A Hand-Waving Dance Teaching System Based on Kinect

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A Hand-Waving Dance Teaching System Based on Kinect

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Abstract. Hand-waving dance is the essence of Tujia culture. Whereas it is facing the danger of dying out. Following a choreographer's direct demonstration or watching videos recorded by dancers is the traditional learning method. Though there will be a certain degree of effect, the preciseness and feedbacks are often not so satisfying. In this paper, by analyzing the application of motion sensing technology in dance teaching, we designed and developed a set of interactive teaching system based on Kinect for Tujia traditional Hand-waving dance. In this system, not only can users learn dance skills, but they can also get an intuitionistic evaluation and review their learning process. Our study aims to solve the problem in Hand-waving dance teaching and provides a new method for Hand-waving Dance learning. Finally, we can see that the interactive learning based on computer is gradually becoming a new popular learning style.

Keywords: Interactive learning · Kinect · Motion sensing · Hand-waving dance

1 Introduction

Hand-waving dance, known as the wonderful work in Tujia culture, is the essence of Tujia minority culture. Nowadays, there are two main ways to carry out the teaching and inheritance of the dance. One way is to learn the hand-waving dance from a choreographer face-to-face instruction. Another is to collect the motions of professional dancers then organize them into texts, images, videos and other multimedia teaching materials for learning. Nevertheless, for the former one, hiring dance coaches can be costly, which is not acceptable to most of the public. For the latter one, the learning effect is not ideal. Let alone conducting scientific analysis of learners. Consequently, we are urgently in need of an effective method to teach hand-waving dance, an endangered intangible cultural heritage.

Motion sensing, also known as motion sensing control technology, is a kind of technology that directly uses body motions, sound, eye rotation and other means to interact with the surrounding devices or environment. During the process, the user's action is identified and analyzed by computers so that feedback can be made [1]. In 2007, Nintendo launched Wii Remote. After the release of this product, the concept of "somatosensory game" appeared. The majority of gamers are very keen on this "farewell game controller" gameplay and they give good feedbacks. Then in 2010, Microsoft launched Kinect and opened the SDK in the Windows platform [2], which provides some

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examples of the human body three-dimensional posture tracking. Microsoft has been promoting and training a number of potential developers until Kinect began public. Kinect v2.0 launched in 2014 made motion-sensing technology really popular. Compared to the first-generation Kinect product, it enhances the depth sensing capability, improves the Output Resolution, reduces the latency of the system and improves the body tracking algorithm [3]. Gradually, in such fields as medical fitness, retail industry, education, training and scientific research, Kinect begins to be widely used [4]. With the further development of motion sensing technology, more and more studies focuses on computer interactive learning. Interactive learning refers to all the human-computer interactions that contribute to learning. It is widely used in various fields such as enterprise innovation, communication ability training, teaching and cultivating, and has achieved good results [5]. As a branch of interactive learning, computer interactive learning makes use of intelligent interactive system and learners in the virtual environment for "human-machine" interaction. For it is interactive and immersive, this computer-based two-way communication is becoming the mainstream learning style.

Therefore, for the teaching of hand-waving dance, motion sensing technology has become a feasible solution. This paper sorts out and analyzes the relevant researches of somatosensory technology in the application of dance education. We will verify that "motion sensing technology can provide a better solution for Tujia hand-waving dance teaching" and design and develop a set of hand-waving dance teaching system based on Kinect. In order to solve the problem exists in traditional hand-waving dancing, the system needs to accomplish the following goals:

1. To avoid being as boring as the traditional teaching method of hand-waving dance.
2. Realizing the real-time scoring of the user's dance motions, to provide timely feedback to the learners.
3. Learners are able to look back at their performance so that learners can self-correct their motions.

The rest of this paper is organized in the following order: The second part briefly summarizes the theoretical basis of this paper and the relevant work already carried out domestically and abroad. The third part introduces the Tujia hand-waving dance teaching system in detail. The fourth part is the summary and prospect of this paper.

