



# VisHanfu: An Interactive System Centered on the Cross-Shaped Flat Structure for the Preservation of Hanfu Culture

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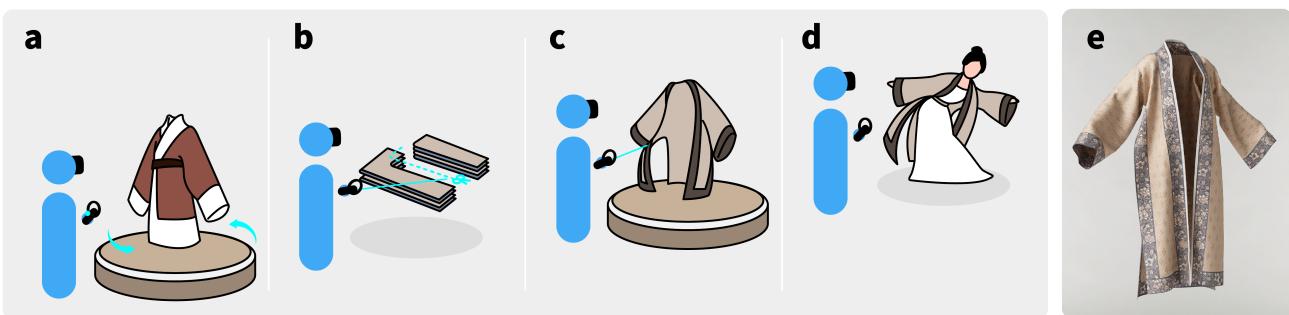
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**Figure 1:** VisHanfu is an interactive virtual reality system for promoting Hanfu culture, in which users can observe the digital restoration model of Hanfu artifacts (a), experience the Hanfu-making process (b), and watch the non-rigid movement of the Hanfu they make in (b) through simple operations such as dragging and dropping (c) and a dance performed by an avatar. (e) shows a Hanfu model created by our digital restoration scheme for Hanfu artifacts.

## ABSTRACT

Hanfu, which embodies the exceptional artistry of dying, weaving, and embroidery, is the emblematic traditional garment of Han nationality in China. However, there is a lack of convenient and immersive promotion methods for Hanfu. In this paper, we presented a virtual reality system focusing on the "Cross-Shaped Flat Structure", which is an integral feature of Hanfu. We restore five representative Hanfu historical artifacts and provide an interactive Hanfu making experience. Combined with highly realistic cloth simulation techniques, it allows users to interactively observe the

movement effects of the Hanfu. The user experiment results show that our system can provide a favorable experience for users and bring a better learning effect, which helps users to enhance their interest in learning and thus contributes to the inheritance of Hanfu culture.

## CCS CONCEPTS

- Human-centered computing → Human computer interaction (HCI); Empirical studies in HCI.

## KEYWORDS

Hanfu, Cultural Heritage, Virtual Reality, Interactive Design

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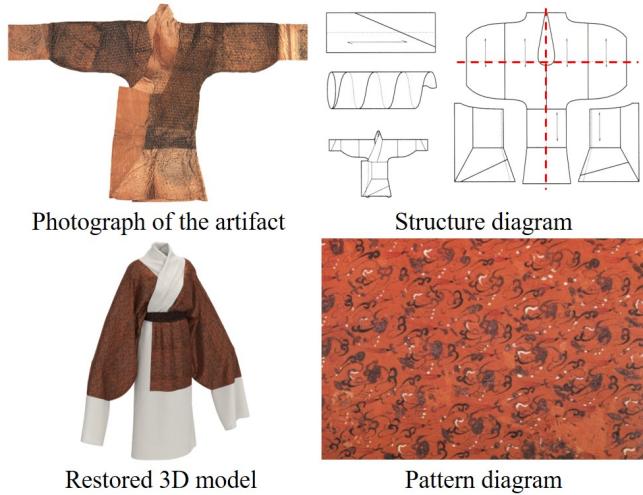
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**Figure 2: The Printed and Painted Floss Silk Padded Gauze Robe [14] from the Hunan Provincial Museum, China, along with its corresponding photograph [14], structure diagram [11] and pattern diagram [14]. The structure diagram illustrates the cross-shaped flat structure in red dotted lines.**

