Design and Implementation of Virtual Sanxian Teaching System

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***Abstract*—In recent years, with the development of human-computer interaction technology and the increasing emphasis on musical education, more and more digital technologies have been applied to facilitate musical instrument teaching and learning. However, most of current studies were focused on digitalization of some popular instruments (e.g., piano, guitar), the interactive systems for traditional musical instruments were rarely involved, which may impede the inheritance of traditional musical instruments. In this study, started from the gamified learning theory, an desktop-VR based system was designed for learning Chinese Sanxian (a traditional musical instrument), with the interaction of mouse and keyboard. A preliminary acceptance evaluation of the virtual instrument teaching system was conducted and analyzed.**

***Keywords*—musical instrument digital interaction, virtual reality, game-based learning**

I. Introduction

Sanxian is one of the traditional Chinese plucked instruments, with a unique shape, elegant timbre, strong expressiveness, and extremely high artistic as well as cultural value [1]. However, in this ever-changing era, influenced by the culture of other nation, the inheritance of traditional musical instruments such as Sanxian is facing great challenges. Moreover, since traditional musical instruments are difficult to obtain or expensive, and require professional music teachers to teach, traditional musical instruments are difficult to inherit and thus facing extinction [2]. Therefore, a new inheritance method is urgently needed to solve the current problems. However, at present, the preservation of Sanxian instrument culture is mostly based on video and text, which is lack of interactivity, and cannot meet the needs of many learners.

The continuous emergence of information technology provides new support for the preservation and inheritance of traditional musical instruments. Therefore, the effective combination of the two is expected to enable the inheritance and further development of traditional musical instruments [3]. However, the existing digital interactive virtual instrument teaching programs mostly focus on modern Western instruments such as piano and guitar [4]. There are relatively few teaching software for traditional Chinese musical instruments, and there is a gap in the study of digital teaching systems for Sanxian musical instruments. Therefore, based on the multimedia teaching theory and gamification, this study designed and developed a Sanxian virtual interactive teaching system. We would like to provide an effective preserving method of Sanxian, to make the teaching of the Sanxian instrument break through the limitations of time and space and become more interactive and convenient.

The rest of the article will be organized in the following order: The second part summarizes the current study of the digital interaction of musical instruments. The third part introduces the interactive playing mechanism of Sanxian instrument and keyboard and mouse. The fourth part introduces the function of each module of the system. The last part is the summary and prospect of this work.

II. Related Work

A. Research of Digital Interaction Mode of Musical Instrument

With the development of technology, playing musical instruments does not have to be limited to traditional methods. Realizing intelligent interaction with musical instruments with the help of related technologies such as virtual reality and augmented reality has become a research hotspot. For example, Figueiredo et al. used color gloves and computer vision technology to detect the movement of the hand by calculating the distance between the hand and the strings, so as to realize the performance of the guitar [5]. In addition to the use of gloves and other wearable devices, the hand can also be directly recognized to achieve the effect. For example, Hsu et al. used Kinect 3D sensors to realize the virtual performance of guitars, drums, and new musical instrument Spider King by recognizing the coordinate positions of gestures [6]. In addition, Zandt-Escobar et al. also used Kinect 3D for gesture recognition technology, designed and developed a piano performance system named "PiaF" to support piano teaching [7].

Based on this trend, information technology-assisted music education has attracted widespread attention from the Chinese government, hoping to promote the reform and remodeling of Chinese music with the help of technology [8][9]. For example, Mei et al. designed a mobile device program that assists piano learning based on augmented reality technology, which serves as real-time feedback of learning during piano practice to achieve the assisted learning effect [10]. Focusing on traditional Chinese musical instruments, Lou et al. designed and developed a computer-

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assisted traditional music teaching system for the appreciation course of Chinese Musical Instruments, which was integrated into the practical teaching to assist the classroom to improve the teaching effect. However, this system only includes the introduction and appreciation of traditional musical instruments and does not introduce how to use them [11]. In the specific study of playing teaching, some researchers have designed a Chinese traditional musical instrument interactive musical instrument system named "ChinAR", which realized the digital teaching of Guqin by using augmented reality and gesture detection technology [12]. In addition, for the learning of other traditional Chinese musical instruments, such as dulcimer and Duxian Qin, there are corresponding digital auxiliary teaching systems, which can not only be used as teaching aids, but also as a self-learning system for traditional Chinese musical instruments [13].

