
Design and Evaluation of a Virtual Simulation System for Huangmei Opera

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Abstract:

We design a Huangmei Opera Virtual Simulation System (HOVSS) for undergraduate students to learn and experience Huangmei Opera culture. This study aims to introduce the system and evaluate its effectiveness and user experience of the system. We used various digital media technologies to demonstrate knowledge and performances related to Huangmei opera. The system mainly includes functional modules such as system management, digital resource library, VR museum, panoramic performance, animation performance, theme games, and knowledge test. We recruited 100 undergraduate students for a controlled trial (HOVSS experimental group, n=50; lecture-style sessions control group, n=50). A knowledge questionnaire is used to compare pre-testing and post-testing learning gains in order to analyze learning effects. The presence questionnaire was used for user experience analysis and system evaluation. The results showed that learning gains in conceptual and procedural knowledge were significantly higher after activities using HOVSS compared to learning through lecture-style sessions. The presence questionnaire analysis shows that the user experience has a high level of presence, indicating that the system is highly effective and exciting to experience. Through user experience experiments and analysis of the results, we found that this teaching method can well propagate Huangmei opera culture and better impact the teaching of Huangmei opera-related content.

Keywords: Huangmei opera, Virtual simulation, Knowledge questionnaires, Presence questionnaire.

I. INTRODUCTION

Huangmei Opera is a traditional opera art and an important intangible cultural heritage of China^[1]. Traditional opera faces serious challenges to its inheritance and development^[2]. Therefore, in the process of inheriting and developing Huangmei opera, apart from maintaining the traditional advantageous features of the art, it is also necessary to adapt to the widespread needs of the new era in

terms of dissemination and presentation methods. Digital media technology has provided new ideas for the diversified presentation of Huangmei Opera, such as digital stage effects^[3], convenient mobile applications^[4], and micro movies^[5], allowing the expression of Huangmei Opera culture to keep pace with the times.

Virtual reality technology, also known as VR, is developing rapidly and is widely used in several fields^[6]. The technologies involved in virtual reality are panoramic interaction^[7], mixed reality (MR)^[8], extended reality (XR)^[9], augmented reality (AR)^[10], and body interaction^[11], which have greatly enriched cultural expressions^[12]. Public cultural education in Huangmei opera needs to focus more on a learner-centered experiential education approach^[13].

To attract more people to learn and understand the cultural knowledge of Huangmei opera, we have designed and developed a virtual simulation teaching system for Huangmei opera using virtual reality technology to help people learn and experience the culture of Huangmei opera. In this paper, we describe the design of the system. Then we have also evaluated the user experience and learning effectiveness of the system.

II. DESIGN AND IMPLEMENTATION OF VIRTUAL SIMULATION SYSTEM FOR HUANGMEI OPERA TEACHING

2.1 Overall Design

The objective of designing the Huangmei Opera Virtual Simulation System is to enable more people to learn about the cultural knowledge of Huangmei Opera better and improve their appreciation of it. The system uses various digital media technologies to demonstrate knowledge and performances related to Huangmei opera. The system mainly includes functional modules such as system management, Huangmei opera digital resource library, Huangmei opera VR museum, Huangmei opera panoramic performance, Huangmei opera animation performance, Huangmei opera theme games, and knowledge test. Figure 1 shows the functions of the system. The system also combines data analysis and intelligent recommendations to track and help users learn and experience better.

The management of system users mainly includes the management of student users and teacher users, covering user registration, user login, information modification, etc. Student users are the main service objects of the system, and they can use the system to learn and experience Huangmei opera knowledge. The teacher user can manage the student users and set the corresponding learning and test content in the system. Huangmei opera digital resource library, Huangmei opera VR museum, Huangmei opera panoramic performance, Huangmei opera animation performance, and Huangmei opera theme games are the main contents of this system, which will be introduced separately below. The knowledge test assessed students' knowledge mastery after the learning experience with this system in the form of a questionnaire to be filled in by students and explained on time. The knowledge

test allows further testing of the learning effect ^[14].