## 1 INTRODUCTION

Hanfu, which encompasses all the traditional clothing categories of the Han nationality in China, has a recorded history of more than 3,000 years [5]. It is a demonstration of the distinguished craftsmanship and aesthetics of Chinese dyeing, weaving, and embroidery, which are of great significance in preserving the traditional culture of China. Through the changes in different dynasties, the length, color, and pattern of Hanfu have been constantly updated, but the majority of styles still follow the cross-shaped flat structure (illustrated with red dotted lines in the structure diagram of Fig. 2), i.e., when the garment is laid out on a flat surface, the horizontal line from the sleeve to the shoulder (horizontal) and the center line of the front and back (vertical) serve as the axes, forming a "cross" [21]. This method of stitching directly from the whole piece of fabric not only avoids the waste of material due to tailoring, but also conforms to the preference of Chinese ancients to hide the shape of the body through loose-fitting clothes. Moreover, the cross-shaped flat structure is an important feature that distinguishes Hanfu from modern clothing and other ethnic clothing of the same period, and it is also an important principle followed in the process of tailoring traditional Han nationality costumes.

With the renewed emphasis on traditional culture in recent years, Hanfu has also received increasing attention as an important part of traditional cultural heritage. However, there are still some problems with the existing methods of publicizing Hanfu culture to the general public: (1) Associations and museum exhibitions require physical presence, which is inconvenient for those in areas with limited cultural resources. (2) Books and videos offer a passive learning experience, lacking personalized and immersive experiences. (3) Some popular movies and TV shows contain fallacies, which

may confuse the public about traditional Hanfu understanding of structure, texture, and cultural meanings.

Therefore, we implemented a virtual reality system, VisHanfu, focusing on the cross-shaped flat structure of Hanfu. In our system, we have detailed the formation reasons and characteristics of the cross-shaped flat structure. Additionally, we have carefully selected and digitally restored five representative Hanfu artifacts from different dynasties, enabling users to interact with these pieces of history in a unique and engaging way. The VisHanfu system offers an interactive and easy-to-use making functionality that enables users to more naturally experience the process of cutting, stitching, and sewing Hanfu. Utilizing advanced, highly realistic cloth simulation technology, users can experience the dynamic, non-rigid motion effects of the Hanfu they create by intuitively dragging and dropping the clothing model through controller operations. We also collaborated with an experienced dancer to capture her Chinese dance performance. This movement data was then transferred to the MetaHuman [8] model, allowing users to watch an avatar perform the dance while adorned in the Hanfu they crafted within our system. We deployed the VisHanfu system in a local museum for a week and invited 150 visitors to experience it. In addition, we recruited 60 participants to take part in the user study conducted in a laboratory environment. The findings suggest that our system effectively boosts users' interest in Hanfu culture. Furthermore, it demonstrates that users acquire a more accurate understanding through our system compared to traditional paper-based learning methods.

## 2 RELATED WORK

### 2.1 Digital Restoration of Traditional Costumes and HCI

There has been growing interest in applying HCI techniques to the digital restoration of traditional costumes. Liu et al. conducted a series of studies on the digital restoration of traditional Chinese costumes based on ancient paintings [17, 18], tomb murals [19] and unearthed costumes [20]. Zhu et al. [34] utilized clothing engineering principles to analyze and digitally restore the costumes of 12 characters portrayed in the DaoLian Painting. These studies focus on ways to digitally restore traditional costumes, but do not allow for user interaction with the restored models. In addition to digital costume construction, Jiang et al. created a multimedia interactive system [13, 32] to demonstrate the valuable and feasible utilization of Virtual Reality (VR) and Augmented Reality (AR) technology in the realms of traditional costume restoration and education. Li et al. developed an interactive VR display system [15] for traditional Chinese costumes, enabling users to explore and enjoy the cultural significance of these garments. Liu et al. conducted digital restoration [22] on traditional costumes unearthed from the Yuan Dynasty through computer interactive reverse engineering experiments and presented them via an interactive interface. However, these studies merely provide static 3D models or pictures of the clothes for users to observe, and there is no access for users to understand the dynamic effect of the clothes through interactive operations. In this work, we provide an opportunity for users to experience the dynamic, non-rigid motion effects of the Hanfu by intuitively

