3D Visualization of Acupuncture Bronze Figures: Research and Application (Postprint)

Authors: Zhang Wenyuan, Li Xiaoxu, Tan Guoxin, Sun Chuanming

Date: 2018-07-23T00:00:00+00:00

Abstract

Acupuncture bronze figures are precious artifacts of ancient Chinese medicine, possessing significant cultural and artistic value. To address issues such as monotonous digital preservation methods, poor user experience, and weak dissemination capacity for cultural heritage like acupuncture bronze figures, this paper proposes a digital approach that comprehensively utilizes technologies including 3D laser scanning, 3D visualization, and virtual reality. Taking the acupoint acupuncture bronze figure from the collection of the Hubei Provincial Museum as the subject, we first employ 3D laser scanning technology for data acquisition and 3D modeling; secondly, utilize XML language for the storage and representation of traditional Chinese medicine knowledge contained within; with particular emphasis on employing an improved quadratic error metric and progressive mesh algorithm to achieve automatic generation of multi-resolution simplified models of the bronze figure; finally, develop a virtual interactive display system for acupuncture bronze figures using the Unity engine, enabling rapid visualization and interactive query of traditional Chinese medicine knowledge such as acupoints, meridians, and common diseases in 3D scenes, providing a reference for the digital preservation and dissemination of historical artifacts and intangible cultural heritage.

Full Text

Preamble

Research and Application of 3D Visualization for Bronze Acupuncture Figure

Wenyuan Zhang, Xiaoxu Li, Guoxin Tan, Chuanming Sun*

(National Research Center of Cultural Industries, Central China Normal University, Wuhan 430079, China)

Abstract: Bronze acupuncture figures are precious artifacts in ancient Chinese medicine, possessing significant cultural and artistic value. To address the limitations of existing digital preservation methods for such cultural heritage—including monotonous presentation, poor user experience, and weak dissemination—this paper proposes a comprehensive digital approach integrating 3D laser scanning, 3D visualization, and virtual reality technologies. Focusing on the acupoint bronze acupuncture figure housed in the Hubei Provincial Museum, we first employed 3D laser scanning for data acquisition and 3D modeling. Second, we utilized XML to store and represent the traditional Chinese medical knowledge embodied in the figure. The core contribution involves implementing an improved quadric error metric and progressive mesh algorithm to automatically generate multi-resolution simplified models of the bronze figure. Finally, we developed a virtual interactive display system for the acupuncture figure using the Unity engine, enabling rapid visualization and interactive querying of traditional Chinese medical knowledge—including acupoints, meridians, and common diseases—within a 3D environment. This approach provides a valuable reference for the digital preservation and dissemination of historical artifacts and intangible cultural heritage.

Keywords: bronze acupuncture figure; cultural heritage; 3D visualization; mesh simplification; virtual reality

0 Introduction

Bronze acupuncture figures represent a significant innovation by ancient Chinese medical practitioners—bronze-cast models of human meridians and acupoints first created during the Northern Song Dynasty' s Tiansheng era, with limited production continuing through the Ming and Qing dynasties. Few figures from the Ming era and earlier have survived, and most are housed in museums, remaining largely unknown to the public. As rare treasures in the history of traditional Chinese medicine, these figures hold substantial historical, cultural, and artistic value [1]. The presentation of a bronze acupuncture figure sculpture to the World Health Organization (WHO) in Geneva in 2017 further underscored their importance and medical significance.

Current acupuncture education primarily relies on two-dimensional printed diagrams, which inadequately represent the complex human meridian and acupoint systems. Bronze acupuncture figures serve as intuitive and effective teaching tools. By employing 3D visualization and new media technologies to display these museum artifacts to the public, we can not only promote the widespread dissemination of traditional Chinese medical culture but also achieve effective preservation and inheritance of this cultural heritage.

In recent years, computer technology, geographic information systems, 3D visualization, and virtual reality have been increasingly applied to the digital preservation and dissemination of cultural heritage [2,3]. For instance, academician

Deren Li discussed the application of virtual reality in digitizing cultural heritage sites such as the Chi Lin Nunnery in Hong Kong and the Mogao Grottoes in Dunhuang [4]. Licheng Zong et al. explored 3D reconstruction and virtual display methods for cultural artifacts using 3D laser scanning [5]. Liming Kong et al. argued that augmented reality (AR) technology holds great potential for revolutionizing cultural heritage presentation, citing applications in architectural ruins, murals, historic districts, and museum exhibitions [6]. Yonglin Huang and Guoxin Tan proposed that digital acquisition and storage, digital restoration and reproduction, digital display and dissemination, and virtual reality technologies can play crucial roles in protecting and inheriting China’ s intangible cultural heritage [7].