2 Relative Work

Although motion-sensing technology has only developed just a few years, it has a good application prospects. In this section, we reviewed the researches on dance teaching and motion evaluation to prove our study was feasible and necessary.

2.1 Studies on Dance Teaching Based on Kinect

According to a great deal of literature, we can see that most works about dance teaching by motion sensing technology relate to Ballet. Matthew kyan's study is a typical sample. He uses the trainer's movement data captured by Kinect cameras to conduct ballet dancing training [6]. The system creates a virtual reality environment consisting of three projectors, where learners can learn ballet with the help of Kinect.

Wang Tong et al. from Harbin Institute of Technology, invented a multi-screen interactive folk dance entertainment system based on Kinect [7]. Similar to Kyan's system. They built a square lab and projected to the four walls. Kinect is placed in the center of the lab. Users can get an immersive experience in this system.

Kar R's work extends the dance application of Kinect to the field of Indian dance. He uses Kinect to discover visually fascinating dance fragments for "Odissi" (an Indian dance) creation and teaching [8].

It is obvious that dance teaching based on Kinect has the characteristics of immersion and interactivity which Tradition dance teaching doesn't possess. So "Kinect provides a better way for interactive teaching of dance" proves to be feasible. However, rarely can we find relevant researches of applying motion sensing technologies to hand-waving dance teaching and Intangible Cultural Heritage protection, so our team mainly focus on the somatosensory teaching and then design a set of dance system to solve the problem in traditional hand-waving dance teaching.

2.2 Studies on Motion Evaluation Based on Kinect

The motion evaluation also becomes a research hotspot recently. Kang shuchen utilized Kinect "Bone Tracking" technology to evaluate the child's static sitting posture and dynamic behavior. This study aimed to test the mobility coordination of children [9]. Wang wenyuan's study realized table tennis teaching based on Kinect, after the four groups of basic action training, their system evaluates the posture of the learners [10].

There are also some researches on dance evaluation. Alexiadis et al. used Kinect's skeletal tracking technique to do dance evaluation [11]. Their program compares the joint positions and joint velocities (the output of the skeleton tracking module) and the 3D Flow-Error by "aligning dance movements from two different users and quantitatively evaluating their performance" to provide feedback to the dancer. Huang et al. from the National Dong Hwa University of Taiwan exploit the Kinect to evaluate a dancer's performance compared to the sample motions of the "teacher". Different from Alexiadis's study. Their criteria are based on posture and tempo accuracy [12].

More Studies show that Motion Evaluation based on Kinect will become a trend. Nevertheless, we haven't found any work related to real-time dance evaluation. Let alone self-assessment. Hence designing a set of dance system which owns good evaluation mechanism will become the focal point of our work.

3 Hand-Waving Dance Teaching System

3.1 Design of the System

Considering the development state of the traditional hand-waving dance, the masses who need to learn the dance are mostly young people from Tujia minority. For young people, the traditional hand-waving dance teaching is boring. The advantage of somatosensory teaching is the natural operation behavior of a user in the process of teaching.

This teaching model is conducive to increase the user's physical and psychological pleasure. In the process of designing motion-sensing application, points should be noted are as follows: the user group, the number of users, user characteristics. The teaching system we designed is mainly for young people. So, when designing functions, interfaces, modules, we should take into account their characteristics.

3.1.1 Interface and Model Design

Consider hand-waving dance as a treasure of Tujia. Elements that carry characteristics of Tujia Minority are mainly employed in the progress of designing the background interface, such as Tujia clothes and jewelry.

For the modeling part, We used the "poly by poly" technique to display the charisma of Tujia boys and girls. In order to improve the operating efficiency, we appropriately reduced some useless vertexes and polygons. The following Fig. 1 shows the 3D models in this systems.

Fig. 1. Models in this system.