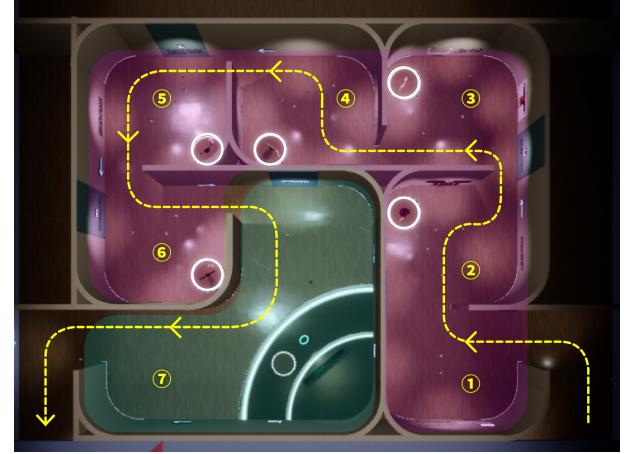
dragging and dropping the clothing model through VR controller operations.

## 2.2 Virtual Reality Exhibition

Virtual exhibit technology has been widely used in the museum and art fields. For example, the system named *Mona Lisa: Beyond the Glass* was presented to the public by the Louvre Museum in 2019 [24], and a VR tour was provided by the National Museum of Natural History [25] and the Palace of Versailles [26]. Virtual exhibitions can also reconstruct and showcase artifacts, buildings, or historical sites that no longer exist or have been completely damaged [28]. Other than the navigation of virtual spaces, VR exhibitions provide interactions to promote entertainment and attractiveness. The Virtual Museum of the Antikythera Mechanism allows visitors to interact with digital exhibits by grabbing and connecting virtual fragments of reconstructed artifacts with VR controllers [2]. Guo et al. [10] modeled and showcased a virtual exhibition of a traditional Chinese musical instrument called Bianzhong, allowing users to interact with it by striking the virtual instrument and hearing its sound. The immersive nature of VR exhibitions sets them apart from physical exhibitions, as users can fully immerse themselves in their own world without being influenced by external factors or other visitors. The Vauquois Tunnel, for instance, is an educational immersive VR exhibition [6] that presents the hidden history beneath the tunnel through a combination of physical and virtual environments. Users navigate the tunnel with interactive tracking props and narration, allowing them to learn about the historical context while experiencing the emotions of soldiers during World War I. Another significant advantage of virtual exhibitions lies in their ability to integrate with a wealth of online resources and other modules. As virtual exhibitions become increasingly capable of simulating real exhibitions and providing additional interactions, scholars have started exploring personalized user experiences. For example, Rikhtehgar et al. [12] combined VR exhibitions with recommendation systems, utilizing user research to identify preferences and tailor content descriptions accordingly. Nevertheless, these exhibitions do not feature costumed artifacts and were not conceptualized with interactive techniques that are specifically tailored to costumed artifacts. To address this problem, in this work, we utilized the highly realistic cloth simulation technology to propose a VR-oriented interaction approach for Hanfu artifacts to help the public better understand the Hanfu culture.

## 3 SYSTEM DESIGN

VisHanfu is an interactive virtual reality system designed to promote Hanfu culture. In this system, users can explore digitally restored models of Hanfu artifacts (Fig. 1(a)), immerse themselves in the process of creating Hanfu (Fig. 1(b)), and observe the fluid movement of their crafted Hanfu through straightforward operations like dragging and dropping (Fig. 1(c)). Additionally, they can enjoy a dance performance by an avatar wearing the Hanfu they created. Fig. 1(e) shows a Hanfu model created by our digital restoration scheme for Hanfu artifacts. According to historical documents, we presented the characteristics and origins of the cross-shaped flat structure and digitally reconstructed five sets of Hanfu artifacts from various dynasties for users to observe. Moreover, users are



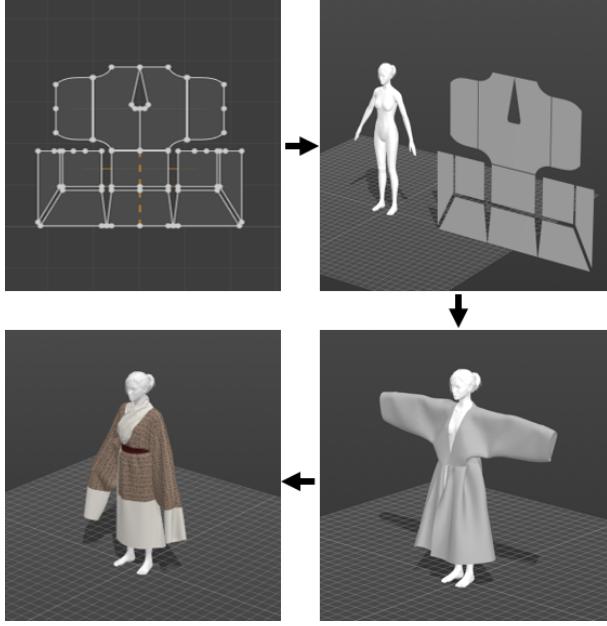
**Figure 3:** The VisHanfu system includes 7 halls. The yellow dotted line represents the user's tour route, and the white circles represent the platforms on which the reconstructed 3D models are placed.