Despite extensive research and applications in cultural heritage digitization and visualization both domestically and internationally, most efforts have focused on material cultural heritage such as ancient architecture and historical sites. Few studies have addressed the 3D visualization of specialized heritage like bronze acupuncture figures and traditional Chinese medical knowledge [8]. This paper uses a museum-collection bronze acupuncture figure as a case study to investigate virtual display methods for both the artifact and its embodied traditional Chinese medical knowledge using 3D visualization and virtual reality technologies, offering new pathways for cultural heritage digital preservation and dissemination.

---

1 Methodology for 3D Model Construction of Bronze Acupuncture Figure

This study focuses on an acupoint bronze acupuncture figure from the Hubei Provincial Museum. Cast in Ming Dynasty style, the figure features 659 acupoints total (355 unilateral acupoints) with 354 acupoint names marked. The figure intuitively displays human meridians and acupoints, serving as an important tool for researching and disseminating traditional Chinese medical knowledge. Creating accurate 3D models of the bronze figure and a corresponding traditional Chinese medical knowledge expression model forms the foundation for achieving 3D virtual interactive display of acupuncture knowledge.

1.1 3D Modeling of Bronze Acupuncture Figure

3D laser scanning technology can rapidly acquire high-density 3D point cloud data of target objects. Its non-contact nature, fast scanning speed, and high precision make it widely applicable in cultural heritage preservation [9,10]. This study employed a handheld 3D laser scanner for non-contact scanning of the acupoint bronze acupuncture figure housed in the Hubei Provincial Museum (Figure 1(a)). During scanning, we ensured uniform lighting across all model parts and performed multiple scans of complex surface regions. After scanning, we processed the acquired point cloud data using professional software for registration and denoising, then saved the results in the Wavefront OBJ (*.obj) format—a universal 3D model file format convenient for import into other 3D modeling software for refinement (Figure 1(b)).

The bronze acupuncture figure model features complex meridian and acupoint information on its surface. To address this, we captured high-quality images of the physical artifact from multiple angles using high-resolution cameras. These photographs were imported into Photoshop for cropping, stretching, and other operations to create texture material files for the bronze figure model. Subsequently, the geometric model obtained in the previous step was imported into Autodesk 3ds Max for detailed texture mapping. After mapping, we used the Render To Textures tool in Autodesk 3ds Max to bake lighting and shadows onto the model as texture maps, thereby reducing real-time lighting and shadow calculations during later 3D visualization and improving rendering efficiency. The final result is shown in Figure 1(c).

1.2 Design of Traditional Chinese Medicine Knowledge Expression Model

The bronze acupuncture figure housed in the Hubei Provincial Museum serves as a carrier for traditional Chinese medical knowledge education. To achieve visual dissemination of this knowledge, this paper employs ontology methods [11] to construct a traditional Chinese medicine knowledge expression model and establishes spatial associations between the knowledge model and the 3D bronze figure model to facilitate subsequent virtual interactive applications.

To express relationships between knowledge elements and enable mapping between the knowledge model and 3D model, we selected the highly flexible native XML language for organizing and representing traditional Chinese medical knowledge. Acupuncture knowledge primarily involves three basic terms: acupoints, meridians, and diseases, with relationships illustrated in Figure 2. Acupoints form the foundation and core, interconnecting with both meridians and diseases. The relationship between meridians and acupoints is one-to-many, while the relationship between diseases and acupoints is many-to-many.

After identifying the inherent attributes of each entity type based on characteristics of traditional Chinese medical knowledge, we structured acupoint knowledge using XML as follows. For acupoints, key attributes include ID, name, function, and location, as shown in Table 1. The structured description format is:

```xml
<?xml version="1.0" encoding="utf-8" standalone="yes"?>
<Acupoints>
  <Acupoint id="A3" name=" 天府" function=" 气喘，鼻衄，上臂内侧痛。"
            location=" 位于人体臂内侧面，肱二头肌桡侧缘，腋前纹头下 3 寸处。"/>
</Acupoints>
```

