Great improvement has been achieved in the protection of national dance through multimedia technology. An interactive design approach for national dance based on realistic 3D character is proposed in this paper. This approach comes with three sub steps: Firstly, the realistic face was reconstructed based on a front photo, in this step, the facial feature points of photo are selected interactively; and then, the realistic face was built through texture mapping and fusion based on the standardized face model database. Secondly, the construction of realistic body is realized through introducing the stretching model and the vector differential adjuster. Finally, the interactive display of national dance is realized by virtual reality engine. The experimental results show that this approach is user-friendly, and can generate a high-quality realistic 3D character in real time while protects the worthy cultural heritage effectively at the same time.

Index Terms—Realistic 3D Character, National Dance, Interaction Design

I. INTRODUCTION

National dance is an important part of intangible cultural heritage. With the great advancement of economy, many precious national dances are struggling to survive due to the strike of modern civilization. One of the most commonly used approaches to protect national dance veritably and systematically are taking photos, recording videos and other multimedia tools. The problem is: the recording outlooks for dancers’ motion are limited, as a result, the reusability and editability is poor.

With the development of computer software and multimedia technology, it has become a trend to protect national dance by three-dimensional digital technology. The current achievements have several shortcomings, the actors in it lack of realistic and insufficient interaction have affect the user immersion and initiative seriously [1]. As a result, it’s important to design professional characters and apparels to provide a more intuitive form for digital dance according to the special characteristics of dancing. However, the generate process of realistic character is often quite complex, and it’s not easy for general users to obtain the necessary equipment and corresponding databases. In the field of computer graphics, realistic characters are the avatar of users in a virtual environment, which can be widely used in human-computer interaction, virtual simulation, and other fields. For example, the participants can be “embedded” in a virtual environment in the production of digital national dancing, making them a form of existence in the virtual world, through which the interest and enthusiasm of the participants could be greatly aroused.

There are four dominant approaches to build realistic characters model currently, they are as follows:

Firstly, using professional modeling software (such as: Autodesk Maya, 3Ds Max), which can create a human model by operate the most basic modeling elements interactively. Although this approach, users have the greatest authority to control, high level of creativity and sufficient familiarity are needed to perform well in the modeling software.

Secondly, using professional capture devices like the three-dimensional scanner to collect data, such as Devernay [2] and Bickel et al [3]. The advantage is that the accuracy of the final model is relatively high, but the results tend to have holes in the model, What’s more, the operation and maintenance of these devices need professional training.

Thirdly, researchers like Sloan [4] taking interpolation operation on the vertices in the same location using a plurality of the samples, to obtain a new model. But the establishment of such a database spends a lot of time and resources; what’s more, it does not take the generation of the entire human body into consideration.

The forth approaches comes that Hilton [5] and Liao et al [6] use the shape features which are extracted from the individual photos to modify the generic model. But...
Hilton’s approach is likely to cause the model cracks. Liao’s approach can generate realistic head model through only a single photo, but it need to select many characteristic points.

This research absorbed the advantages in the third and fourth approaches, and proposed a unified approach which can generate realistic 3D faces based on a single font photo and generate realistic 3D body based on the vector difference. Then the realistic character will be bond with the motion capture data of national dance, and then be displayed in the multimedia platform interactively. There are several sub-steps in the face modeling. Firstly, the standardized face model database should be constructed, and interactively select the facial feature points of the input picture. After that, we’ll choose the best matched face model based on the face features. Secondly, the approach of triangular deformation and bilinear interpolation are used to achieve texture mapping from photo to three-dimensional model, and the introduction of Alpha picture of face to realize the fusion transition from the photo texture to the neutral texture of the model in order to generate realistic 3D face. In the step of body generation, firstly, a reference model, a vertical stretching model and a horizontal stretching model are constructed in accordance with the model structure of the human body; secondly, a vector difference adjuster is employed to interactively adjust the control points in the reference model; lastly, a realistic character model is automatically generated based on the control points’ coordinates. This approach can overcome the problems associated with other approaches, such as: the need to master professional model software, cracks or holes generated in the result model, and make it easy for users to interactively build a realistic character model. Through the application of this approach into national dance, we can promote the digital preservation and propagation of national dance.