able to create a virtual Hanfu by completing some easy interactive tasks that we have designed. Experts were consulted to ensure that the knowledge related to Hanfu artifacts and their making process involved in the system is accurate. By using two kinds of presentations, i.e., high realistic 3D models and animated dance motion sequences, users can observe the non-rigid movement of the Hanfu.

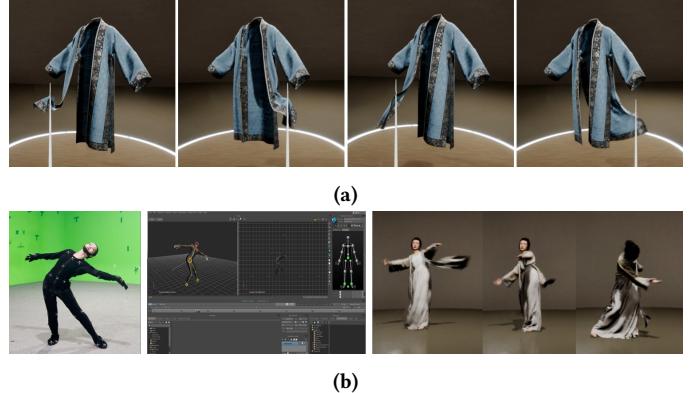
**Virtual Scenario Construction.** A virtual reality scenario that simulates a real museum was constructed (Fig. 3). In the first hall, we introduce the origin and characteristics of the cross-shaped flat structure. Next, we set up five exhibition halls corresponding to the five dynasties of China (Pre-Qin, Han, Tang, Song and Ming) in chronological order. In each hall, not only do we include a representative 3D model of Hanfu artifacts in that era, but also we display additional items on the wall beside the model to help the user learn about the artifacts more thoroughly. These items include photographs of the artifacts, diagrams of their cross-shaped flat structure, diagrams of their patterns, as well as textual introductions. In the last hall, users can experience the Hanfu-making process.

**Digital Restoration of Hanfu artifacts.** We consulted experts in Hanfu research and chose five sets of Hanfu artifacts representative of different dynasties to be digitally restored. In accordance with the archaeological report, we reconstructed 3D models of the Hanfu artifacts based on structural and dimensional information, and reproduced their textures based on pattern diagrams and material information (Fig. 4). The 3D models are placed on platforms in each hall (see the white circle in Fig. 3); users can manipulate the controller to rotate the model and modify their viewing distance for convenient observation of the artifacts. Accompanied by the illustrations adjacent to the model, users gain a deeper understanding of the artifact information and the evolution of Hanfu styles across various dynasties.

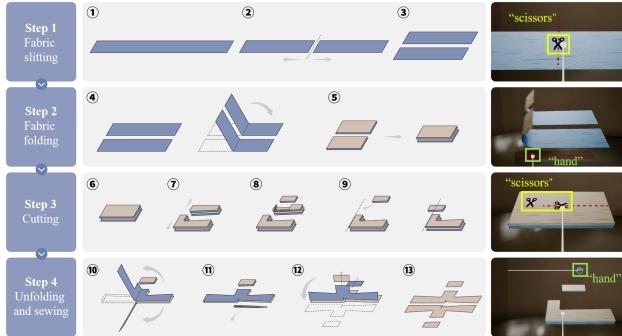
**Virtual Hanfu Making.** We have divided the traditional Hanfu-making process (according to the stack-cutting method in literature [33]) roughly into four simple steps (Fig. 5). **Step 1:** Fabric slitting.



**Figure 4: The digital restoration of Hanfu artifacts.** We reconstructed 3D models of the Hanfu artifacts based on structural and dimensional information, and reproduced their textures based on pattern diagrams and material information.