For disease knowledge representation, we must consider not only the characteristics of disease knowledge itself and its associative relationships with acupoints but also the pose information of the 3D bronze figure model during visualization to enable rapid positioning in 3D interactive scenes. Therefore, disease ontology attributes are defined as shown in Table 2. The disease ontology model is designed as:

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<Diseases>
  <Disease id="ZQGY" name="支气管炎" modelRotation="0,0,0" modelScale="2"
           modelPosition="-1.51,0.02,0" mainAcupoints="大椎、肺俞、膻中、天突">
    <AssociatedAcupoint id="M14"/>
    <AssociatedAcupoint id="G13"/>
  </Disease>
</Diseases>
```

Here, the AssociatedAcupoint child nodes establish one-to-many relationships between diseases and acupoints. The meridian ontology design follows a similar pattern, using AssociatedAcupoint child nodes to establish associations between meridians and their corresponding acupoints. Using the Hand Taiyin Lung Meridian as an example, the knowledge model is designed as:

```xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<Meridians>
  <Meridian id="STYFJ" name="手太阴肺经" targetRotation="4.8,359.4,0"
            scale="1.5" position="0,0,0">
    <AssociatedAcupoint id="A1"/>
    <AssociatedAcupoint id="A2"/>
  </Meridian>
</Meridians>
```

After using XML to represent and store all knowledge regarding acupoints, meridians, and common diseases embodied in the bronze acupuncture figure, we employ the DOM parsing method recommended by the W3C (World Wide Web Consortium) to rapidly parse the knowledge model and obtain attribute information for any node related to acupoints, diseases, or meridians.

2 Simplification Algorithm for 3D Model of Bronze Acupuncture Figure

The 3D model of the bronze acupuncture figure designed in this study must display on web browsers and mobile devices such as smartphones. Therefore, we employ LOD (Level of Details) technology to simplify the 3D model and improve visualization efficiency. LOD technology, proposed by Clark, is a representative model simplification algorithm whose main idea is to simplify complex models through simplification algorithms to achieve efficient rendering speeds, increase 3D scene fluidity, and conserve computer resources [12].

For model simplification strategies using LOD technology, this paper primarily adopts an edge-collapse-based simplification algorithm to automatically generate continuous LOD models of the bronze acupuncture figure. The edge-collapse algorithm based on quadric error metrics (QEM) proposed by Garland et al. [13] offers fast computation and high simplification quality, making it a classic mesh simplification algorithm.

2.1 QEM Algorithm

The fundamental idea of the QEM algorithm is to first determine the error matrix for each vertex, then calculate the cost of edge collapse based on the vertex error matrices. During edge collapse execution, the algorithm always selects the edge with the minimum cost to collapse until the model reaches the desired resolution. The specific method for calculating edge collapse cost is as follows.

Assume point v is a point in 3D space, and p is a plane in 3D space associated with triangles connected to v. Plane p is defined by the equation $ax+by+cz+d = 0$, where $a^2 + b^2 + c^2 = 1$. The squared distance from vertex v to plane p can be expressed as:

$$d^2(v) = (v^T p)^2 = v^T (pp^T) v = v^T K_p v$$

where $v = [x, y, z, 1]^T$ and $p = [a, b, c, d]^T$. We refer to $K_p = pp^T$ as the fundamental error quadratic form of plane p, used to solve for the squared distance from any point in space to that plane.

Assuming the set of triangle planes associated with vertex v is $P(v)$, the quadratic error metric for this vertex is defined as the sum of squared distances to these triangle planes:

$$\Delta(v) = \sum_{p \in P(v)} d^2(v) = \sum_{p \in P(v)} v^T K_p v = v^T \left(\sum_{p \in P(v)} K_p \right) v$$

Let the quadratic error metric matrix for vertex v be $Q'(v)$, then:

$$Q'(v) = \sum_{p \in P(v)} K_p$$

This matrix is a 4th-order symmetric matrix representing the sum of quadratic matrices K_p of faces in set $P(v)$.

If edge (v_i, v_j) is collapsed to a new vertex $\bar{v}$, the edge collapse cost can be calculated using the above formula:

$$\Delta(\bar{v}) = \bar{v}^T(Q_i' + Q_j')\bar{v} = \bar{v}^T Q' \bar{v}$$

where $Q' = Q_i' + Q_j'$.

2.2 Improvement of QEM Algorithm

Although the classic QEM algorithm enables rapid model simplification, it only considers distance metrics, causing loss of important geometric features such as sharp edges and corners after large-scale simplification [14]. Consequently, many scholars have proposed improvements [15-17], though some still suffer from issues like disappearing tip features, boundary contraction, and computational complexity. To preserve tip features of the original model as much as possible during simplification, this paper proposes an improved QEM algorithm.

