Research on Key Technologies of Museum costume virtual exhibition based on Web3D

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Abstract. The paper systematically summarized the research status of the key technologies of virtual display of costume in museum based on Web3D. Including 3D costume modeling technique, 3D body modeling technique, collision detection technique and Web3D technique. In addition, the paper analyzed the technological difficulties of virtual display of costume in museum. Furthermore, the development trends of virtual display of costume in museum were proposed.

1. The technical background of the digitized museum

The costume museum is a carrier of cultural inheritance, and it provides precious information for costume studies. The increasingly mature and developing virtual reality technique and internet technology contribute the technical supports to the all-dimensional exhibition of the costume exhibits in the museum, and provide 3D virtual costume display platforms of networking, virtualization and humanization. The users can understand external features and historical properties of costumes, and appreciate details of their grains and textures in the museum.

At present, the digitized museum costume is mainly made by a two-dimensional combination of pictures, where the panorama technique of Google Street view is applied. Shanghai Silk Museum is a representative in this aspect. Similarly the Costume Museum of Drexel University gives an all-dimensional (360°) exhibition of costumes by QuicktimeVR technique which is also a two-dimensional combination of pictures, that is, displaying the detailed features of costumes by taking the local photos of costumes,(show in Figure1). It is still rare to exhibit the costumes in museums by the 3S virtual technique. In the 3D virtual exhibition, the 3D costume model is designed with cloth models made by the simulation software tools the costume designing CAD. Kang made the 3D costume model with the Rococo style of the 18th century using DCSuite and MayaQualoth modeling software, which provided a reference method for the 3D display of online museums, (show in Figure2). The online 3D digitizing virtual exhibition is a new orientation of museum costume development, whereas the support of multiple techniques is needed for the lifelike simulation of costumes. This paper introduces the key technical studies involved in Web3D museum costume virtualization, describes the costume modeling, 3D body modeling, collision detection, and Web3D virtual reality engine technology, sums up the technical bottleneck of costume virtual exhibition, and proposes the development direction of Web3D costume virtual exhibition in museums.
2. Key techniques and development situations of Web3D-based museum costume virtualization

It needs multiple technical supports including 3D costume modeling, 3D body modeling, collision detection and Web3D engine technology to construct the online museum costume virtual exhibition.

2.1 3D costume modeling technique

The real 3D costume model is constructed for the 3D modeling of museum costume virtual exhibition, while the simulating costume material is the foundation of building the 3D costume model. The costume material, made up of natural or artificial fibrous meshy fabrics, is a flexible substance like the thin-shell structure with such features as anisotropy, incompressibility and tension resistance. The material model is built mainly by three ways: geometric method, physical method and their mixing method.

2.1.1 Geometric method

The costume material is simulated by the geometric modeling way by studying the physical properties of the material. This method gives the more orderly and uniform wrinkles without respect to texture and elastic coefficient of the material. The earliest geometric model is the catenary model made by Weil. This model was used to simulate the catenary state of material by setting the constrained points on the material shape in free suspension calculated based on catenary, but it couldn’t be applied to simulate wrinkles. After that, Ng and Grimsdale proposed the X-section model, where the pure geometric change was used to simulate the shape of the costume material in the special conditions. In recent years, the technique that the geometric method is used to represent the flexible materials has been developed continuously. Sturnpp proposed a self-adapting shape matching method that divides the material grids into a group of overlapped aggregation by preprocessing. In this method, figure out the location of material points in absence of restriction under the effect of gravity first, then match the points with the location aggregation after changing to determine their target location, and finally change the points to the target location. It can keep an efficient calculation in the case of a small aggregation[1].

2.1.2 Physical method

The physical mechanical model of material was built based on the physical properties of garment material to work out the material state every moment by the Newtonian dynamics.

The method under study is the mesh of the $m \times n$ masses, each mass being positioned at time $t$ on the point $P_{i,j}(t)$ where $i=1, \ldots, m$ and $j=1, \ldots, n$. The evolution of the method is governed by the fundamental law of dynamics:
\[ F_{i,j} = \mu a_{i,j} \]  

(1)

where $\mu$ is the mass of each point $P_{i,j}$ and $a_{i,j}$ is its acceleration caused by the force $F_{i,j}$. $F_{i,j}$ can be divided between the internal and external forces.