**Figure 6: The virtual Hanfu display.** (a) Users are able to observe the non-rigid motion effect by dragging and dropping the model vertices. (b) The generation process of an animation with avatar dancing in Hanfu.



**Figure 5: The process of traditional Hanfu production** consists of four steps, including “Fabric slitting”, “Fabric folding”, “Cutting”, “Unfolding and Sewing”. Users can interactively experience this process in the VisHanfu system.

To divide a whole piece of fabric into two pieces, the user slides the “scissors” icon along the dotted line using the VR controller. **Step2:** Fabric folding. The user uses the VR controller to manipulate the “hand” icon along the dotted line to fold and stack the pieces cut in Step 1 along the center line. **Step3:** Cutting. The user cuts the fabric into pieces along the dotted line with the controller by manipulating the “scissors” icon. **Step4:** Unfolding and Sewing. The user uses the controller to manipulate the “hand” icon to unfold the pieces, and our system will automatically perform the sewing step to get the complete Hanfu.

**Display of the virtual Hanfu.** Utilizing cloth simulation technology [7, 23, 31], our system enables highly realistic, non-rigid movements of Hanfu. We provide two display solutions to present the virtual Hanfu that were created previously by the user: (1) 3D model. The 3D model of virtual Hanfu is placed on the platform, and a variety of textures are pre-produced for users to choose from. Users are able to observe the highly realistic non-rigid motion effect by dragging and dropping the model vertices (Fig. 6(a)). This enhancement significantly elevates the user experience by offering greater freedom in observing the clothing, surpassing conventional rigid transformations such as translation, rotation, zoom-in, and zoom-out. (2) Performance of Dance. We invited an experienced dancer to perform a Chinese classical dance, utilizing motion capture technology to record her movements. This data was then transferred to a high-precision MetaHuman model featuring a typical Chinese facial structure. The result is an animated avatar performing the dance in Hanfu (see Fig. 6(b)). This process incorporates cloth simulation techniques, enhancing the realism of the Hanfu’s movement. By integrating Hanfu with Chinese classical dance, users gain a richer appreciation of Hanfu’s aesthetic appeal.

**Implementation.** Our VisHanfu system is developed using Unreal Engine 5 [9] (UE5, Version 5.1.1) and optimized for the VIVE XR Elite headset [30]. The digital restoration garment models were created in Style3D [16] and imported into UE5. To enhance fabric material performance, Adobe Substance 3D Painter [1] was used to generate highly realistic texture bitmaps, which were then imported into UE5 and transformed into material assets. Vicon [29] optical motion capture equipment and Autodesk Motion Builder [3] were used to produce dance animation compatible with the Metahuman avatar [8].

## 4 USER STUDY

We conducted a user study to evaluate the VisHanfu system. Participants were asked to complete a questionnaire. The system usability was assessed using the SUS scale, the effectiveness was measured

by five questions related to Hanfu, and the engagement was evaluated using the UES-SF scale. In addition, a question was included to explore whether our system could help to increase users' interest in learning about Hanfu culture. 60 participants were recruited, 30 in each of the experimental and control groups. The experimental group included 14 males and 16 females, ranging in age from 19 to 33 ( $M = 23.80$ ,  $SD = 3.80$ ). The control group included 15 males and 15 females, ranging in age from 19 to 35 ( $M = 25.93$ ,  $SD = 4.22$ ). The user study was conducted with the informed written consent of each participant and was approved by our university ethics review board.

Participants in the **experimental group** were asked to utilize VisHanfu system for around 20 minutes to learn about cross-shaped flat structures, view five Hanfu artifacts, and experience the making process. After that, each user answered a 28-question questionnaire and received an interview.

Participants in the **control group** spent 20 minutes studying a paper-based material that contained all the Hanfu-related knowledge mentioned in the VisHanfu system. The participants completed a questionnaire consisting of five questions at the end of the study.

#### 4.1 Questionnaire Results

The **experimental group** questionnaire consisted of 28 questions. Questions 1-10 were from the SUS scale, and question 11 was used to investigate whether the user's interest in learning Hanfu increased after using the system. Questions 12-23 were from UES-SF scale for assessing the users' engagement. Questions 24-28 focused on Hanfu culture and were designed to evaluate the effectiveness of the VisHanfu system in facilitating the learning of Hanfu knowledge. The questionnaire for the **control group** contained 5 questions, the same as Questions 24-28 of the experimental group questionnaire.

