spatial variations, which depicts different degrees of weathering and can further be analyzed to acquire spatial and temporal appearance properties for synthesizing the weathering process. We tried to simulate the weathering process of bronze, and synthesized a piece of weathered sample according to the current study in Mao-Kung Ting.

Then we captured spatially-variant BRDF from each surface point on the flat sample using a linear light source device.(Fig. 2b) [10], and we fitted parameters of the isotropic Ward model [11] for each point to form a 7D appearance space defined by reflectance features.

It is typical for sample points to have a dense distribution in the appearance space. Hence we are able to construct an appearance manifold, which is a neighborhood graph among these sample points, by connecting each point to its k nearest neighbors and pruning the outliers in the graph.

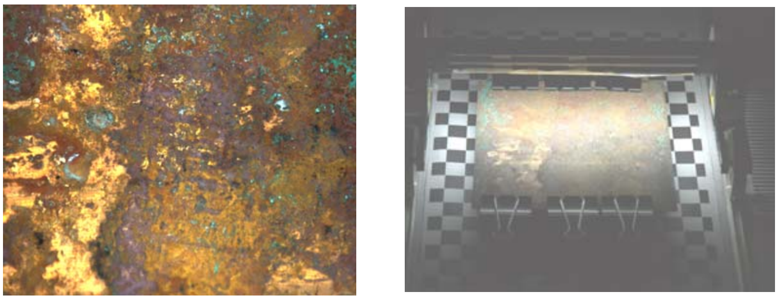

Fig. 2. (a) The weathered bronze sample. (b) The spatially-variant BRDF data capturing device

After constructing the appearance manifold that approximates a subspace of weathered surface points for the material, the user identifies two sets of points to present the most weathered and least weathered appearances respectively. We then defined the degree of weathering for each point in the appearance manifold according to its relative distance between the two sets.

Consequently, a weathering degree map has been obtained by replacing the appearance value of each sample point with its corresponding degree value in the appearance manifold.

Assuming we have distribution of large scale time-variant weathering degrees over the surface, which may be generated by manual specification or using existing visual simulation techniques, weathering and de-weathering appearances on a 3D model can be synthesized with the computed appearance manifold and degree map.

We used a multi-scale texture synthesis technique, like the one proposed in "appearance manifolds" [6], to synthesize the time-variant appearance sequence frame by frame. Specifically, the progress of synthesis includes three steps for each frame: 1) Initialize the degree values of each pixel by extrapolation from the appearance of the preceding frame. 2) Interpolate the initial degree values according to their geodesic distance along the shortest path to the set of most weathered points in the appearance manifold. 3) We needed to consider the neighborhood information on the material sample and incorporate changes in texture characteristic over time to avoid undesirable repetition of texture patterns. The initial appearance frame is finally refined by synthesis with multiple neighborhood scales.

4.2 Breath Detection

Whenever a user walks toward the UWB, the device begins to detect breath of the user. Then, the UWB data will be transmitted to system via Bluetooth; afterwards, the collected data will be analyzed by the system. These data also illustrate how human breathing impacts on the change of the Mao-Kung Ting during its aging process.

4.3 View-dependent Display

The View-dependent display aims to provide users with the effect of visual fidelity, so that the displayed virtual artwork will be adjusted according to different view angles of the user. (Fig. 3)

Implementation processes of the view-dependent display are as following. First, the viewpoint of the user is estimated according to the position of the user's head. Since the interaction is designed for a single user, in a simple environment, a camera can capture a human object via foreground detection. Codebook Model is used for foreground detection. Then, according to the human features in the human object, such as face or hair, the position of the user's head will be identified in the image.

In this system, the stereo camera, with two optical lenses, contains distance information in pixels between camera and object in an image based on triangle theory. We can acquire a 3D coordinate with a camera from stereo image pair **(**I_{left}, I_{right}**)** by pixels:

$$p_{Camera(i,j)}(x,y,z)=\Gamma(I_{left},p_{(i,j)},I_{right}) \qquad (\mathbf{1})$$

$$\forall p_{(i,j)} \in I_{left}$$

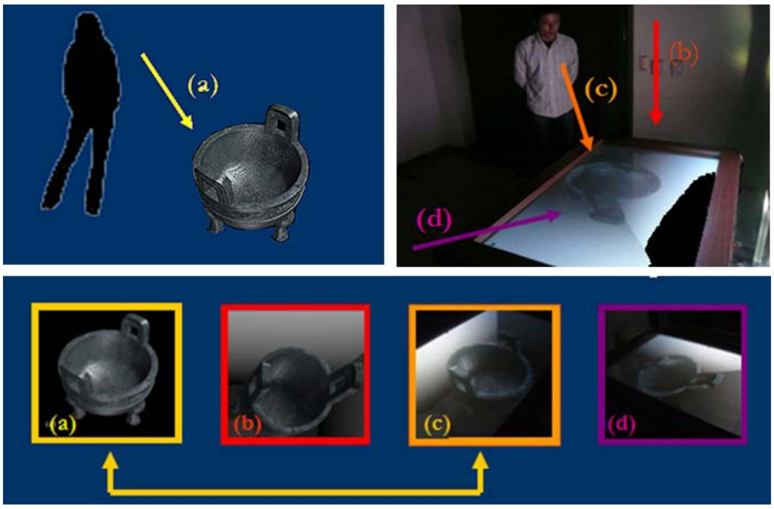

Fig.3. The left image shows that the user stands in front the real MKT. The right image shows that different view points in front of the display table. The bottom image shows that the user's view (c) is almost as real as seen by a visitor in front of the MKT (a).

Nevertheless, a 3D coordinate acquired from the original position must be transferred to a display-centered coordinate. Therefore, we set the calibration board aligned with the surface of the tabletop. Through calibration, the extrinsic parameter $[\mathbf{R}_c \mid \mathbf{t}_c]$ is acquired from the camera. $\mathbf{T}_c$ is the vector for the distance from camera to the center of the calibration board. According to the Eq. 1, we can also transfer a displayed-centered coordinate to a camera-centered one.

$$P_{Camera}[X,Y,Z]=[R_c \mid \vec{t}_c]P_{imTop}[X,Y,Z] \qquad (\mathbf{2})$$

$P_{camera}[X,Y,Z]$ is the set of $\boldsymbol{p}_{camera}(x,y,z)$. Actually, a partial 3D coordinate relative to the camera can be acquired from the stereo camera. Therefore, we can use the inverse function of $[\mathbf{R}_c \mid \mathbf{t}_c]$ to acquire a 3D coordinate relative to surface of the tabletop.

$$P_{imTop}\left[X,Y,Z\right]=[R_c^{\ T} \mid -R_c^{\ T}\vec{t}_c]P_{Camera}\left[X,Y,Z\right] \qquad (3)$$

Since the camera detects the position of the user's head, and a 3D coordinate relative to the surface of the tabletop acquired, the effect of view-dependent display is accomplished.

5 Conclusions

Our artwork provides a virtual exhibition system to lead museum visitors to experience the unique features of an ancient artifact, Mao-Kung Ting. We have illustrated how technologies strongly support the design considerations of systems, such as de-/weathering technology, breathing based biofeedback technology, computer vision technology, and view-dependent display technology, which play a vital role in our systems. The demo video can be found at: http://ippr.csie.ntu.edu.tw/MKT/MKT.html

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