The internal force is the resultant of the tensions of the springs linking $P_{i,j}$ to its neighbors:

\[ F_{\text{int}}(P_{i,j}) = -\sum_{(k,l) \in R} K_{i,j,k,l}(l_{i,j,k,l}^0 - l_{i,j,k,l}) \]  

(2)

Terzopoulos was the pioneer of the physical simulation method. In this method, the material was meshed by the elastic mechanic model; after that, the material location was figured out by the semi-implicit integral method. This model was a continuous one with gigantic calculation quantity, and it could not include mechanical parameters of basic materials such as elasticity modulus. Breen proposed the fabric particle system model. The model dispersed the material into many non-volumetric mass points, which interacted by a series of non-mass springs in consideration of stretching compressing force, shear force and outward plane bending force of the fabrics. This model was similar to the microstructure of the fabrics, and it was better in mechanical simulation with a lower complicated calculation. However, this model was used to deal with the isotropic problem. Provet put forth the mass point-spring model by combining particles with elastic deformation. So he worked out the structural force, shear force and bending moment among the particles by connecting the virtual particles with the same mass by the massless springs. This model was simple and useful, and could realize simulation and numerical calculation quickly. So it is widely used. However, there are some defects in the model, for example, the system can’t directly capture the outline effect of the object. For diversified material textures (such as light and thin silk cloth and thick woolen), the proper motion model parameters should be selected to present the dynamic properties of different materials in the material virtualization [2].

2.1.3 Mixed method

Kang et al. Proposed a global-local mixed approach to simulate deformation of the wrinkled skirt hemlines. Cordier et al. Carried out a division of the dress model by the spatial distance under the dress in a stationary state, where the close area was simulated by the geometric method, and the far one was simulated by the physical method. The model was divided based on the stationary state, so it was limited to some extend. Scholars proposed other costume simulation methods such as self-adapting network method, and parallel computation technique, and they all were developed on the basis of geometric and physical methods.

2.1.4 Comparison of three model methods

The geometric method has stable and efficient calculation, but lacking of autokinetic effect after image composition. The physical method is an effective technical means to simulate the real material effect and keep main physical properties and key features of the material by establishing the material mechanical model. By this way, the effective numerical solution is available to present the more real simulation effect. However, the physical simulation shows the real-time algorithm is affected with its poorer stability and complicated calculation. The mixed method can improve the real-time targeted simulation in the precondition of not reducing a real effect. In short, the geometric method has the best simulating and outline comparing effects, but most difficult in calculation and poor in real-time simulation. The physical method is poorest in simulation effect and sense of pendant, but with the easiest calculation and best real-time simulation. The mixed method falls between geometric and physical methods, but the material textures simulated by it are best.

2.2 3D body modeling technique

The 3D body model is a main part of virtual dressing. Funge et al. Proposed five model-grading levels of the 3D body in 1999, that is, geometric level, motion level, physical level, behavior level and perception level. Both sense of reality and technical complexity are in a progressive increase in the five levels, and most current studies focus on the first three levels. In order to meet the requirement of
costume virtual exhibition the 3D body data are acquired first, then the body model is built by the specific modeling method in building the real body model.

The body data are acquired mainly by direct and indirect methods. In the direct method, dimension data of all parts of human body can be measured directly with such tools as tape and range-viewfinder. In the indirect method, the body data are obtained mainly by scanning and photographing means such as laser measurement, stereoscopic photograph, white-light phase measuring and multi-view 2D image data. At present, the most common method is non-contact 3D body scanning system, such as TC 2NX-16 and Human solutions.

After the body data are acquired, it is a key for the virtual 3D costume exhibition how to build the real digitizing body model. The 3D body models are mainly the models based geometric and physical methods. In the geometric modeling, the body model is built by using the measuring data based on the geometric elements such as line, polygon, simple shape (cylinder and sphere), and curvic face. In the parameter curve modeling approaches, the NURBS curvic face has become the industrial standard that describes the outline of an object. This technique needs to divide the body into several parts, and constructs the NURBS curvic face after the control points are calculated inversely based on each part of body data points. Meanwhile, it also considers the smooth splicing of all parts. In the physical modeling, both physical properties and external environmental factors are considered on the basis of external geometric characteristics of human body. By this way, the real modeling effect is available, and the dynamic features of the body can be expressed.

With development of reverse engineering technology, the 3D scanning and reverse engineering processing can present a fast and efficient modeling of human body. All-sided body 3D form is gained with the processing of point cloud data obtained by such reverse engineering software as Geomagic and Rapidform, so as to satisfy the requirement of fast body modeling. In addition, the reverse engineering software can also carry out the processing of patch organization and patch relaxing for the model, to adjust the accuracy of body model.

2.3 Collision detection

The costume model in virtual dressing may collide with the body model. So the collision detection is another key technique for costume dressing simulation. Scholars have made great contribution in the collision detection field, putting forth a complete set of more mature theories and algorithm. In theory, the collision is judged by solving the intersection calculation of the geometrical characteristics of object model, that is, judging whether the boundary of a material is intersected with that of another material, and whether it is intersected with that of body model. At present, the collision algorithms are graph-based and image-based detections. In the graph-based collision detection, the model is often divided into the small units in the same volume or the bounding boxes with slightly big volume and simple geometrical characteristics to simulate the model; the geometric objects for the intersection detection is reduced as much as possible in number, to improve the real-time algorithm. In the image-based collision detection algorithm, the intersection of two objects based on the sampling of 2D images of objects by the image hardware and the corresponding deep information.