From Equation (11), we know that different positions of the new vertex $\bar{v}$ produce different edge collapse costs, affecting the edge collapse sequence and ultimately the simplified model' s accuracy. For selecting the new vertex $\bar{v}$ during edge collapse, two main strategies exist: (1) Calculate $\Delta(\bar{v})$ for both edge endpoints and the midpoint, selecting the point with the minimum collapse cost as the new vertex—some improved algorithms use this half-edge collapse approach to improve computational efficiency. (2) For each edge, select the point that minimizes $\Delta(\bar{v})$ as the new vertex—this method yields better simplification results but requires greater computational effort.

This paper combines both strategies. For non-boundary edges, we first solve for the minimum value of $\Delta(\bar{v})$; if obtainable, we use the corresponding point as the new vertex. If not, we adopt Strategy 1, selecting the point with minimum quadratic error from the endpoints or midpoint. For boundary triangle edges, we directly apply Strategy 1 to select the new vertex.

Literature [18] confirms that absolute curvature is more suitable for triangular mesh model simplification than Gaussian curvature or mean curvature. Since multiplying an adaptive weight with a quadratic error matrix does not change the matrix' s fundamental properties but only alters the edge collapse sequence [14], our improvement strategy multiplies the vertex' s quadratic error matrix by the vertex' s absolute curvature to create a new error metric matrix. The specific implementation of the improved algorithm is as follows.

Assume the geometric body shown in Figure 3. Its mean curvature H is defined as:

$$H = \frac{1}{2A} \sum_i m(e_i)\theta_i$$

where H represents the bending degree of adjacent triangular faces, A is the total area of triangles associated with vertex v, and $m(e_i)$ is the angle between normal vectors of the two triangular faces adjacent to edge e_i.

The Gaussian curvature of the geometric body is:

$$K = \frac{1}{A}\left(2\pi - \sum_i \theta_i\right)$$

This Gaussian curvature represents surface bending, where θ_i denotes the vertex angles associated with vertex v.

Assuming k_1 and k_2 are the two principal curvatures at vertex v, the following formulas apply:

$$H = \frac{k_1 + k_2}{2}$$

$$K = k_1 \cdot k_2$$

$$k_{1,2} = H \pm \sqrt{H^2 - K}$$

The absolute curvature K_{abs} at vertex v is:

$$K_{abs} = |k_1| + |k_2|$$

Assuming edge (v_i, v_j) collapses to new vertex $\bar{v}$, the improved edge collapse cost is:

$$\Delta'(\bar{v}) = ||v_i - v_j|| \cdot \left(K_i^{abs} \cdot \bar{v}^T Q_i' \bar{v} + K_j^{abs} \cdot \bar{v}^T Q_j' \bar{v}\right)$$

where $||v_i - v_j||$ is the distance between vertices v_i and v_j, and K_i^{abs} and K_j^{abs} are the absolute curvatures of v_i and v_j respectively.

2.3 Implementation of Progressive Mesh Algorithm Based on Improved QEM

Conventional mesh simplification algorithms can only construct static LOD models. During 3D visualization, multiple pre-constructed LOD models must be loaded for different viewing distances to achieve smooth transitions. The Progressive Mesh (PM) algorithm can rapidly generate mesh models at different levels of detail according to system requirements, enabling mutual transformation between any two LOD models [15]. The PM algorithm is a model simplification method based on edge collapse and vertex split operations. Its principle is to record the sequence of simplification operations during each mesh simplification step, allowing reconstruction of the initial model based on this operation sequence. The basic operations of the PM algorithm are illustrated in Figure 4.

As shown in the figure, the PM algorithm must store necessary information during each edge collapse operation, including: (1) the two vertices of the collapsed edge, v_{from} and v_{to}; (2) the removed triangles T_{remove}; (3) the triangles T_{effect} whose vertices change after edge collapse.

Therefore, the specific process for generating multi-level detail models using the improved edge collapse cost function and PM algorithm is as follows:

a) Import and initialize the model.

b) Calculate the quadratic error matrix $Q'(v)$ and absolute curvature K_{abs} for each vertex in the original model.

c) Calculate the cost for each vertex to collapse to its neighboring vertices using Equation (11), store the minimum cost value and new vertex position, and create a vertex queue.

d) Sort vertices in the queue in ascending order based on cost values.

e) Retrieve the first vertex from the queue and perform edge collapse. Assuming the edge to collapse is (v_{from}, v_{to}), this operation folds point v_{from} onto point v_{to}, removes point v_{from} and triangles associated with this edge, replaces v_{from} with v_{to}, and removes v_{from} from the vertex queue.