As noted above, hardware devices such as data gloves and Kinect 3D somatosensory cameras are not popular, or the corresponding software design is not complete, it is difficult to enter the public's field of vision. Augmented reality or desktop virtual reality technology can be well popularized and promoted with the help of computers and mobile devices, and is applicable to a wide range. At the same time, through literature review, it is found that there is almost no research on the digital teaching system of Sanxian instruments. Therefore, this study uses desktop virtual technology to design Sanxian virtual interaction system.

B. Theoretical Basis

Meyer proposed multimedia instructional design principles, aiming to reduce extraneous processing in learners' cognitive processing, rationally use essential processing, promote generative processing, and finally realize meaningful learning by relying on media technology[14]. In the multimedia learning environment, how to stimulate learners' learning motivation by designing the presentation of teaching materials, so that they can actively carry out cognitive processing becomes very necessary. And gamification teaching can effectively stimulate learners' enthusiasm for learning.

Gamification was defined by Deterding in 2011 as "using gamification design elements in a non-gamification context to stimulate user participation" [15]. The three most common gamification elements are Points, Badges and Leaderboards, referred to as PBL [16]. With the reform of education, the advantage of gamification teaching to stimulate students' initiative has been widely concerned by many scholars. Researchers integrate various gamification elements into mathematics, science, computer and other fields to explore the impact on learning effects and emotions [17]. Vankúš et al. sorted out the influence of the use of game-based learning in the field of mathematics on student emotions, and the study found that game-based learning has a positive impact on student motivation, participation, attitude, and flow state [18].With the support of virtual reality technology in the field of natural sciences, Hwang et al. compared the learning effects in gamified and non-gamified contexts and found that students' academic performance and attitudes can be improved under the drive of gamified elements [19]. In computer courses, Kumar et al. found that with the encouragement of gamification elements such as grades and badges, as well as the support of augmented reality technology, learners showed higher learning motivation [20]. Focusing on the learning of musical instruments, Ishak et al. adopted gamification teaching idea, set the level of passing through, and guided learners to learn traditional Musical Instruments from China, Malaysia and other countries in the game with realistic sound and attractive animation [21].

As noted above, gamification teaching has achieved good results in many disciplines, but there is almost no research on the application of gamification teaching methods to Sanxian instruments. Based on this, this research will combine multimedia teaching design principles to design gamification elements and integrate them into the Sanxian virtual teaching system to stimulate learning interest and achieve better learning results.

III. System Design

The components of the Sanxian include drum, strings, rod, crown, mountain pass, shafts, etc. The strings are the main vocalizers of the Sanxian, and the three strings of itare divided into sub-string, middle string, and old string [22]. The specific structure is shown in Figure 1. The playing techniques of Sanxian are flexible and changeable. Players generally use their left hand to hold Sanxian and play it with their right hand. Playing techniques are divided into three types: single technique, compound technique and assembly technique. Among them, the single technique is the most basic technique, which is widely used in Sanxian performance. The specific performance method is that the right hand is used to "play" and "pick" the strings, and the left hand is used to press the strings. The "play" string is the action of plucking the strings from top to bottom to make sound. The "pick" string is plucking the strings from top to bottom to make sound. The posture of playing the Sanxian is shown in figure 2 [23]. Although the playing techniques of Sanxian are complex and changeable, they are all based on the single technique. Therefore, we use the single technique as the main content of Sanxian teaching in our system.

