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Abstract: The advent of 3D virtual presentation technology for clothing has led to the gradual popularisation of digital virtual clothing in the modern fashion industry. However, there remains a gap between the application of this technology and the integration of cultural attributes in the field of digital communication of traditional cultural clothing. Consequently, the objective of this paper is to propose the establishment of a fusion system integrating archaeological research on traditional culture with emerging virtual presentation technology. This paper draws inspiration from the replicability and easy dissemination of digital products to combine cultural archaeology and digital technology. The aim is to provide ideas for the diversity of dissemination of cultural heritage. The research object is Diplomatic Envoys, a Chinese mural painting of the Tang Dynasty that depicts friendly exchanges between countries. The research is divided into two research stages. A CLO3D software-based digital restoration test was conducted to reproduce the costumes of officials and foreign envoys depicted in the Tang Dynasty mural. The FAHP model was employed to verify the accuracy of the restoration results. The experiment demonstrated that the digitally reconstructed clothing exhibited a high degree of similarity to the unearthed mural figure clothing object. Furthermore, the restoration result passed the credibility verification, resulting in a ‘credible’ outcome. The application of digital virtual simulation clothing restoration methods offers two key advantages. Firstly, in comparison with traditional clothing restoration methods, digital restoration enables the rapid assessment of the resulting clothing effect, thereby reducing the likelihood of secondary damage to cultural relics due to manual errors. Secondly, the benefits of digital technology facilitate the convenient storage, replication, and dissemination of clothing data information. Data can not only be extended to online exhibition halls but also to game animation, clothing production, and other fields for the purposes of creative redesign and information dissemination. Furthermore, these benefits can penetrate the education industry to disseminate information to the public through all-round display models and explanations.

Keywords: digital virtual simulation technology; costume restoration; cultural heritage; fuzzy comprehensive evaluation system

1. Introduction

Digital modelling and simulation technology in digital virtual simulation technology represents an important integrated application within the context of the intelligent era of Industry 4.0 [1]. In this context, the digital clothing design method applied to the fashion market has emerged as a nascent field. The generation of products depends on the application of 3D software to generate surreal and data-intensive digital 3D clothing virtual forms. These forms can be either pure digital products or digital models of physical
products [2–4]. The integration characteristics of digital technology make it a versatile tool that can be applied to a wide range of fields. Its potential for integration with artificial intelligence (AI) technology, for instance, is significant. AI has the potential to transform the direction of text-to-image systems, and this integration could contribute to the growth of digital fashion businesses [5]. Furthermore, digital presentation technology can also be extended to other fields to achieve cross-border applications. This includes the field of clothing archaeology, where digitally modelled clothing and unearthed clothing objects exhibit a high degree of similarity [6]. Digital graphics also offer a certain degree of convenience, which will be conducive to the modern redesign and sustainable development of ancient clothing [6].

In recent years, the digital twin of clothing and the creation of digital 3D models of clothing has become a new avenue for digital clothing archaeological research [6]. While traditionally viewed as antithetical, the fields of art and science have increasingly intersected since the second half of the 20th century. This has led to the application of scientific methods and research to the field of cultural artifacts, primarily through physical and chemical analyses. Digital technology has become the primary means of disseminating cultural heritage in the Internet era, particularly in the protection of cultural artifacts such as clothing archaeology [7,8]. In the contemporary era, three-dimensional (3D) displays offer a superior visual experience compared to the two-dimensional (2D) alternatives [9,10]. Additionally, their efficiency in data circulation enables the reuse of data copies to a near-perpetual extent, making them an optimal solution for the long-term preservation of historical images and their associated contents [11].