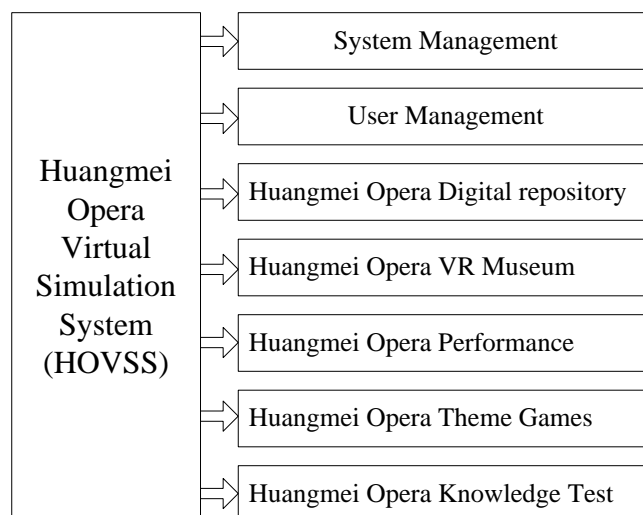


Fig 1: System function diagram

The acquisition of student learning behavior data and intelligent recommendations are important advantages of the virtual simulation teaching system. Students' learning behaviors are recorded through the system. The recommendation algorithm can recommend the content of interest to the user and supplement the necessary knowledge ^[15-16]. For example, in the VR museum, the system can recommend more display contents that are of interest to students according to their preferences.

This system uses a variety of digital media development technologies. The main works were as follows:

- (1) We use 3ds Max modeling software to produce three-dimensional virtual scenes and display models ^[17];
- (2) We use Maya 3D modeling software to produce 3D animations of Huangmei Opera ^[18];
- (3) We use Unity software development for interaction design ^[19];
- (4) We used Java to develop the main functions of the system ^[20];
- (5) We use MySQL for database development ^[21];
- (6) We use Htc Vive to realize VR roaming and interaction development ^[22].

The system is designed using a user-centered approach, with the participation of Huangmei Opera professionals, lecturers, and system developers in the design and review of the system ^[23]. The system

has undergone two rounds of usability testing with the instructor and student samples and was modified to form the final version for the teaching application study in this paper.

2.2 Digital Repository of Huangmei Opera.

The knowledge of Huangmei Opera is the basic content of this system. We collected and organized the knowledge related to Huangmei Opera to establish a digital repository of Huangmei Opera ^[24]. The knowledge of Huangmei Opera is extensive and complicated, involving history, representative characters, audio and video, costume ornaments, musical instruments, screenplays, scores, etc. To provide users with a convenient way to learn about Huangmei opera, we have designed a Huangmei opera knowledge graph to facilitate a more intuitive understanding of Huangmei opera knowledge and provide functions such as retrieval and download ^[25]. Figure 2 shows the Huangmei opera knowledge map.