II. REALISTIC FACE GENERATION

The realistic sense of three-dimensional face can be reflected in the perspectives of facial model and texture. In the approach proposed in this paper, the users will participate in the texture specification and model adjustment. Both of these two processes are highly simplified, and we can view the results in real-time. Five steps in detail are contained in the approach proposed in this paper:

Step1. Feature point calibration: Get the front face photo, and mark 11 feature points which are spread over eyes, nose, mouth and so on to determine the approximate location of the five sense organs and facial form.

Step2. Model matching: Construct the standardized three-dimensional face model database, and match the most similar model in the corresponding face database to minimize the differences of facial bones.

Step3. Texture mapping: Map the texture feature of photo face on the matching model through the algorithm of triangular deformation and bilinear interpolation.

Step4. Skin color fusion: Use an Alpha picture to achieve the gradient from the overlay texture to model texture in the face boundary area.

A. Feature Point Calibration and Model Matching

If the face photo is obtained, a suitable face model should be selected according to the positional relationship of the facial feature points. Now some standardized 3D face model database had already been constructed, such as UND [7], BU-3DFE [8], and BJUT [9]. These face model databases had been widely used in face generation, face recognition and other fields.

Different 3D face model database have different standards on race, age, gender, light, etc. The approach of this paper is mainly for the Chinese people. We built a Chinese face model database with three-dimensional scanning equipment. The types of face were divided into five types which is show in Fig. 1, such as oval-shaped, inverted triangle, long-shaped, square and round. However, the neutral head model (as shown in Fig. 2) is completed by the reference of CANDIDE-3 neutral face model [10].

Figure 1. The types of face, (a) is oval-shaped type; (b) is inverted triangle type; (c) is long-shaped type; (d) is square type; (e) is round type.

Figure 2. The neutral head model, (a) is the front view and (b) is the side view.
texture mapping, in this paper, we select 11 feature points on the input photo and the face model, as shown in Fig. 3. Through which, the facial features and facial type can be confirmed approximately, so that we can get the most suitable model.

Model matching approach is as follows: First of all, number the feature points to calculate the distance and proportionate relationship between the main feature points; Secondly, use literature [12] for reference to determine the general facial type; Finally, match the Euclidean distance of the corresponding feature point between model and photo in the corresponding facial type database, and get the nearest 3D model.

\[
E = \sum_{i=1}^{n} (D_i - D_i')^2 \cdot \lambda_i
\]  

(1)

And \(D_i\) is the distance between two feature points in the photo, \(D_i'\) is the corresponding distance in 3D model, and \(\lambda_i\) is the weight value for each feature point distance, \(n\) is the quantity of the corresponding distances.

B. Texture Mapping

High-quality texture mapping can make the model more realistic. In the approach proposed in this paper, the face texture generated consists of two layers texture: the first layer is the model neutral texture, it is a default texture which is blinded on the model; the second layer is the cover texture, it should be obtained from a good quality photo. The feature points’ position marked by neutral texture and coverage texture would form two 2D point sets—Set \(V_1\) and Set \(V_2\). Due to the discrepancy existed in hand-marking, it’s much more likely that the corresponding points in \(V_1\) and \(V_2\) are not in the same location precisely. So a mapping approach is needed to combine the two sets naturally. Take \(P_1 \in V_1, P_2 \in V_2\), and extend \(P_1, P_2\) to the 3D vector, \(P_i = (X_i, Y_i, 1), P_j = (X_j, Y_j, 1)\). After obtaining the transformation matrix for each point, the transformation of feature points needs to be applied to the pixels around the feature point. The triangular deformation in the process will be used to apply the cover texture to the model texture. The pixels in the triangle are affected by the vertexes of triangle. Assuming that the three vertexes of the triangle are \(P_1, P_2, P_3\). Set these vertexes as the three columns of a matrix, forming a 3 * 3 matrix \((P_1', P_2', P_3')\). Assume that the transformed triangle is \((P_1', P_2', P_3')\), then:

\[
M \cdot (P_1, P_2, P_3) = (P_1', P_2', P_3')
\]

(2)

For the Point \(P_i\) in the triangle, \(P_i\) will be derived by \(M \cdot P_i\), then, the mapped coordinates of all the points in the triangle can be obtained. For the unmapped point, all the coordinate values are integers, the coordinate value after mapping may not be an integer, so the pixels are unable to be mapped one-to-one with texture picture. Therefore, a sampling approach is needed for taking sample for texture color. In this paper, bilinear interpolation approach (as shown in Fig. 4) which can provide a good quality effect is used for sampling.