The Seville Principles define the digital preservation of historical artifacts as virtual archaeology and explain terms such as virtual restoration, virtual anastylosis, virtual reconstruction, and virtual recreation [12]. The innovation and diversity of digital technology are decisive attributes allowing for the presentation of clothing products to the world. With regard to the application of the method, numerous scholars have conducted a series of studies and experiments. For instance, CLO3D, 3dsmax, and other clothing engineering design software [13] have been employed to digitally simulate and present traditional Chinese clothing, including women’s attire from the Yuan Dynasty [6] and Tang Dynasty [14]. The results are conducive to dissemination and secondary creative design, representing a technical approach worthy of adoption. In the field of multi-criteria decision-making (MCDM), the FAHP evaluation method represents a highly effective technique for the evaluation of schemes, whereby factor weights are determined and integrated into the decision-making process [15]. The FAHP combines the fuzzy comprehensive evaluation (FCE) and the analytic hierarchy process (AHP) and is widely employed in the evaluation of systems, the assessment of effectiveness, the optimisation of systems, and other related fields [16]. However, in recent years, research on the virtual simulation restoration of figures in graphic artworks has tended to overlook the necessary parameter data and modelling details required before using the technology and the careful archaeological dialectics. As a result, the accuracy of the restoration results is very low. Furthermore, it is important to note that the inclusion of an artist’s subjective thoughts in their works of art results in the figures being presented subjectively. Therefore, it is more appropriate to refer to this as ‘reproduction’ rather than ‘restoration’. The author presents a comprehensive research model for the digital restoration of cultural clothing. The model involves multiple analyses and dialectics of documents, images, and objects in the initial research samples before technical support is applied. This approach aims to obtain the most accurate cultural artifact data. The documentary evidence of the clothing system and culture is used to obtain accurate clothing pattern data due to the cultural significance of clothing in displaying identity. Prior to implementing the digital restoration methods, the authors conducted a literature investigation, a field investigation, and expert interviews. This approach not only provides a practical investigation of the figure modelling in the flat fresco but also references the clothing style of three-dimensional figure pottery figurines from the same period and clothing style. The overall appearance of the clothing style is recorded from a three-dimensional perspec-
After comprehensively integrating archaeological data, virtual simulation technology was used to present and adjust the restoration. Following the comprehensive integration of archaeological data, the restoration, presentation, and adjustments were conducted via virtual simulation technology. The accuracy of the restoration results was then verified by means of an FAHP model.

In terms of the dissemination of traditional cultural clothing data, digital clothing is predominantly employed in museums and other cultural and museological institutions with educational and communication attributes. Here, a significant number of archaeological exhibits are reconstructed with 3D visualisation, with the objective of assisting users in comprehending historical places and times and opening up prospects for the protection and dissemination of historical traditional clothing (such as educational activities, heritage popularisation and other communication methods). Furthermore, digital technologies facilitate the design process through data analysis, enabling virtual prototyping and providing personalised recommendations. These innovations optimise the supply chain and promote efficiency, sustainability, customisation, and customer engagement in the fashion industry. Visual display types are divided into four categories: 2D, 2.5D, 3D, and VR. The current digital virtual simulation and modelling software primarily focuses on providing 3D visualisation rather than immersive VR. However, the immersive experience offered by full VR is becoming increasingly popular in the field of human–computer interaction. Consequently, future research on the heritage of traditional clothing culture must encompass not only the exploration of the transition from research and protection to 3D virtual presentation and popularisation but also the expansion into data storage, data editing, immersive experiences, and other related fields.