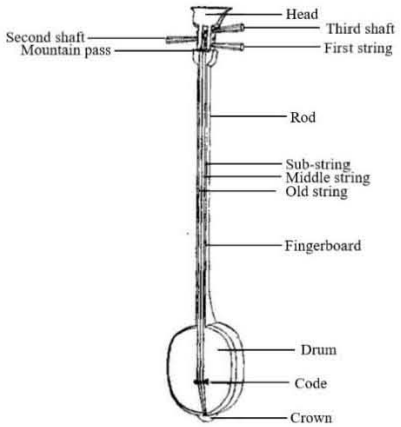

Fig. 1. The structure of Sanxian [22]

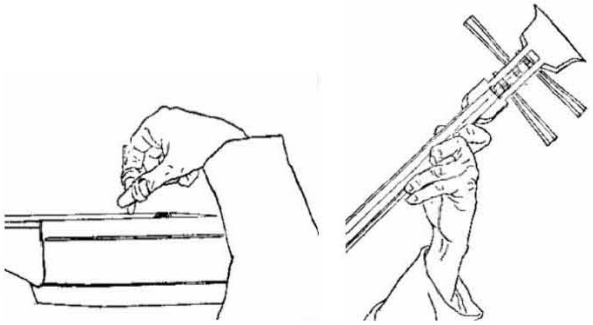

Fig. 2. The right hand playing the strings and the left hand pressing the strings [22]

A. 3D Model design

The construct of 3D models is the first task of the virtual interaction. In the development of this system, 3D modeling is divided into two parts: the Sanxian model and the hand model, which are all constructed based on the 3D modeling software Maya. The model renderings of the Sanxian and hand are shown in figure 3.

Sanxian model construction:This system use Maya structure construction function to construct the overall outline of Sanxian based on the structural characteristics of the real Sanxian. Use the basic three-dimensional models to construct the specific part of Sanxian. Use Boolean, smoothing, chamfering and other tools to optimize the edge and model accuracy. After the modeling is completed, import the model into unity3D development system, and set the rendering effect of the light to achieve a real visual effect.

Hand model construction: Unlike the Sanxian model, building a hand model requires adding skeleton part to the base model. After constructing a hand model with five fingers naturally open, use skeleton components to complete the work of skeleton construction, skeleton binding and weight adjustment and finally adjust the hand model to match the button.

Fig. 3. Model renderings of the Sanxian and hand

B. Interaction design

The interactive operation based on the mouse and keyboard is simple, flexible and diverse, the technology is mature and the equipment is easy to obtain. It is currently one of the mainstream human-computer interaction methods. The mouse can proportionally synchronize the detected movement distance of the user's hand to the screen, which is an extension of the user's hand, and the keyboard can transmit instructions issued by the user by detecting the button pressed by the user. In addition, the combined operation of the mouse and keyboard also plays an important role in the interaction between the user and the computer. In the interaction with the virtual scene, the user sends out commands such as “click button”, “select object”, “move object” through “mouse click”, “mouse press”, “mouse movement” and other methods. At the same time, the user can also trigger events by "pressing the button" or "long pressing the button" through the keyboard.

In the virtual Sanxian interactive system, realizing the simulation of performance is the core of the development process. In the virtual Sanxian teaching system, learners can see the appearance of Sanxian through the display screen and associate the texture of the object, but learners cannot touch Sanxian with their hands, which will create a sense of distance between the user and the system. Therefore, we chose the keyboard-mouse interaction method that is closest to the actual performance of the Sanxian. On the one hand, the interaction method based on the mouse and keyboard can make up for the sensory limitations, restore the process of Sanxian playing to the greatest extent, and enhance the experience realism of user. On the other hand, the user's knowledge transfer ability can be used to shorten the time for users to familiarize themselves with the system.

According to the actual way of playing the Sanxian, this virtual teaching system maps the main chord-pressing points of the Sanxian to the keyboard. The basic chord-pressing point of the left hand corresponds to the left side of the keyboard, and the trigger button for the right-hand technique is set on the right side of the keyboard. Press the keyboard keys to simulate left hand and right hand movements. In addition to the simulation of the relative position of the user's hands, audio synchronization is also needed to mobilize the user’s sense of hearing and further enhance the realism of the system. At the same time, there should be a medium in the virtual scene. In the virtual performance of Sanxian, this medium is the "hand" in the scene. It passes through the wall between the user and the system and serves as an extension of the user's hand. Therefore, it replaces the user to touch the Sanxian model and it can reduce the isolation between the user and the system and enhance the sense of participation.