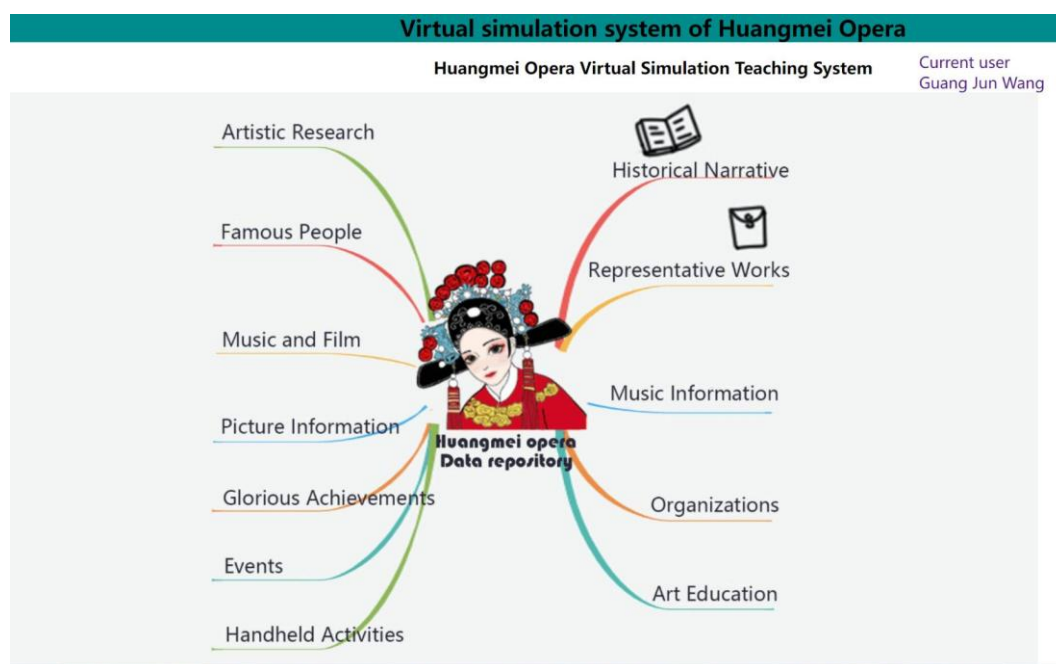


Fig 2: Huangmei Opera knowledge graph

2.3 Huangmei Opera VR Museum.

Huangmei Opera VR Museum is to build a virtual Huangmei Opera Museum by virtual reality technology. Users can roam in the first person and interact with the objects in the scene. Users as if visiting an actual museum. This breaks the limitations of space and time to visit freely ^[26].

First, we design the content and interaction of the virtual museum display. Then, relevant information about the content to be displayed was collected and collated, and the design content

included 3D scene design and exhibit design. The 3D scene model was then imported into Unity, and the interactive features were then implemented. Finally, a WebGL version was released in Unity and integrated into the web system for testing and improvement. Figure 3 shows the effect of the Huangmei Opera VR Museum.



Fig 3: Huangmei Opera VR Museum

Head-mounted virtual reality technology has greatly enhanced virtual reality immersion and set off a new trend in developing virtual reality technology ^[27]. Currently, the commonly used head-mounted virtual reality display technologies include computer-based (Htc Vive), mobile terminal-based (Storm Magic Mirror), and VR all-in-one machines. This system uses Htc Vive for virtual reality VR roaming. Htc Vive consists of a headset, handle, and optical sensor. The user only needs to wear the headset and hold the motion controller (handle) to efficiently operate the system for roaming and interacting with the Huangmei Opera VR Museum. Figure 4 shows the Htc Vive structure and display effect.

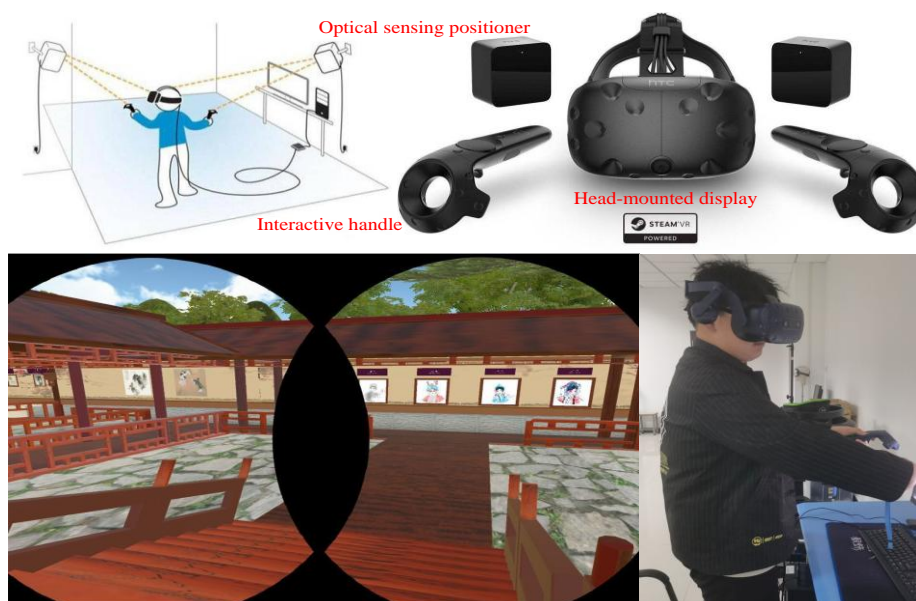


Fig 4: HTC Vive system structure and system effect

2.4 Huangmei Opera Panoramic Performance and Animation Performance.

Huangmei Opera stage performance is the primary expression form of Huangmei Opera. We design the panoramic video respectively so that students can experience the formal Huangmei Opera performance without going out of the meeting. At the same time, creating Huangmei Opera animation is an exciting expression of Huangmei Opera performance.