f) Recalculate edge collapse costs for point v_{to} and its neighboring points, and update the vertex queue.

g) Record the current edge collapse operation.

h) If the vertex queue is empty or user requirements are met, proceed to step i; otherwise, return to step e.

i) Terminate.

---

3 Experiments and Analysis

The improved QEM-based progressive mesh algorithm was implemented using Visual C++ and the OpenGL library. Multi-scale simplification experiments were conducted on the bronze acupuncture figure triangular mesh model using a computer configuration of Windows 10, Intel Core i7-4770 CPU @ 3.40 GHz, 8 GB RAM, and NVIDIA GeForce GTX 1050 Ti graphics card. The simplified results were visualized using the open-source MeshLab software [20], as shown in Figure 5.

The bronze acupuncture figure triangular mesh model consists of 15,926 vertices and 31,857 triangular faces. Table 4 presents vertex counts, triangle counts, and time consumption information after applying different degrees of simplification using both algorithms.

Table 4 Model Information and Time Consumption at Different Detail Levels

Simplification Rate	Vertices	Triangles	Time (s)
50%	7,963	15,928	22.3
90%	1,593	3,185	22.7
95%	798	1,592	23.6

As shown in Table 4, when the model is simplified by 95%, the number of vertices decreases from 15,926 to 798, and the number of triangular faces decreases by 30,265. The OBJ model file size also reduces from 5,696 KB to 50 KB. While memory consumption decreases and visualization rendering efficiency improves significantly, our algorithm still maintains good model quality.

Results obtained using the QEM simplification algorithm in MeshLab are shown in Figure 6. In terms of algorithm execution efficiency, our algorithm averages 22.85 seconds across the three simplification scenarios, while the QEM algorithm averages less than one second. Since our algorithm must calculate vertex absolute curvature for edge collapse cost and store necessary information during edge collapse, its time complexity is higher than QEM. Although progressive mesh construction based on the improved QEM algorithm requires longer preprocessing time, the simplification information sequence can be completed during this phase and reused directly in subsequent simplification processes without regeneration. During 3D visualization, forward or backward tracking of the simplification information sequence with corresponding operations enables real-time generation of appropriate LOD models and smooth model transitions.

Comparison of results from both algorithms reveals that as simplification degree increases, our algorithm significantly outperforms QEM in preserving model tip features. Important contour features such as the figure’ s fingers, nose, and ears remain well-preserved even at simplification rates above 90%. This is because our algorithm considers not only the vertex quadratic error matrix but also utilizes vertex absolute curvature, which better expresses tip features on model surfaces. Figure 7 shows rendering results of the original model using mean curvature, Gaussian curvature, and absolute curvature respectively. The absolute curvature features of the figure’ s fingers, nose, eyes, ears, and forehead are more pronounced than other curvature features. Multiplying absolute curvature with the vertex quadratic error matrix increases the error metric in these regions, altering the edge collapse sequence and thereby preserving important features of the original model in the simplification results.

4 Design and Implementation of Unity-Based Virtual Interaction System for Bronze Acupuncture Figure

Based on the key technologies discussed above, we developed a virtual interactive display system for the bronze acupuncture figure using the Unity engine and C# programming language, enabling dynamic interactive display of the bronze figure and traditional Chinese medical knowledge in a 3D environment.

4.1 System Design

The construction process for the virtual interactive display system is illustrated in Figure 8. The system comprises two main components: 3D modeling and virtual reality technology development. The 3D modeling phase involves acquiring high-precision 3D point clouds of the bronze acupuncture figure using 3D laser scanning, followed by texture rendering and baking in 3DS Max to output the 3D model. The traditional Chinese medical knowledge expression model is constructed using XML, creating three structured document datasets for acupoints, meridians, and common diseases. Multi-resolution models generated by the simplification algorithm are imported into Unity, where LOD strategies are set, model display scenes are constructed, interactive interfaces are designed, and message responses for various interactive display functions are programmed in the Visual Studio 2015 development platform.