2. Literature Review

2.1. Digital Restoration of Flat Image Cultural Relics

In the field of digital protection and restoration of 2D flat images, such as paintings and murals, several modern technologies can achieve ideal rendering effects. Adobe Photoshop CC is a professional digital repair tool that can effectively handle most flat image repair and restoration tasks. However, it requires subjective detection to be applied and operated. To address this issue, M. Barni et al. proposed a technical system for the removal of cracks in old paintings and murals to complete the restoration of plane works. In addition, Del Mastio et al. referred to the LCITools software, which was developed at the Media Integration and Communication Center (MICC) at the Center of Excellence and Image Processing and Communications Laboratory (Laboratorio di Comunicazioni ed Immagini (LCI)) at the University of Florence. The software aims to protect digital reproductions of artworks through watermarking technology and virtually repair some typical defects. A. De Rosa et al. introduced a two-step restoration process. Firstly, they identified image defects through a segmentation algorithm. Then, they used rigatino and puntino technology to virtually restore images. Their work focused on the virtual restoration of artworks. There are also many applications of innovative techniques for the restoration of images in graphic works into three-dimensional ones. For example, Lanitis et al. proposed a method for restoring damaged faces in cultural heritage artifacts. By defining the 2D shape and the spatial relationship between facial features, the undamaged face data are used to estimate the complete 3D shape of the face. The texture of the damaged area is predicted to generate a restored 3D model of the face. Additionally, they presented a vivid three-dimensional virtual presentation of the head of the figure in the flat painting works. It is evident that the diversification of technologies can not only repair damaged parts of an image but can also calculate graphic art images through point algorithms. This can generate a three-dimensional image that is more conducive to presentation and communication. Therefore, it is worth learning and applying.
However, there are few studies on restoring figure costumes in planar cultural artifacts, particularly tomb murals. Liu Kaixuan et al. conducted the three-dimensional digital restoration of clothing using virtual fitting technology, revealing a more comprehensive development of ancient clothing [28]. Their virtual simulation and restoration of the costumes in planar paintings, such as The Night Revels of Han Xizai [14] and DaoLian Painting [29], provide a valuable reference for the inheritance and protection of cultural clothing. The paintings that have been handed down through the past dynasties have been carefully preserved and copied by humans. As a result, they are relatively well-preserved and have clear characters. In contrast, tomb mural artifacts that have been deeply buried are eroded by the natural environment and have weak image integrity due to significant damage. To study their clothing images, it is indispensable to use technology and research to fill in the walls that have been damaged by the passage of time. The restoration of a flat character and its subsequent study for three-dimensional presentation can be a tedious process. Therefore, maintaining the integrity of the image presentation is crucial for restoring handed-down paintings in academic circles. The paintings that have been handed down through the past dynasties have been carefully preserved and copied by humans. As a result, they are relatively well-preserved and have clear characters. In contrast, tomb mural artifacts that have been deeply buried are eroded by the natural environment and have weak image integrity due to significant damage. To study their clothing images, it is indispensable to use technology and research to fill in the walls that have been damaged by the passage of time. The restoration of a flat character and its subsequent study for three-dimensional presentation can be a tedious process. Therefore, maintaining the integrity of the image presentation is crucial for restoring handed-down paintings in academic circles.

2.2. Digital Restoration of Three-Dimensional Relics

Digital technology is also used to create digital models for the protection and restoration of three-dimensional cultural artifacts, such as clothing, sculptures, and architecture. In 2003, the University of Michigan proposed using the same digital models to represent physical products. This concept was later referred to by subsequent researchers as the mirror spatial model and the information mirror model [30]. The earliest example of its application is the 3D digital restoration of cultural relics such as sculptures and buildings. For instance, as noted by J Montusiewicz et al., Stanford University used 3D scanning technologies to digitally preserve Michelangelo’s sculptures and reconstruct models of them in virtual space [31]. Digital technology has proven to be useful in various industries, including archaeology. The advantage of this approach is its ability to quickly and intuitively visualise the overall effect and efficiently adjust parameters to address shortcomings. However, the fashion industry often overlooks the potential of information technology. Clothing serves as a silent communication medium, representing identity and cultural values and facilitating cultural exchange. The digital preservation of textile and garment cultural heritage can be enhanced by using artificial intelligence algorithms. This can facilitate the study of the digital restoration of ancient clothing and textile styles and structures [32]. Specifically, the combination of digital preservation techniques with genetic algorithms [33], neural networks [34], fuzzy logic [35], etc., is a current area of interest in heritage protection [36]. Jerzy Montusiewicz et al. used structured-light 3D scanners (SLSs) to scan historical cultural clothing and create 3D models [31]. However, this technique is not yet widely used. Yu, Qianqian et al. proposed a fast-scanning method for offline point cloud generation and introduced a free cutting, grouping, and seam generation algorithm for 3D virtual clothing. They formed a complete technical route based on geometric modelling for stimulating and applying 3D scanning to clothing [37]. Muller and Sohan [38–40] conducted a systematic survey on a large quantity of information on historical clothing, including an image drawing algorithm to study image modelling and stitching methods. In summary, the support of 3D scanning, cutting, adjustment, and other technologies provides technical support for the application of digital virtual simulation technology in cultural inheritance and communication cases.