The costume material is soft relatively and deformed easily. So the collision detection is more complicated for the material. Bridson et al. speeded up the collision detection by the axial gradation bounding box. Harmon et al. Proposed a new approach of different rigid action zone, simplifying the collision detection, reforming Bridson’s practices, and improving the robustness of algorithm. Choi et al. detected the collision by the space decomposed method, that is, after the space including materials was decomposed, each particle and triangle as well as corresponding space coordinates were written down, and the collision detection was completed independently. This method was efficient but it is close to the property of linearity. Besides the collision of material and human body, the self-collision of materials should be detected. Baraff proposed the solution scheme of global intersection analysis, to solve the problem about the self-collision of materials on the intersection face. In this method, the unreal stretching behaviors might occur to affect the real representation of the materials when the material was in a lower resolution and more complicated. Schwartzman et al. employed the hierarchical data structure and algorithm to realize efficient self-collision detection.
2.4 Web3D technique

The Web3D technique is a most core one to construct the museum costume exhibition system, including such modules as model management, resources management, and server dispatching. All modules work coordinately to realize the dynamic presentation of costume changes. These modules have sound compatibility with the low-end hardware, and provide the strong technical support and guarantee for the exhibition of museum costumes.

The Web3D technique based on VRML is an earliest Web3D modeling technique, but the model generated by VRML produces the poor simulated effect with its poor illumination and texture, which restrict the exhibition of museum costume details. For the Web3D technique based on HTML5, WebGL is a 3D drawing standard, which allows to combine JavaScript and OpenGL together. WebGL can provide the hardware 3D accelerating rendering for HTML5Canvas. It can exhibit 3D scenario and model more smoothly in the browse with the help of system display card, and create the complicated navigation and data visualization. The engine-based Web3D can constitute the bottom-layer-oriented function library by trimming and packaging of technical details. Current mainstream engines are Java3D, Unity3D and Flash3D.

The Web3D technique has powerful interactivity, stronger sense of reality and online transmission. It is used for protection of the museum costumes not only to spread cultural arts of museum costumes by internet technology but also to overcome the defects in costume exhibition by the means of traditional characters, pictures and videos. By this, the museum costumes are more real, visualizing and influential in exhibition.

3. Problems and developing direction in Key techniques

3.1 Problems and bottleneck in key techniques

There are the following problems in the museum costume virtual exhibition platform based on Web3D by existing techniques:

a) Some researchers have done more studies on reality and real-time simulation of materials. Though the remarkable progress is made in effect and property, these can not satisfy the requirements of application for museum costume simulation. The dressing effect of costume depends on the properties of its materials, and a great deal of instance data are needed to build more efficient material model in analyzing deformation and mechanical features of real materials. Moreover, the body collision detection is more complicated in the virtual scene, and the system calculation performance is restricted. As a result, a better calculating balance is difficultly achieved between the sense of reality and frame drawing of museum costumes, so that the natural reality of scene can’t be guaranteed.

b) It is inevitable for the museum costume virtual exhibition by webpage Web3D in mobile devices with the development of mobile internet. However, due to the limited calculating performances of webpage and mobile platform as well as plenty of fined 3D costume models needed for virtual museum costume exhibition, these models not only make the storage space rapidly expanding, but also directly affect the network transmission and download. For this reason, it is one of the technical bottlenecks for the museum costume virtual exhibition how to quickly build the light 3D costume model.

3.2 Developing direction of related techniques

3.2.1 Build multi-accuracy 3D material and costume models

The material physical properties are obtained by KES and video capturing experiments to enrich the instance data of costume materials, and efficiently establish the relation of deformation and mechanical characteristics of the materials. The deformation curvature and stretching changes are studied by area in consideration of analysis of the multi-accuracy material model, to refine the highly deforming area and improve the fidelity effect of wrinkles. The simplified calculation is applied for difficultly deforming area to build the multi-accuracy 3D material and costume models.

3.2.2 Develop the Web3D engine fit for costumes

The Web3D engine fit for costumes is developed to detect the collision of models quickly, provide standard body model and drawing means that can present a sense of reality, and realize natural reality and beauty of materials, light/shadow, particles and animation effect. In addition, the museum costumes
can be appreciated in more perspective by using this engine, and simple interaction can be available to enhance the experience on site. All this is a trend of the museum costume virtual exhibition.

4. Conclusions

This paper summarizes the current situation and progress in studies on main key techniques for the museum costume virtual exhibition platform based on Web3D. It states that coordination and realization of 3D costume modeling, 3D body modeling, collision detection and Web3D engine technique are necessary for the building of the virtual exhibition platform. The related techniques become very mature in study, but some technical bottlenecks exist still. Finally, this paper gives the developing direction of the museum costume virtual exhibition based on Web3D, that is, building multi-accuracy 3D material and costume models and developing the Web3D engine fit for costumes.

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