Traditional Huangmei Opera experience mainly goes to the theater to see live performances. We use the form of panoramic video to record the performance scene, which allows the audience to experience the Huangmei Opera performance immersive at home. Panorama refers to the 360-degree seamless recording of real scenes through real pictures and images, which can be viewed 360 degrees through the screen ^[28]. We shoot a panoramic video of the live performance of the Huangmei Opera. The video allows users to see the actual situation on the opera stage and enables you to see the audience's reaction and environmental information off stage freely. Users can watch the real performance scene of Huangmei Opera in 360 degrees. In addition, you can also use the Htc Vive headset immersive experience of the real Huangmei Opera stage performance effect. Figure 5 shows the effect of the panoramic performance of Huangmei Opera.



Fig 5: The effect of panoramic performance of Huangmei Opera

To improve the interestingness of Huangmei Opera animation performance, we produce Huangmei Opera performance animation. We animated Huangmei Opera using the classic excerpts from Huangmei Opera "Emperor's Female Son-in-law". The animation characters are in cartoon mode, making character animation, expression animation, costume animation, and matching with Huangmei Opera audio. The performance animation method can better enhance users' interest in learning. Figure 6 shows the effect of the animation of Huangmei Opera performance.



Fig 6: The effect of animation of Huangmei Opera performance

2.5 Huangmei Opera Theme Games.

Interactive games can enhance students' interest in learning and deepen their impression of knowledge. We have designed several games on the theme of Huangmei Opera, including "Guess the name," "Find the difference," "Collection," and so on. These games are embedded with the knowledge of Huangmei Opera and give students a better understanding of it through gamification.

The Guess the Name of the Opera game is played by playing a section of the opera tune and asking students to determine the name of the opera within a set time limit. This method improves students' knowledge and responsiveness to opera. Figure 7 shows the effect of the Guess the Name of the Opera game.

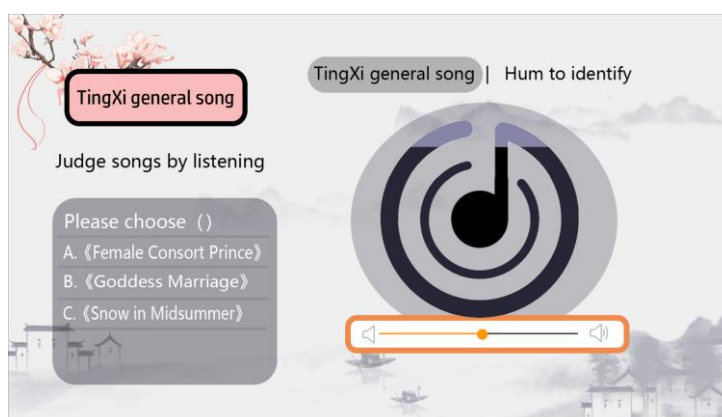


Fig 7: The guess the name

The Find the Difference game involves finding the differences between two similar pictures within a set time. We have designed various images of various opera characters, costumes, and props. The different parts between them so that students can deepen their memory by finding the differences between them. Figure 8 shows the effect of the Find the Difference game.