However, based on the statistics of restored objects, it is evident that textile cultural artifacts are difficult to preserve due to their perishable nature and limited samples. As a result, there have been few attempts at digitally restoring them. In their research on
the digital restoration of three-dimensional clothing objects, Liu, Kaixuan et al. used CLO Standalone software to restore the robe of Mangwangdui Han Tomb in Changsha, China, during the Han Dynasty [41]. Similarly, Feng, Geheng et al. used the style 3D software to digitally restore silk clothing found in the Huangyan Song Dynasty tomb in Zhejiang Province [42]. Shi, Hui et al. used the AlphaM4 3D body scanner to obtain 3D human models, used reverse engineering technology to build personalised human models, and conducted a 3D virtually simulated technology display of the research object, which was the complete mapping of Inner Mongolia cotton robe samples in the Yuan Dynasty [43]. Digital virtual simulation technology can efficiently transform digital information into product form, making it easier to predict both the overall form and details. Additionally, adjustments to the plan can be made quickly and with high accuracy, while preserving data and enabling faster communication. However, few scholars in the academic community have conducted scientific evaluations of the restoration results, which is an important aspect of the evaluation process. Regarding evaluation, Liu, Kaixuan et al. conducted a study on the restoration of the ‘Spring Outing Painting of Madam Guo’ garment. The restoration effect was comprehensively evaluated using the fuzzy analytic hierarchy process (FAHP). The research results were then thoroughly evaluated [44]. Although the evaluation results are credible, the accuracy of academic research is still questionable. Some of the restored versions contain controversies. This research solely concentrates on the restoration and protection of archaeological artifacts. However, when it comes to traditional cultural clothing, the archaeological analysis of the shape, colour, and details of the research samples is generally not comprehensive enough, resulting in low accuracy. Furthermore, the interpretation of the cultural significance behind the clothing carrier is not included, but enhancing cultural meaning is particularly important. The use of digital technology in the restoration of cultural artifacts brings the form and meaning of these artifacts closer to their original era. This provides valuable references for restoration efforts and ensures that the results of digital technology restoration are worthy of consideration. When studying the fundamental principles of clothing, it is undeniable that computers provide a simple and effective method for restoring the aesthetics and forms of cultural artifacts [45–47]. Digital technology has gradually replaced traditional forms of cultural heritage preservation, such as oral storytelling and written documentation, due to its advantages in interactivity and visual representation [48]. However, digital heritage preservation presents certain challenges. Ack, Lien et al. suggested that feedback on experimental results may not solely be attributed to the methods employed but could also be influenced by the combination of human factors and digital resources [49]. Therefore, the integrated application of prior knowledge, data management results, and digital resource methods is essential. Zhao, Shichao et al. conducted a qualitative assessment based on interviews, seminars, and field study data, and provided constructive suggestions for cultural protection. It is evident that empirical studies are necessary for analysis and reference in the early stages of digital protection [50]. An in-depth analysis of the restored objects should be carried out to obtain the most accurate data. With the aid of digital technology, this text presents the most accurate and noteworthy restoration results. Theoretical research and technical presentation of cultural clothing are complementary and indispensable. Subsequently, the fuzzy analytic hierarchy process (AHP) and other result evaluation methods can be employed to present the most credible and worthwhile 3D clothing effects.

2.3. Digital Technology and Heritage Dissemination

The fashion industry has embraced advanced digital solutions to automate processes at different levels of the supply chain, including the implementation of Industry 4.0, the Internet of Things, intelligent manufacturing, and cloud manufacturing. Although design tools such as 3D computer-aided design (CAD) are available, there is still a lack of connection with the user base. This affects the efficiency of these tools throughout the design and manufacturing processes [51]. In the apparel industry, traditional 2D CAD systems are used to generate different plate sizes for apparel-making [52]. With the development of
apparel simulation technology, some CAD plate-making systems used in the commercial field have a layout that can be converted into clothing pieces covering the virtual human body to test the clothing design results [53,54]. The CLO3D system includes features such as 3D human modelling, parametric punching, 3D virtual sewing and fitting, fabric texture attribute setting, and dynamic display, which enable the display and design of three-dimensional presentations [55]. Additionally, the system can construct dynamic clothing models through image acquisition equipment [56]. This 3D virtual presentation mode is commonly used in the modern clothing industry, particularly in virtual fitting technology for the clothing marketing scene. It allows for fabric simulation design and dynamic display functions, which are more intuitive and convenient than traditional 3D displays [55]. This application form provides a method source and technical inspiration for presenting the restored cultural clothing results. The use of 3D technology software, such as CLO3D 3dsmax [13], in the clothing industry and clothing engineering allows for the clear, vivid, and intuitive presentation of structural details of clothing [57]. Additionally, it can bring fragile and damaged historical clothing to life [58]. For the digital virtual reconstruction of ancient clothing, manual modelling through computer software is more accurate and flexible for adjustments [59]. Digital information transmission has fewer limitations, allowing for quicker and more convenient spread and development, such as in film animation, online exhibition halls, innovation, redesign, and other digital cultural transmission methods [60]. Moreover, during the dissemination process, digital reproductions enhance museum collections, multimedia exhibitions, and online presentation programmes [61]. For example, they can be used in ‘cloud displays’ [58] and ‘cloud museum’ [62].