In general, as the design principles shown in figure 4. At the level of Sanxian knowledge, this system is based on the musical theory knowledge, structural characteristics, and playing techniques of Sanxian. At the theoretical level, the teaching process is designed with the idea of gamification teaching, and the multimedia teaching theory is used as a guide for the use of technologies. At the technical level, 3D modeling technology is used to construct the Sanxian musical instrument and hand model, the keyboard-mouse interaction technology is used to design the virtual instrument interaction, and finally, the entire virtual Sanxian musical instrument teaching system is constructed by virtual reality technology.

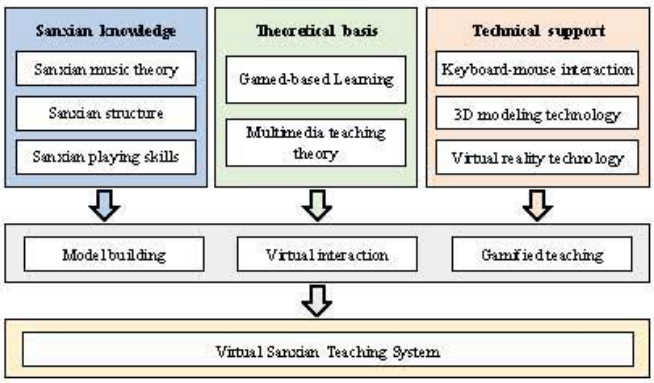

Fig.4. Design principles

IV. System Function Module Implementation

Based on the theoretical knowledge and playing techniques of Sanxian musical instruments guided gamification teaching theory, this system designed four functional modules, including Sanxian introduction, structure display, simple interaction, and entertainment mode modules. The virtual system is used to simulate the playing of a real Sanxian instrument, which promotes learners from theoretical knowledge to practical operation, from simple interactive operations to complex exercises to complete the entire song. This system guides learners to systematically learn the music theory knowledge and performance techniques of Sanxian instrument, which is from theory to practice, from simple to

complex. The main page and specific modules of the system are shown in figure 5.

Fig. 5. Main page diagram

A. *Sanxian Introduction module*

The Sanxian introduction module (As shown in figure 6), consists of three parts: a brief description of development, related music theory, and appreciation of famous songs. Use the segmenting principle in multimedia teaching principles to present the knowledge of Sanxian in blocks instead of uninterruptedly in the form of a continuum. Allows learners to control the pace of learning to filter learning materials. Firstly, the brief description of the development of Sanxian presents learners to the entire development process of Sanxian from ancient to modern times, which guides learners to understand the history and culture of Sanxian knowledge, and stimulates learners' interest in learning. Next, the related music theory part introduces the playing method and range of Sanxian. Then, appreciation of famous songs part is to show the performance of Sanxian in the form of video. The play, pause and stop buttons below are convenient for users to watch the video flexibly. Throuth these three functions, learners can learn the basic music theory and playing techniques of Sanxian, laying a foundation for further learning to operate Sanxian.

In general, this module is a combination of video, audio, pictures, text, etc., to give users a preliminary understanding of Sanxian's cultural background and basic music theory.

Fig. 6. Introduction module diagram

B. *Structure display module*

The structure display module (As shown in figure 7), displays the structural characteristics of the Sanxian in a three-dimensional manner. It mainly includes mouse hovering instructions and rotating zoom functions, which are designed to guide learners to have a clear understanding of the shape and characteristics of Sanxian.

The mouse floating indication function allows the user to place the mouse arbitrarily on the various components of the Sanxian model, then the detailed introduction of the corresponding structure will appear on the right panel, allowing the user to have a more thorough understanding of the structure of the Sanxian. Furthermore, in order to better observe each structure from multiple angles, the rotation zoom function allows learners to press the left mouse button and move to rotate the 3D model of the Sanxian. At the same time, the middle mouse button can also be scrolled to zoom the model for detailed observation. In addition, the module also uses the modality principle and is equipped with Sanxian related background music. Learning in the atmosphere of Sanxian music can create a more immersive learning environment and promote the in-depth participation of learners. At the same time, learners can control the pause and play of background music according to their own preferences.