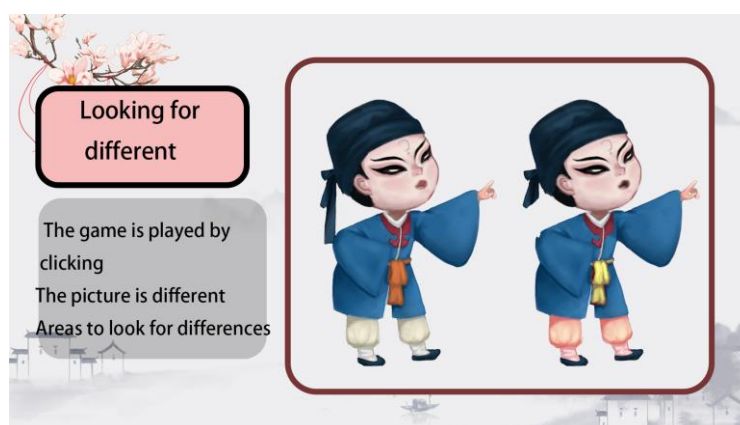


Fig 8: The Find the Difference Game

Find it in the block diagram below

Correct costume

drag to

Corresponding position



III. METHODS

We used a knowledge questionnaire and the presence questionnaire to analyze the system's teaching effectiveness and user experience. The design and program flow of this experiment is shown in Figure 10.

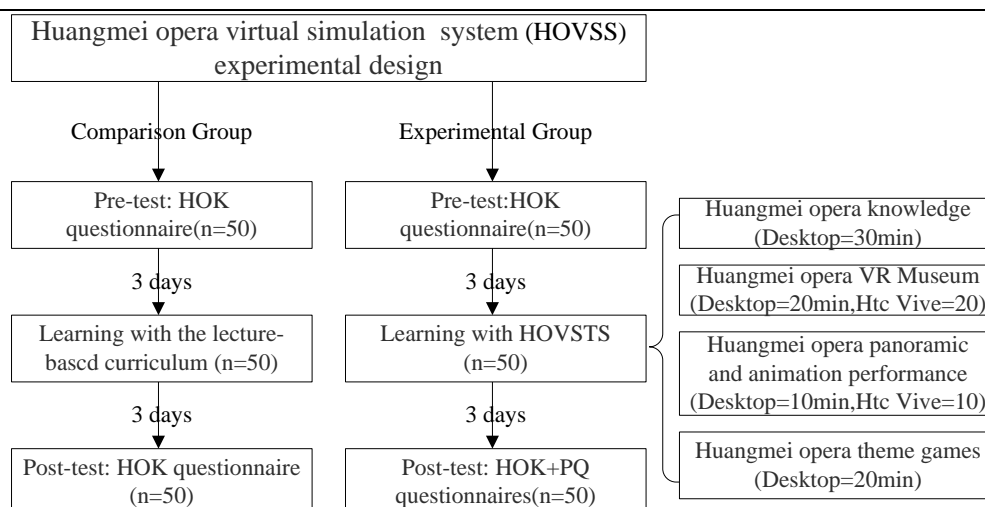


Fig 10: The flow chart of the design and program

Students in the control group ($n = 50$) learned to a standardized lecture-style sessions. Two professional teachers delivered these sessions of Huangmei opera using a power-point traditional presentation of approximately 3-4 hours. Students in the experimental group ($n = 50$) studied in the HOVSS environment for three hours.

3.3 Data Collection and Analysis.

We used a knowledge questionnaire to assess and compare participants' learning effects. The Huangmei Opera Knowledge (HOK) questionnaire was developed to evaluate the cultural knowledge and appreciation of Huangmei Opera.

This was carried out and administered by three teachers specializing in Huangmei Opera. There were 50 multiple-choice questions, and the time limit for the questionnaire was 60 minutes. We used Cronbach alpha to analyze the HOK questionnaire, which reached 0.82, indicating a high internal consistency of the questionnaire^[29].

We used percentages to calculate the correct answers to the HOK questionnaire responses. Descriptive statistics were used to record pre-testing and post-testing results, for example, by analyzing the mean and standard deviation of the corresponding test data for all participants. Learning gain refers to the learning effect gained through study. In this study, to avoid learning differences in prior knowledge, we calculated the learning gain for each participant as follows:

$$\text{Learning gain} = [(\text{post-testing score}) - (\text{pre-testing score})] / (\text{pre-testing score}).$$

The control and experimental groups calculated the mean, median, and standard deviation (SD) overall learning gain. A Mann-Whitney U test was used on the non-parametric data to compare

learning gains, with effect sizes of $r^{[30]}$. We used SPSS (version 21) to analyze the data.

For the corresponding assessment and analysis of participants' user experience of the HOVSS environment, we used the Presence Questionnaire (PQ). Singer and Witmer developed the PQ to assess the effectiveness of participants' experience of the virtual reality system ^[31].