C. Skin Color Fusion

After texture mapping, color difference may appear obviously in the texture boundary. This is because the color difference between the neutral Fig and overlay Fig. There are a variety of approaches to eliminate this difference, Rocchine [13] achieved the fusion transition by the linear interpolation on texture boundary, but it is difficult to achieve a smooth transition if the texture color difference is too large or texture overlapping ranges is too small. The approach used in this part is to draw an Alpha Fig with natural transition effects, and eliminate the boundary mutation by setting the transition area of boundary.
The Alpha Fig which is shown in Fig. 5 forms a transition area in the face boundary by the gradation of gray. In the fusion process, the neutral Fig, overlay Fig, and the Alpha Fig will be processed as the same size. The mixed formula of these three Figs is as follows:

\[
C(x, y) = C_{\text{neutral}}(x, y) \ast (255 - C_{\text{alpha}}(x, y)) + C_{\text{overlay}}(x, y) \ast C_{\text{alpha}}(x, y)
\]

(3)

and \(0 \leq C_{\text{alpha}}(x, y) \leq 255\)

The pixels in Alpha Fig would participate in the mixture as the mixed interpolation weight, and the natural fusion would be finally achieved. The fusion effect is shown in Fig. 6.

III. REALISTIC BODY GENERATION

It is still a very challenging task to build a realistic body model interactively. The approach in this part can overcome the shortcomings existing in other approaches, for example: the requirement of mastering professional model software, cracks or holes generated in the model. This part makes it easy to build realistic virtual character models interactively. The steps in detail are as follows:

Step1. Design a set of realistic body models including a reference model, a vertical extension model and a horizontal extension model.

Step2. Obtain the vector differences between control points in the reference model and the horizontal and vertical stretching models.

Step3. Design a vector difference adjuster, and adjust every control point in the reference model interactively to generate realistic body model.

A. Reference Model

Most of the body height of Chinese adults varies from 150cm to 185cm [14, 15]. Take the body difference between male and female, we constructed a female and a
male standard reference model respectively. The height range of the reference model was set between 155CM and 185CM, and was divided into seven segments with 5CM per segment. So, a single model height variation will be in the range of -2.5cm-2.5cm. The other two models with the same structure of reference model are also designed: a vertical extension model which is higher than the reference model; a horizontal extension model which is fatter than the reference model. The three models are shown in Fig. 7.

B. Vector Differential Calculation

The key step of this approach is to obtain vector coordinates of control points rapidly and accurately. It can be solved by designing the model file designed into an m-tree data structure. The right and left hand, leg, and the chest of character model, which are marked above the m-tree, can be quickly found by traversing the m-tree, and then the vector coordinates of their control points are obtained. Using this approach, coordinates vector of the control points of the reference model, vertical extension and horizontal extension model are obtained respectively

\[ M_{op} = \{x, y, z\} \], where x, y, z respectively represent the coordinates of x, y, z axis, \( M \in \{H, F, C\} \), \( D \in \{W, L, O, N\} \), \( p \in \{r, l\} \), H represents the hand, F represents the foot, C represents the chest, \( W \) represents horizontal extension model, \( L \) represents the vertical extension model, \( O \) represents the original model, \( N \) represents the new model, \( r \) represents right side, and \( l \) represents left side.

After obtaining the vectors of the three models, the following formula is used to calculate vector differences of horizontal extension model and reference model, vertical extension model and reference model:

\[ \Delta M_{dp} = M_{dp} - M_{dp}' \]

and

\[ D' \in \{W, L\}, D'' = 0 \] (4)

C. The Design of Vector Differential Adjuster

In this part, a vector differential adjuster is designed to allow users modify model shape in real-time. The model is divided into different components, such as head, hands, feet and chest. Except for the head, two kinds of adjuster are designed for the other three components. One controls the parameter of vertical increment, and the other controls the parameter of horizontal increment.