Not only that but George Pavlidis et al. listed 3D digitising methods for ancient cultural heritage records. They argued that the comprehensive documentation of cultural heritage is a complex process that involves three main stages: three-dimensional digitisation; digital data processing and storage, archiving, and management; and representation and reproduction [63]. The advancement of digital technology has facilitated the creation of digital museums for material cultural heritage, which can aid in the preservation and transmission of such heritage. The replicability of technology can be used to spread cultural heritage by transforming it into 3D models for easy learning and observation by future generations [14]. This is particularly important for clothing culture, as the number of physical clothing items unearthed is very limited, causing great difficulties in establishing its inheritance. Furthermore, the figures in the flat cultural artifacts are displayed on a two-dimensional surface, making it impossible to observe the three-dimensional details. This limitation hinders the inheritance and expansion of the artifacts in later periods. To address this issue, the modern fashion industry’s virtual simulation technology for clothing can be used. By employing digital plate-making, dressing simulation, material rendering, and other methods, the mural figures can be visualised more efficiently and vividly.

A classification of technologies relevant to the digital restoration and virtual presentation of clothing has been created based on an analysis of pertinent literature in Table 1. The table uses time as an axis and shows the rate of progress and evolution of digital presentation in the field of cultural heritage. It also presents the most comprehensive, scientific, and appropriate method to apply to the author’s research while analysing and sorting out the advantages of the technology. Consequently, Adobe Illustrator, Clothing CAD, CLO Standalone OnlineAuth, the FAHP assessment method, and other methodologies used in the modern fashion industry for the virtual simulation of clothing are employed to achieve more efficient and vivid visualisation of mural figures’ clothing in terms of the style of drawing, digital plate-making, dressing simulations, material rendering, and other related aspects. The evaluation weight is determined by the proportion of expert interviews. Scientific methods are used to test the accuracy of digital simulation results.
<table>
<thead>
<tr>
<th>Authors (Year)</th>
<th>Repair Object</th>
<th>Method Properties</th>
<th>Spatial Dimension</th>
<th>Techniques</th>
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</thead>
<tbody>
<tr>
<td>De Rosa, A. et al.</td>
<td>Painting</td>
<td>Recovery and filling</td>
<td>two-dimensional</td>
<td>Partitioning algorithm, rigatino technique, puntino technique</td>
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<td>(2001) [26]</td>
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<td>Mastio, A.D. et al.</td>
<td>Painting, fresco</td>
<td>Edge detection, crack removal, lacuna filling</td>
<td>two-dimensional</td>
<td>Canny method, Sobel, Prewitt, Frei-Chen method, Shepard interpolation technique, HVS system, watermarking technique</td>
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<td>(2007) [25]</td>
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<tr>
<td>Lanitis, A. et al.</td>
<td>Wall paintings,</td>
<td>Face reconstruction</td>
<td>two-dimensional</td>
<td>Laser 3D scanner, Z-buffer algorithm, PCA model, texture restoration algorithm</td>
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<td>(2009) [27]</td>
<td>religious icons,</td>
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<td>paintings</td>
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<td>(2021) [31]</td>
<td>clothing</td>
<td>3D scanning technologies,</td>
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<td>Bin Wang</td>
<td>Smart museum</td>
<td>Digital museum, artificial</td>
<td>three-dimensional</td>
<td>Mirror spatial model, information mirror model, mobile terminals, websites, etc.</td>
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<td>(2021) [30]</td>
<td></td>
<td>intelligence, tree algorithm, data</td>
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<td>heterogeneous network algorithm</td>
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<tr>
<td>Kaixuan, L. et al.</td>
<td>Plain unlined silk</td>
<td>Recovery object analysis, structural</td>
<td>three-dimensional</td>
<td>Adobe Illustrator, AHP, 3D interactive pattern-making technology, CLO standalone, human–computer interactive costume pattern-making technology</td>
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<tr>
<td>(2022) [41]</td>
<td>gauze gown</td>
<td>analysis, confirmation of size</td>
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<td>Kaixuan, L. et al.</td>
<td>Painting, sculpture,</td>
<td>Ratio method, costume pattern analysis,</td>
<td>two-dimensional</td>
<td>Adobe Illustrator, CLO3D, Fuyi Garment CAD</td>
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<td>(2022) [28]</td>
<td>murals, archaeological</td>
<td>costume style analysis, costume fabric</td>
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<td></td>
<td>objects</td>
<td>analysis</td>
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<td>Kaixuan, L. et al.</td>
<td>Painting</td>
<td>Virtual fitting technology, image</td>
<td>two-dimensional</td>
<td>CLO3D</td>
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<td>(2022) [29]</td>
<td></td>
<td>editing technology, image processing</td>
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<td>Kaixuan, L. et al.</td>
<td>Painting</td>
<td>3D virtual sewing, digital simulation</td>
<td>two-dimensional</td>
<td>CLO3D, fuzzy comprehensive evaluation</td>
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<td>(2023) [14]</td>
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<td>restoration</td>
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<td>Yu, Qianqian et al.</td>
<td>Hakka cardigan</td>
<td>Digital restoration, 3D virtual display,</td>
<td>three-dimensional</td>
<td>Photoshop, Autodesk Maya, CORELDRAW, 3D scanning system, Laplace mesh deformation algorithm</td>
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<td>(2023) [37]</td>
<td></td>
<td>collision detection, numerical algorithm</td>
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<td>Feng, Geheng et al.</td>
<td>Silk garment</td>
<td>Analysing structural dimensions and</td>
<td>three-dimensional</td>
<td>style3D, fuzzy comprehensive evaluation</td>
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<td>(2023) [42]</td>
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<td>fabric patterns</td>
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<td>Shi, Hui et al.</td>
<td>Robe</td>
<td>Body scanning technology, building a</td>
<td>three-dimensional</td>
<td>AlphaM4 3D, reverse engineering technology</td>
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<td>(2023) [43]</td>
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<td>personalised human model</td>
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3. Methods and Applications