According to the results, our system has good usability, helps to enhance users' interest in learning about Hanfu culture, and performs well on scales assessing user engagement. In addition, the experiment demonstrated that users studying Hanfu-related knowledge using our system (experimental group) scored higher on the Hanfu-related knowledge questionnaire compared to participants using traditional reading materials (control group), with significant differences.

*System Usability (Question 1-10):* We calculate the SUS score, which returns a score of 75.00/100 with an SD of 13.82, indicating that the VisHanfu system has good usability [4].

*User Interest (Question 11):* We investigated users' subjective opinions of whether their interest in studying Hanfu culture has risen as a result of utilizing the system. A score of 5 means "strongly agree" that the VisHanfu system increases their interest in Hanfu culture, while a score of 1 means that they do not think the system contributes anything to increase their interest. The mean score for this question was 4.40, with a standard deviation of 0.68. All participants scored above or equal to 3, indicating that our system might increase their interest in learning Hanfu culture.

*User Engagement (Question 12-23):* We use the UES-sf scale for measuring users' engagement in using the VisHanfu system, and it is further divided into four subscales to investigate the focused attention (FA, Question 12-14), perceived usability (PU, Question

	Overall	Focused attention	Perceived usability	Aesthetic appeal	Reward
Score	4.26	4.89	3.53	4.42	4.58

**Table 1: The results of the engagement evaluated by UES-sf scale.**

Question	24	25	26	27	28
Experimental group	86.67	93.33	80.00	100.00	100.00
Control group	83.33	83.33	53.33	66.67	80.00

**Table 2: The accuracy (in percentage) of Questions 24 to 28 in both experimental and control groups.**

15-17), aesthetic appeal (AE, Question 18-20), and reward (RW, Question 21-23). According to the calculation rules in [27], the results of the UES-sf scale are shown in Table 1. The results demonstrate that the VisHanfu system has achieved better ratings, both overall and on the subscales.

*Learning Effectiveness (Question 24-28):* These questions were used to evaluate the effectiveness of learning Hanfu knowledge in different ways. Five questions were included. The user's knowledge of the Hanfu artifacts displayed in the exhibition part was assessed using Questions 24 and 25, while understanding of the characteristics and origins of the cross-shaped flat structure was assessed using Questions 26 and 28, respectively. We designed Question 27 to evaluate the user's comprehension of the Hanfu production process.

We calculated the accuracy for each question in the experimental and control groups (Table 2). We performed the Chi-squared test to determine whether the difference between the two groups' performance on each question was significant. On Question 24, the accuracy of the experimental group is 86.67%, and the control group achieves 83.33%. On Question 25, the experimental group's accuracy is 93.33%, while the control group has only 83.33%. We do not observe significant differences between the two groups on Question 24 ( $\chi^2 = 0.13$ ,  $p = 0.72$ ) and Question 25 ( $\chi^2 = 1.46$ ,  $p = 0.23$ ). Question 26 was more difficult, so the accuracy of both groups was lower, 80% for the experimental group and 53.33% for the control group. There was a significant difference between the two groups on this question ( $\chi^2 = 4.80$ ,  $p = 0.03 < 0.05$ ). Questions 27 and 28 reached 100% correctness for the experimental group, whereas for the control group, the accuracies were only 66.67% and 80%, respectively. Additionally, significant differences were observed on these two questions ( $\chi^2 = 12.00$ ,  $p = 0.001 < 0.05$ ;  $\chi^2 = 6.67$ ,  $p = 0.01 < 0.05$ ). It shows that the experimental group obtained a higher accuracy on all five questions than the control group.

The total score of Questions 24 to 28 was analyzed using the independent-samples T-test, and there are significant differences between the experimental and control groups ( $t = 4.16$ ,  $p = 0.000 < 0.05$ ). The results indicate that using the VisHanfu system allowed users in the experimental group to more thoroughly understand knowledge about Hanfu, including the origins and characteristics

of the cross-shaped flat structure, information about the five Hanfu artifacts, and the method of Hanfu production.

## 4.2 Interview Results

We also interviewed users on their system experiences, asking them to answer the following questions.