After obtaining every vector differential above, adjusters are employed to control the incremental impact for the various components of the reference model in this part. The control points’ vector coordinators of the new model are obtained through continuously adjusting:

\[ M_{op} = M_{op} + \alpha \Delta M_{op} + \beta \Delta M_{tp} \] (5)

While \( \alpha \) represents the incremental parameters of horizontal extension model, \( \beta \) represents the incremental parameters of vertical extension model.

When the body is extended or shortened, the joints between body and foot would have a crack. In order to solve this bug, the formula (6) and (7) are used on feet parts [16]:

\[ F_{op} = F_{op} + \alpha \Delta F_{op} + \beta \Delta F_{lp} + \beta \Delta C_{lp} \] (6)

\[ F_{op}' = F_{op} + \alpha \Delta F_{op} + \beta \Delta F_{lp} + \beta \Delta C_{lp} \] (7)

While \( \beta \) represents the feet’s control parameters of vertical extension model, \( \beta \) represents the chest’s control parameters of vertical extension model.

IV. NATIONAL DANCE INTERACTION DISPLAYING

It is only a technical way to design a realistic role and bind the dance motion which is captured by motion capture system. It is only an important step to realize the digitized recovery of dance, but not our ultimate goal. Only through a convenient way to display, even with some entertainment features, and in the aid of high-speed network, the masses can have the opportunity to watch and understand this recovery achievement [17]. It can promote the protection and spread of the cultural heritage efftely. In this paper, Funeral dance of Tujia nationality, a Chinese national dance, is selected as a typical demonstration. Through recovering the realistic actor, the national dance is displayed by multi-dimensional based on the multimedia interactive platform, which realized the digital representation and spread of national dance [18]. The interaction design process is shown in Fig. 8. Through the module of behavioral interaction, the user can manipulate the behavior of realistic actor and watch the activities of the recovered group culture interactively.

V. EXPERIMENTAL AND ANALYSIS

In order to verify the robustness and accuracy of the proposed approach, the experimental system is developed based on the Visual Studio 2010 platform. The configuration of experimental computer is Inter i5-2400 CPU@3.10GHz and 4GB memory. In this experiment, the effectiveness will be certificated from the two aspects: the realistic character generation and multimedia interactive display.

A. The Generation Experiment of Realistic Character

The 3D face model database is constructed by capturing the different user face with the MH/MHT 3D scanner, and the models are standardized pretreatment. The face type of input photo is determined through the proposed approach. Then the most similar model is matched in corresponding face database, and achieving the texture mapping and fusion automatically. According to users’ height and body proportions, they can adjust the combination deformation for the different parts of the model and even the whole body in vertical and horizontal direction. Fig. 9 is a 3D head model and the body model which was obtained by adjusting the composition changes. Therefore, the approach in this paper can be used to control the model deformation interactively, and to generate the realistic character quickly.
In this part, the dance motion is obtained from live performance based on the principle of true representation. Therefore, the experiment system collects the dance motion from dance actor by motion capture system. Then, the funeral dance is reappeared dynamically and realistically by binding the realistic character.

Finally, based on the archaeological map, recovering the real 3D scene of Badong County, building the performing venues, and expressing the funeral dance visually by human-computer interaction, Fig. 10 is the final effect of this dance.

C. Result Analysis

For the analysis of realistic character generation, this approach is a simple, yet very effective way to interact with users and has the most similarity with the photo. This approach provides the function of skin color fusion, and can adjust the model to achieve the optimal model, and less feature point were selected which reduced the complexity of the algorithm and the computation time.

For the application of national dance display, the advantages come as follows:

1) Through the interactive system based on realistic character, visitors’ immersion are strengthened and learning desire stimulated, which can guide the user to understand the relative display content better.

2) Taking advantage of this platform, users can realize the interaction and learning of national dance in a friendly interface in a very simple way.

VI. CONCLUSION

In this paper, an approach of national dance protection based on realistic character is proposed. It provides a more realistic interactive display platform for the field of dancing. As a tool, it is a symbol that the traditional dancing art can get faster and better development; while at the same time, as an idea, it represents a big progress in the combination of dance and digitization. In addition, the approach of realistic character generation are of better robustness which does not require users to master professional modeling software, and it’s convenient for the user to build realistic character models. It can also be widely used in the virtual campus, virtual libraries, and virtual museum and so on.

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