3.1.2 Interaction Design

The system interacts with the user's somatosensory manipulation, which is divorced from the shackles of third-party tools such as the mouse and keyboard. By recognizing the position of your hands, you can move your hand in front of the Kinect instead of mouse movement and click operation. The learner uses the palm to operate the system and choose the module function. Considering the usability of the system, the mouse interacts with the "hover" operation by which you can choose a function after Staying on a button for 3 s. Figure 2 below shows the functional interaction of the system.

Fig. 2. Interactive method

3.1.3 Module Design

In the progress of designing hand-waving dance teaching system module, the education and entertainment should combine effectively. In an interactive system, the user is both a learner and an Instructor. The purpose of the system is to enable users to learn hand-waving dance in a happy mood. So, we try to accomplish the following points when designing different teaching modes:

- To be inspired in learning
- To learn in different ways
- To get feedback in real time
- To do self-correction
- To compete with friends

Of course, all of these must correspond with the learner's knowledge and age. Hence we set up four teaching modes in this system, they are practice mode, feedback mode, double mode and playback model. Specific features will be shown in Sect. 3.3.

3.2 Implementation of the System

3.2.1 Operation Process of the System

We designed the basic framework of this system according to the characteristics of Kinect and Hand-waving dance. Functions are as follows: 1. Data collection 2. Data analysis of skeletons 3. Interaction with system 4. Evaluation of dance (Fig. 3).

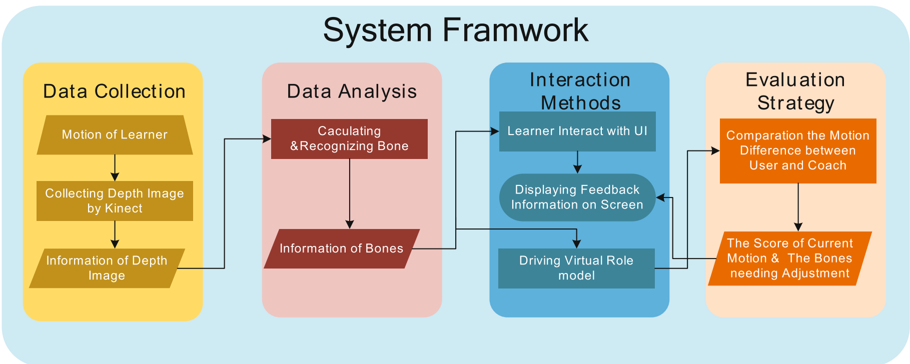

Fig. 3. System framework

Steps 1, 2, 3 are mainly as follows: Kinect identifies and captures the Learner's depth image. The position of the current user's each joint can be recognized by running the background-clipping and bone recognition algorithms on the image. User's joints location information collected by the system controls the virtual characters in the scene to interact with the scene.

After a simple interaction with the system, we need to get real-time feedback.

Therefore, Step 4's core idea is to evaluate the user's dance posture in real time. The actions involved in the system are divided into two categories and bound to two types of 3D body model respectively. One of them is coach's action. The action performed by the professional hand-waving choreographer pre-collected and bound to the coach model. Another is user's action. Users can utilize Kinect to control their own character model, perform Tujia hand-waving dance motion.

3.2.2 Key Techniques

(1) **Motion Capture.**

Motion capture technology can measure, track and record the position of users' various parts of the body during exercise, then convert the position into computer-recognized data coordinates, and coherent data coordinates can be applied in the field of 3D animation [13]. Common motion capture techniques include mechanical motion capture, electromagnetic motion capture, active optical motion capture, and passive optical motion capture. Though these technologies have high accuracy, they are always expensive and have a complex operating process. So, to correspond to the original design intention. we still use Kinect to capture virtual choreographer's movements. The camera in Kinect can obtain user's 20 joints (19 bones) information, including the location and rotation and some other information in the three-dimensional space.