Fig. 7. Structure display module diagram

C. *Simple interaction module*

The simple interactive module (As shown in figure 8), guides users to simulate playing through teaching, which is the core part of Sanxian teaching. Using the signaling principle in multimedia teaching design principles. Give learners tips on how to play a Sanxian instrument and highlight the main learning materials to help learners reduce unnecessary external cognitive processing. Therefore, this module maps the string positions on the strings to the keyboard according to the single technique of Sanxian playing. The left panel of the interface presents the fingering key position map, that is, each finger of the left-hand controls different key positions on the keyboard respectively. The specific key positions are shown in figure 9. Different keys on the keyboard represent different strings on the Sanxian, and pressing the key will sound the notes of the corresponding string. The right hand is responsible for controlling the left and right buttons on the keyboard, which are used to "play" and "pick" the strings to achieve playing. This function guides users to learn the fingering of Sanxian and guides simulated playing operations.

The user can also click the button with the mouse to change the position of the strings held by the hand, thereby realize the free "playing" of the virtual Sanxian. For users who have learned something, the recording function in the upper left corner can record the most recent playing process and playback and enjoy it. On the one hand, users can correct deficiencies based on real-time feedback; on the other hand, users can gain a sense of accomplishment and stimulate interest in learning.

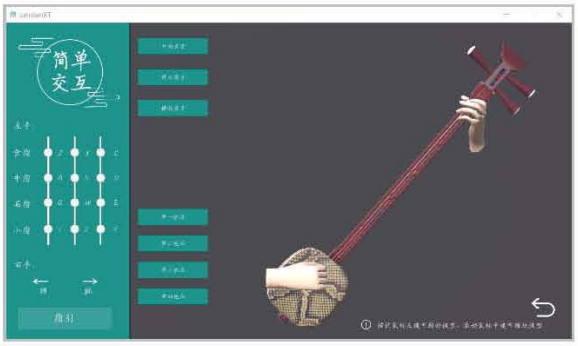

Fig. 8. Simple interaction module diagram

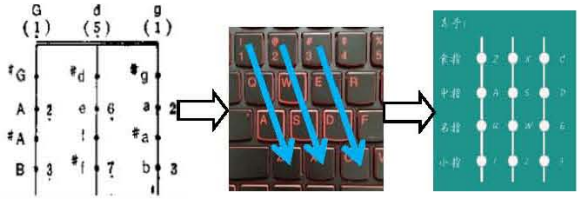

Fig. 9. Playing keys map

D. *Entertainment mode module*

The entertainment mode module (As shown in figure 10), introduces gamification design elements. After the user completes the prescribed actions, the corresponding "stimulus" and "feedback" are given. If the performance is correct, the corresponding sound will be emitted, the color of the picture will become brighter, and the virtual hand will simulate playing. Affirm the learner's behavior through color and auditory stimulation, which enriches the feedback of the system and enhances the user's interest.

To enhance the effect of gamification teaching, the game is divided into three levels: easy, medium, and difficult according to the difficulty of the Sanxian music. The more difficult patterns have a faster pace. The challenge mode enables learners to follow the step-by-step learning of Sanxian from simple to difficult, which meets the different learning needs of learners. This includes the study of the classic Sanxian song *Eighteen Boards*. The feedback of learning results is a scoring type. The scoring mechanism indirectly sets learning goals for learners, so that learners' operations become quantifiable scores. At the same time, according to the degree of completion of the learner's music, a model of the Sanxian is drawn on the left panel of the interface. The higher the degree of completion of the track, the more complete the model drawing. The gamification mechanism arouses learners' desire for victory and defeat, gives learners a sense of accomplishment, and then stimulates learners' interest in learning.