*MQ1: What are your perceptions of Hanfu culture before and after using our system? Will you investigate Hanfu culture later? How do you learn about it?*

Participants who reported a heightened interest in Hanfu engaged in various activities to learn more, including reading books, conducting online searches, and visiting museums. A notable expression of this enthusiasm was seen in children, with one stating their intent: "I will ask my mother to take me to a museum with more Hanfu artifacts on my next holiday". During the system experience, some participants asked us about Hanfu, such as "Where was this artifact unearthed?" "Who wore it before?" and "On what occasion was this suit worn?" After the experience, several participants used their phones to look for interesting topics to discuss with our staff, such as "Was this dress in this color in ancient times?" and "What is the name of this cutting method?" Based on this feedback, we believe the VisHanfu system has enhanced users' interest in Hanfu culture and, therefore, has the potential to promote it.

*MQ2: How does the VisHanfu system differ from existing promotion methods for Hanfu culture? Which one do you prefer?*

This inquiry helped us with analyzing the pros and cons of this interactive virtual reality-based system vs reading, visiting, and watching videos. We summarized the participants' replies and concluded that they preferred our unique interactive system over standard learning techniques for Hanfu culture. Reading and viewing movies are less immersive and natural than our method. One boy noted that this approach fosters independent exploration among children. A majority of children favored the interactive learning aspect. Additionally, several parents observed that this immersive VR system parallels the experience of taking their children to a museum to view artifacts, with the added benefit of being more cost-effective and travel-free, thus making it particularly appealing for children.

## 5 DISCUSSION

**Contribution to HCI.** We designed an interactive system to help users learn about Hanfu, which helps the dissemination and preservation of Hanfu culture while expanding the application scope of human-computer interaction technology. Furthermore, by integrating cloth simulation technology, we have achieved highly realistic, non-rigid movement of Hanfu models within a virtual reality environment. This enhancement allows users to not only perform basic operations like dragging and dropping but also to interact through a simulated dance experience. This allows the user to observe the clothes from different views and understand the wearing effect in a more detailed way compared to the existing systems, which can only be operated by rotating. Therefore, our system provides insights for enriching the user's interaction experience with Hanfu and other clothing artifacts.

**Expanding our research to more applications.** Our research holds implications for the practice of cultural heritage preservation in general. Through a digital restoration method, users gain the opportunity to perceive the entirety of artifacts within virtual spaces that may be difficult to access or even fragmented in the physical world. Allowing users to experience the restoration or creation process, potentially sparking their interest and actively contributing to the preservation of cultural heritage. In terms of education, our user study has demonstrated the effectiveness of the VisHanfu system in conveying Hanfu knowledge, surpassing traditional learning mediums. The feedback from users is expected to provide insights and further facilitate research into the potential of immersive interactive systems on users' learning efficiency.

**Limitation and Future Work.** The system, not specifically tailored for different age groups, revealed through user studies that the Hanfu-making component was relatively straightforward for middle-aged individuals. However, this aspect of the system was suitably challenging for both children and the elderly. In order to provide users with the freedom to pick the level of difficulty of the experience, we will further update this part by adding different modes (for example, the procedures for making the Hanfu in the HARD mode will be split into more detailed steps). Additionally, only five sets of Hanfu models were available for users to observe in the system. We will continue to add more models in the future.

## 6 CONCLUSION

We designed the VisHanfu virtual reality system to enable users to closely observe exquisite Hanfu artifacts and actively participate in the Hanfu-making process. This design aims to heighten user interest in learning about Hanfu culture and to facilitate its broader dissemination. We propose a solution for the digital reconstruction of Hanfu artifacts. Compared to existing Hanfu model reconstruction methods, our approach achieves an improvement in the efficiency of texture reconstruction by parameterizing the texture maps while ensuring accuracy. Regarding the display of Hanfu models, our system utilizes cloth simulation technology, enabling users to observe the real-time, non-rigid motion of their custom-designed Hanfu through intuitive drag-and-drop interactions. Additionally, by capturing a dancer's movement data, our system allows users to view an avatar performing a Chinese dance, adorned in the Hanfu they created. Our system was implemented in a museum setting, and the results indicate its strong usability and effectiveness in enhancing user interest in learning about Hanfu culture. A user study involving 60 participants yielded similar findings, demonstrating that our system significantly boosts user engagement. Moreover, participants who interacted with our system scored higher on the questionnaire compared to those who relied on traditional learning methods, such as reading paper materials.

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