The system functional structure is shown in Figure 9, primarily consisting of two modules: 3D model interaction and traditional Chinese medical knowledge interaction. Model interaction includes basic operations such as scaling, rotating, and translating the bronze acupuncture figure model. Knowledge interaction focuses on displaying basic information about the bronze figure, acupoint click querying, meridian distribution information display, disease knowledge, and associated acupoint information presentation.

4.2 Implementation of Interactive Functions

Basic interactive functions such as translation, scaling, and rotation of the bronze acupuncture figure are primarily implemented in Unity by setting camera properties, which will not be elaborated here. We focus instead on the implementation methods for interactive display functions of traditional Chinese medical knowledge.

Acupoint click querying represents an important system function. Two implementation approaches exist: (a) Add a script to each acupoint component and individually write programs to obtain acupoint information. While computationally efficient, this method requires manually adding scripts and response events for all 354 acupoints, resulting in enormous workload and low development efficiency. (b) Capture mouse click events in Unity, then use Unity' s Raycast mechanism to emit a ray from the mouse click position into the virtual 3D world. Through collision detection, we obtain information about objects intersected by the ray, pass the object ID to the XML parsing program for the traditional Chinese medical knowledge model, and finally retrieve corresponding acupoint information for display.

Clearly, the second approach offers higher development efficiency and is adopted in this study. The specific algorithm steps are:

a) Capture mouse events.

b) If the left mouse button is clicked, proceed to step c; otherwise, proceed to step k.

c) Obtain the mouse click position.

d) Create a ray from the mouse click position into the Unity world.

e) If the ray collides with an object, proceed to step f; otherwise, proceed to step j.

f) Obtain the collided object hit.

g) Pass the hit object' s ID to the acupoint ontology parsing program to retrieve the acupoint knowledge model.

h) Activate the information display interface and show acupoint information.

i) Modify the hit object' s material and proceed to step k.

j) Hide the information display interface.

k) End.

The resulting acupoint click interaction effect is shown in Figure 10, where the currently queried acupoint is marked with a red dot, and knowledge information including the acupoint' s name and efficacy is displayed on the left.

Since the interaction functions for common diseases and meridians are similar, we briefly illustrate the implementation using common diseases as an example. When clicking the "Common Diseases" button in the system interface, a secondary menu appears listing names of common internal and surgical diseases, as shown in Figure 11.

The algorithm for responding to buttons in this secondary menu is:

a) Obtain the button object corresponding to the mouse click.

b) Pass the button' s name attribute to the disease ontology parsing program to retrieve relevant attribute information for the corresponding disease node from the disease XML document.

c) Extract the modelRotation, modelScale, and modelPosition attribute values stored in the disease node and assign them to the bronze figure model' s transform to adjust the model' s position and pose.

d) Extract the AssociatedAcupoints list stored in the disease node, locate the spatial positions of corresponding acupoints on the model based on each acupoint ID, and highlight these acupoint points on the 3D bronze figure model.

e) Extract the mainAcupoints information from the disease and display text knowledge including disease names and associated acupoints in the 3D scene.

f) End.

The final interactive display effect for disease knowledge is shown in Figure 12.

4.3 System Release

After implementing all system functions, leveraging Unity' s cross-platform capabilities enables rapid compilation and deployment to various application platforms including Web browsers, Android, and iOS mobile systems. The system adapts automatically to different terminal screen resolutions, features a user-friendly interface, and offers simple operation, as shown in Figure 13. By enabling 3D interactive display of bronze acupuncture figures and traditional Chinese medical knowledge via the Internet and smartphone terminals, we maximize resource sharing and enhance the experiential quality and dissemination power of cultural heritage.

---

5 Conclusion