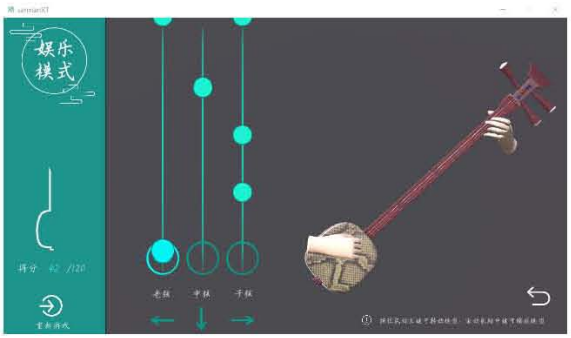

Fig. 10. Entertainment mode diagram

V. System Evaluation

In order to evaluate users' acceptance of the Sanxian virtual teaching system, this study designed a questionnaire based on the technology reception model to measure students' acceptance of learning media. The TAM scale was adapted from the one developed by Liu et al. based on the measures proposed by Davis [24][25]. The scale consists of perceived usefulness dimension (five items), perceived ease of use dimension (five items) and continuance intention to use dimension (three items), respectively. Perceived usefulness is used to measure the user's subjective feelings and satisfaction with the system. Perceived ease of use is used to measure how effortless users use the system, that is, to measure the ease of use of the system. Continuance intention is used to measure whether the learner will continue to use the system or is willing to apply this type of system to the learning of other musical instruments. All items of these scales were rated on a 5-point Likert scale. The Cronbach's α for the scale of perceived usefulness, perceived ease, and continuance intention were 0.873, 0.684, and 0.903 respectively, indicating acceptable reliability of the scale. As shown in figure 11, this paper organized Chinese traditional musical instrument fans to fill out the questionnaire and investigates their acceptance of the virtual Sanxian teaching system. A total of 71 participants participated, and 68 valid questionnaires were eventually recovered.

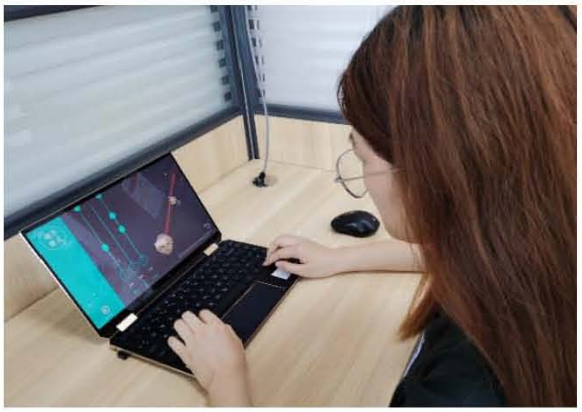

Fig. 11. User evaluation

The questionnaire survey results show that in terms of perceived usefulness, 70.59% of the participants supported that the virtual Sanxian teaching system can help them learn how to play Sanxian, 76.47% said that it can effectively improve learning efficiency, and 58.83% said the instrumental music teaching software is more effective than other musical instrument learning software, and up to 94.12% of the participants said that the system is helpful for musical instrument learning.

In terms of perceived ease of use, more than 80% of the participants said that the virtual instrument teaching system is easy to use. Specifically, 94.12% of the participants agree or very much agree that the system has a friendly interface and strong operability. 88.24% of the participants said that the relevant prompt messages in the system can help solve most of the problems encountered in using the system. However, 41.18% of users still said that they would always encounter one or another problem when using the virtual instrument learning tool to learn.

The survey on continuance intention shows that more than 80% of the participants are willing to use such a virtual

interactive teaching system in their future learning of music, and also agree to use similar virtual interactive systems in more disciplines. At the same time, they are willing to recommend the system to friends around.

VI. Conclusion

In this study, guided by the performance of the Sanxian musical instrument and supported by virtual reality technology, a desktop-based virtual Sanxian teaching system was designed and implemented. With the help of the high interactivity of virtual reality and the ease of use of keyboard and mouse. This work fills the gap in the digital teaching of traditional Chinese musical instruments Sanxian. In game-based teaching, learners can learn about Sanxian theory and playing techniques in this system. It provides an effective digital tutoring tool for the preservation and inheritance of Sanxian instrument culture.

However, This study has a number of limitations. First of all, based on the keyboard and mouse interaction method, it fails to fully simulate the playing of Sanxian, and there is a certain difference between it and the actual playing. Therefore, follow-up research will continue to explore technologies that not only meet the needs of the public, but also have high interactivity and authenticity as support (e.g., data gloves). Secondly, there is no extensive teaching practice to prove the teaching effect of the system, then the further extensive application of the system is the next work. Therefore, empirical study needs to be carried out for future work to verify the practicability of the system.

Acknowledgment

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