In the system, we invited a professional Hand-waving choreographer to participate in the process of action recording. And exported action model which is in .dae format can be assigned in unity to the Tujia Coach for they have the same skeleton. As for learners, they study the dance in front of the camera. The system compares learner's gesture and posture with the virtual coach and then give feedback to the learner. Figure 4 is the process of action capture and model binding.

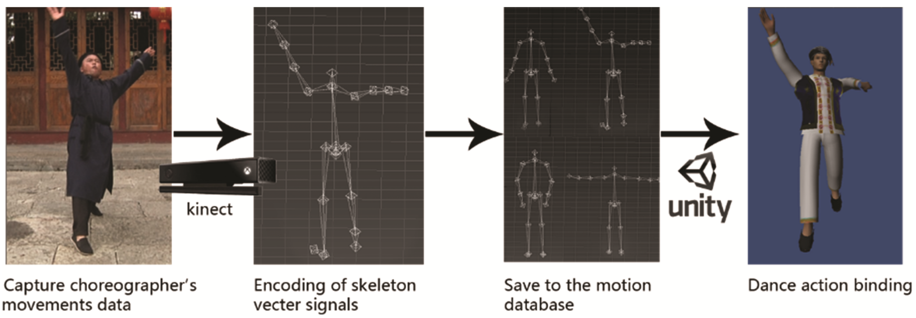

Fig. 4. Motion capture & Action binding

(2) **Dance Real-time Evaluation**.

In Unity, each joint of the character model is seen as a game object. The property "Transform" can be used to get the position and movements information of these key skeleton points in the world coordinate system. Therefore, the difference between the skeletal eigenvector matrix can be calculated by extracting the skeletal vector information on the user model and the coaching model. Kinect V2 can recognize 25 joints data of the human body. Considering the feature of Hand-waving dance, we removed five unrelated joints. The remaining 20 joints make up 19 skeletons. Figure 5 is the skeletal structure that can be recognized in Kinect (the red points are removed joints).

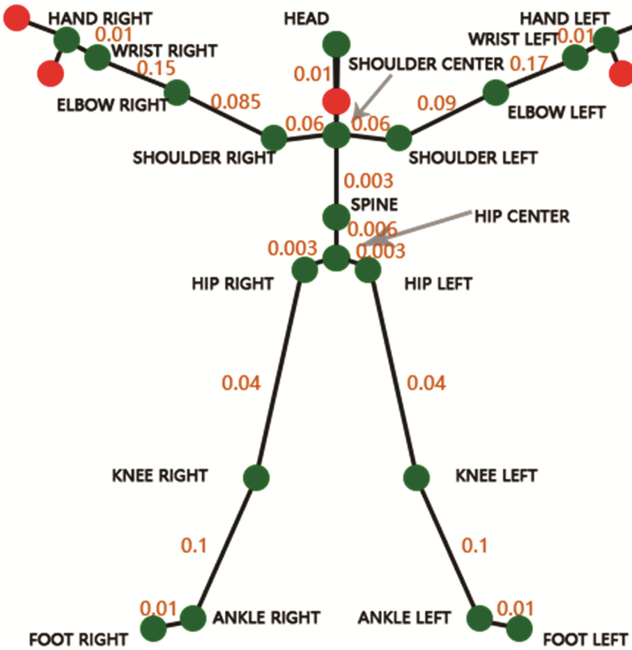

Fig. 5. Structure of human skeleton (Color figure online)

Each bone has its own position and angle information when a person takes some actions [14]. In this system, the coach and the learner may not have the similar figure. Thus, we characterized one specific motion by exploiting cosine features of 19 bones we defined. For example, for the bone between Left Shoulder and Center Shoulder joint, assuming that their spatial coordinates are (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2), then the skeletal space vector is $(X_1-X_2, Y_1-Y_2, Z_1-Z_2)$, the cosine of the vector relative to each axis can be obtained by calculation. Figure 6 shows the calculation step.