IV. RESULTS

All participants completed the trial requirements, including pre-testing and post-testing, and used the experience PQ questionnaire. The experimental group had a strong interest in the virtual simulation teaching system and was very active in completing the learning and VR experience.

4.1. Learning Effect.

The comparison and experimental groups were comparable in learning outcomes and efficiency. In the pre-testing, the experimental group scored 52.4 ± 12.3 points, and the control group scored 51.8 ± 13.6 points, which were not significantly different. The control group scored significantly lower on the questionnaire and the learning gains and outcomes than the experimental group on the post-testing. Their scores on the post-testing were close to 100%. The total scores of the control group improved, but the experimental group was significantly better than the comparison group. Table I compares the pre-testing and post-testing learning gains.

TABLE I: Comparisons of Pre-Testing and Post-Testing Learning Effect between the Two Groups of Students

	Pre-testing Score		Post-testing Score		Learning gain		Statistical tests	
	Exp. (n=50)	Control (n=50)	Exp. (n=50)	Control (n=50)	Exp. (n=50)	Control (n=50)	Mann-Whitney U	Effect size, r
Overall:	52.4 ± 12.3	51.8 ± 13.6	94 ± 5.9	79.5 ± 12.7	$Mdn. = 82.4 \pm 19.1$	$Mdn. = 53.7 \pm 7.3$	1863***	0.72

Note: Exp, experimental group; Control, Control group. *** $p < 0.001$.

4.2. User Experience Analysis.

The PQ questionnaires of all participants in the experimental group were counted and analyzed, and the results showed that participants felt a high level of presence when learning in the HOVSS environment, indicating a good user experience with the system. The results were as follows: (5.3 ± 0.9) for the Involved/Comparison subscale, (4.6 ± 1.2) for the Natural subscale, and (4.9 ± 1.3) for the

Interface Quality subscale. These results are high or similar to those of other previous studies of VR systems, such as Witmer et al. (5.2 ± 0.8 ; 4.1 ± 1.1 ; 4.8 ± 1.1 , respectively) and Dubovi et al. (5.2 ± 0.7 ; 4.7 ± 1.03 ; 5.0 ± 1.1 , respectively) [32].

V. DISCUSSION

To address the current shortcomings in the dissemination and teaching of Huangmei opera culture, we have designed a virtual simulation teaching system for Huangmei opera. Through user experience experiments and analysis of the results, we found that this teaching method can well propagate Huangmei opera culture and better impact the learning of Huangmei opera-related content.

The knowledge graphing and gamification presentation can improve the intuitiveness and fun of knowledge and enhance the learning efficiency of users. Knowledge is presented in a tree-like structure, simulating the thinking process of the human brain, similar to a mind map, which can effectively improve students' cognitive level and memory. Combined with the VR museum and various related games, it can improve users' independent learning and associated cognitive abilities, thus increasing their interest in education and deepening their understanding of knowledge. Through the analysis of the control group experiments, the learning gain of users using this system is significant.

This digital system can break the limitations of space and time, allowing students to learn and experience repeatedly and freely, increasing their interest in learning and accelerating the spread of cultural knowledge and artistic charm experience of Huangmei Opera. It provides a new and effective way to preserve, transmit, and disseminate Huangmei Opera culture.

This study also has limitations: (1) The system's content needs further improvement. The content of this system's animation and game parts needs to be further designed and increased to satisfy more learning and experience. (2) The participants recruited for this experiment are mainly university students with high knowledge and reflective ability. More participants with different knowledge levels can be recruited for the pilot study later, and the system's robustness can be improved based on feedback to facilitate this system to serve a larger population.

VI. CONCLUSION

This study uses virtual reality technology, knowledge mapping, and artificial intelligence to design and develop a virtual simulation teaching system for Huangmei Opera. Through experimental analysis, it has a good effect on the teaching and experience of Huangmei Opera knowledge. It fully demonstrates that this form can be good for providing new forms of protection and dissemination for the art of Huangmei Opera, breaking space and time limitations. It also offers new ways for the development of other arts.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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