The digital preservation and inheritance of intangible cultural heritage has consistently received significant national attention. However, traditional digital methods remain relatively monotonous, primarily relying on text, images, audio, and video for simple documentation, making it difficult to intuitively and dynamically present the connotations of certain cultural heritage items. This study applies 3D laser scanning, 3D visualization, virtual reality, and mobile Internet technologies to the digital preservation of bronze acupuncture figures and their embodied traditional Chinese medical knowledge. Our approach not only creates realistic 3D models that run smoothly on mobile terminals such as smartphones but also enables virtual interactive display of traditional Chinese medical knowledge through these models, making acupuncture-related knowledge more accessible, understandable, and disseminable. The proposed technical methodology provides a new solution for the digital preservation and dissemination of historical artifacts combined with intangible cultural heritage.

However, the traditional Chinese medical knowledge expression model proposed in this paper remains relatively simple, with insufficiently deep application of ontology theories and methods. For different categories of intangible cultural heritage projects, future research should develop more effective digital preservation, inheritance, and dissemination methods based on their specific characteristics.

References

[1] Xueyan Zhen, Huiqin Zou. National ceremony: bronze acupuncture figure [J]. China Health Human Resources, 2017 (6): 90-91.

[2] Jin Ze. Digital protection and construction of world cultural heritage objects: taking as an example, ancient buildings at Norbulingka in Tibet [J]. Sciences of Conservation and Archaeology, 2017, 29 (4): 115-122.

[3] Murphy M, Mcgovern E, Pavia S. Historic building information modelling: adding intelligence to laser and image based surveys of European classical architecture [J]. ISPRS Journal of Photogrammetry and Remote Sensing, 2013, 76: 89-102.

[4] Deren Li. The application of virtual reality technology to cultural heritage protection [J]. Journal of Yunnan Normal University: Humanities and Social Sciences, 2008, 40 (4): 1-7.

[5] Licheng Zong, Bin Ren. Research on digitalization method of cultural relics based on computer aided design [J]. Computer Engineering and Applications, 2017, 53 (15): 250-254.

[6] Liming Kong, Xiaoman Rong. Application of augmented reality in cultural heritage visualization: a review [J]. China Cultural Heritage, 2017 (2): 62-69.

[7] Yonglin Huang, Guoxin Tan. Research on digital protection and development of Chinese intangible cultural heritage [J]. Journal of Huazhong Normal University: Humanities and Social Sciences, 2012, 51 (2): 49-55.

[8] Xiaoxu Li. Research on visualization of TCM knowledge about bronze acupuncture figure based on VR technology [D]. Wuhan: Central China Normal University, 2017.

[9] Qingquan Li, Bisheng Yang, Wenzhong Shi, et al. Real-time acquisition, modeling and visualization of 3D spatial data [M]. Wuhan: Wuhan University Press, 2003.

[10] Junfeng Suo, Yong Liu, Zhiyong Jiang, et al. Modeling of ancient building based on 3D laser scanning point cloud data [J]. Science of Surveying and Mapping, 2017, 42 (3): 179-185.

[11] Zhihong Deng, Shiwei Tang, Ming Zhang, et al. Overview of ontology [J]. Acta Scicentiarum Naturalum Universitis Pekinesis, 2002, 38 (5): 730-738.

[12] Clark J H. Hierarchical geometric models for visible surface algorithms [J]. Communications of the ACM, 1976, 19 (10): 547-554.

[13] Garland M, Heckbert P S. Surface simplification using quadric error metrics [C]// Proc of the 24th annual conference on computer graphics and interactive techniques. 1997: 209-216.

[14] Xiaohui Du, Baocai Yin, Dehui Kong. Edge collapse simplification based on weighted quadric error metrics [J]. Journal of Beijing University of Technology, 2007, 33 (7): 731-736.

[15] Yaolin Gu, Zhengming Zhao, Jiangtao Wei. Multiresolution mesh simplification algorithm with distance-weighted quadric error metric [J]. Computer Engineering and Design, 2007, 28 (8): 1966-1968.

[16] Weihai Chen, Lihong Xu, Jingmeng Liu, et al. Quadric error metrics for mesh simplification based on feature matrix [J]. Journal of Beijing University of Aeronautics and Astronautics, 2009, 35 (5): 572-575.

[17] Shiyong Xiong, Qinhan Li, Airong Xie. Simplification algorithm for 3D LoD model based on half-edge collapse [J]. Computer Engineering and Design, 2016, 37 (3): 655-659.

[18] Pulla S, Razdan A, Farin G. Improved curvature estimation for watershed segmentation of 3-dimensional meshes [J]. IEEE Trans on Visualization & Computer Graphics, 2001: 1-15.

[19] Hopper H. Progressive meshes [C]// Proc of the 23rd International Conference on Computer Graphics and Interactive Techniques. 1996.

[20] Cignoni P, Callieri M, Corsini M, et al. MeshLab: an open-source mesh processing tool [C]// Proc of the Eurographics Association. 2008: 129-136.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv —Machine translation. Verify with original.