$$\cos\alpha = \frac{x_2 - x_1}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}}$$
$$\cos\beta = \frac{y_2 - y_1}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}}$$
$$\cos\gamma = \frac{z_2 - z_1}{\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}}$$
$$(\sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \neq 0)$$

Fig. 6. Steps of calculating cosine eigenvalue

Three cosine eigenvalues (cosα, cosβ, cosγ) of each bone severe as an eigenvector and save on a matrix. So, we can get a 19*3 characteristic matrix. After extracting the eigenvector of each bone in Instructor's model and learner's model. We innovatively use the Euclidean distance to compare the similarity of the feature matrix. Then the difference degree $\mathbf{e}_i$ of eigenmatrix in each bone can be calculated.

There are eight motions in hand-waving dance. Each motion has its own characteristics. Different parts of a body have different frequency. So, we can achieve the frequency of the use of each bone according to a Hand-waving dance video, and then determine each bone's weight $\boldsymbol{w}_i$. The weight of each bone marked with orange numbers in Fig. 7. We use $\boldsymbol{d}_{max}$ and $\boldsymbol{d}_{min}$ represents maximum difference and the minimum difference degree of the motion. And finally, through the following algorithm to obtain real-time scores.

$$\text{socre} = \frac{d_{(u,c)} - d_{max}}{d_{min} - d_{max}} * 100 \qquad (d_{(u,c)} = \sum_1^{19}(w_i * \mathrm{e}_i))$$

Fig. 7. Key Algorithm

At the same time, we extracted the least standard four parts of each frame and displayed on the screen. This allows the user to get timely feedback. The Fig. 8 below shows the evaluation result of one motion.

The frame rate of Kinect v2 upgrades to 30 fps compared to 15 fps of its first generation which makes the amount of data updated per second become much larger and real-time evaluation become much more referential.

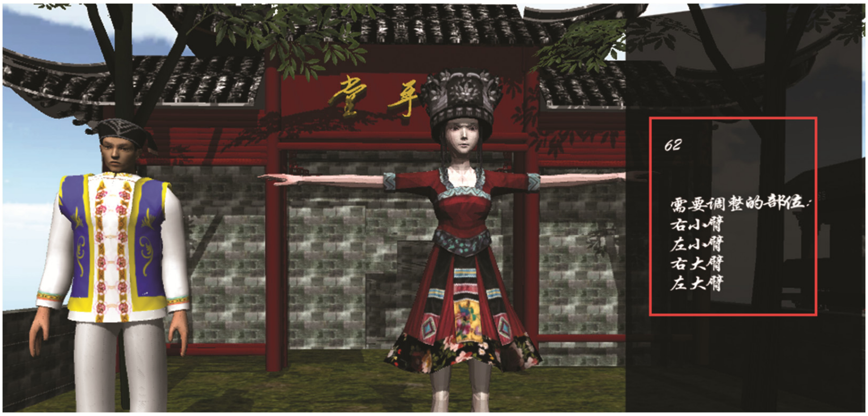

Fig. 8. The evaluation results of one motion.

3.3 Function Module Introduction

Based on the characteristics of Kinect and Hand-waving dance, the teaching system is divided into the following four modes: practice mode, feedback mode, double mode and playback mode, Fig. 9 below shows the system function module, with a variety of methods to realize basic exercises of Tujia Hand-waving dance and reflective learning.

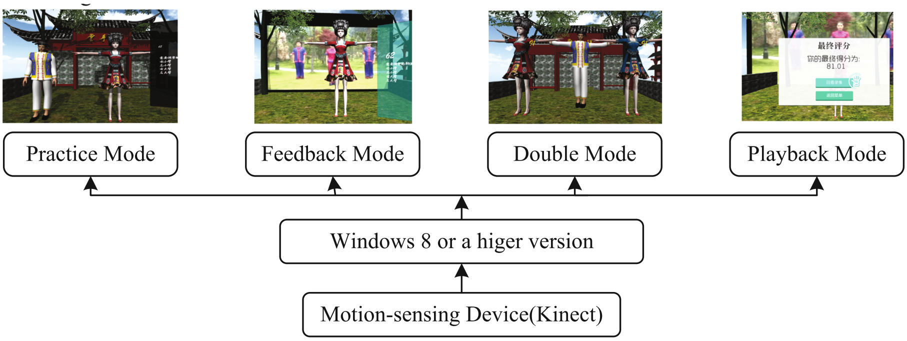

Fig. 9. Function module of this system

3.3.1 Practice Mode

Practice mode is the first scene of this system. Hence, users can dance following the virtual choreographer just like following the real choreographer beside them. This mode can help new learners of hand-waving dance know more about the basic moves of hand-waving dance and its essentials since the basic movements of each dance are determined by the professional choreographer. In addition, each basic movement contains several frames of the static move and the movement database contains almost all the basic movements of hand-waving dance for evaluation of the user's movement. Moreover, the method for movement evaluation has been illustrated above. Players can imitate the moves of virtual choreographer in practice mode eventually. The player can go into the next movement only if the score of this movement reaches 65. Otherwise, the player cannot go ahead until this movement is qualified.

3.3.2 Feedback Mode

Learners can master the basic movements of hand-waving dance after practice mode. But the continuity of the whole dance needs to be improved. Hence, feedback mode is designed and developed based on this. Users can learn the whole continuity of hand-waving dance by following the virtual choreographer in feedback mode. What's more, each movement of the player can be recognized and scored according to the movement compared to the corresponding standard ones in movement database. More importantly, the substandard four important parts can be demonstrated to help the user adjust immediately. Therefore, learners can get the essentials of each movement and the whole continuity of dance after feedback mode.

3.3.3 Double Mode

The double mode is an integration of learning partner, competitiveness and enjoyment. Kinect can be used to track two learners at the same time. It means that two users can learn hand-waving dance together following the same virtual choreographer. And they are learning companions who can learn from each other. The evaluation results are the final evaluation of their overall dance movements and there will be scores to enhance the enjoyment at the end of the dance. Above all, two users can learn together and enhance learning enjoyment by competition and cooperation.

3.3.4 Playback Mode

Playback mode makes it possible for reflective learning of the dance, which is not easy in the traditional dance learning. After learning a passage of dance, users may need to check the learning outcome and find out the problems existing in the learning process. The recording and replaying function can be used to record and replay the learning process of the user to promote his/her reflective learning. Being aware of the shortage of their own learning, learners can improve their learning correspondingly.

Figure 10 shows the system used by a learner.

The initial application site of this system locates in Changyang, Yichang, Hubei Province. After our guidance, the staffs in Tujia Museum learned the Hand-waving dance in front of the Kinect. They grasp some key motions of this dance and expressed their satisfaction with this system.

Fig. 10. Learning experience

4 Conclusion

Hand-waving dance is a national Intangible Cultural Heritage. It is the essence of Tujia ethnic culture and the evidence showing that Tujia is different from other minorities. While the developing condition is not ideal. Hand-waving dance teaching and heritage are facing a challenge. Therefore, this article analyses the application of motion sensing technology in dance education and design and develop an interactive Hand-waving dance teaching system to improve current dancing teaching. It also fills the gaps in relative researches. At the same time, the study also plays an important role in the protection of Hand-waving dance and the intangible cultural heritage.

It is observed that the interactive blended learning has gradually become a mainstream in education through this study of interactive dance teaching. More and more researches have proved that computer-based interactive learning will become a trend for future education. We believe that motion sensing technology will integrate with the intelligent wearable device and virtual reality technology to open up an “Anybody at any time, in any place, by any way, learn any content” wisdom learning era.

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