The Tang Dynasty (618–907) in China was renowned for its open and inclusive atmosphere, marked by frequent diplomatic exchanges and cultural interactions with nations from around the world. This led to the creation of splendid cultural and artistic treasures. Within the international diplomatic context, specific clothing styles often reflected the political and cultural characteristics of different countries. China has been known as the ‘King-
dom of attire’ due to its unique cultural heritage. As a special cultural heritage, ancient clothing reflects the lives, thoughts, and wisdom of ancient people and serves as a symbol of national culture [64]. The term ‘Silk Road’ was coined by the German geographer Ferdinand von Richthofen in his book ‘China’ (p. 454, [65]). It refers to the trade routes that linked China with the regions between the Amu Darya and Syr Darya rivers in Central Asia, as well as with India from 114 BC to 127 AD. The term ‘Silk Road’, written as Seidenstrassen in German, originated from the renowned Chinese fabric ‘silk’, which was famous worldwide in ancient times. This name gained recognition and acceptance among numerous scholars from both the east and the west [66]. The trade routes of ancient times provide insights into the expansion of the ancient transportation network, which laid the foundation for the flourishing diplomatic activities of the Tang Dynasty. The Tang Dynasty’s transportation network extended beyond the overland Silk Road between Central Asia and India, encompassing routes such as the Steppe Silk Road, the Maritime Silk Road, the Tang–Tibet Ancient Road, and the Tea Horse Ancient Road. These networks formed a regional grid for trade and diplomacy that radiated across the continents of Asia, Europe, and even Africa [67]. The Tang Dynasty of China is renowned for its cultural richness and artistic achievements, which were considered among the finest in the world during its time. The Tang tomb murals are particularly noteworthy, offering a unique and authentic perspective on various aspects of society and artistic standards during that era [67]. It is worth noting that paintings depicting ancient diplomatic scenes are rare and their existence is limited. During a visit to the Shaanxi History Museum in June 1998, U.S. President Bill Clinton pointed to the Tang tomb mural ‘Diplomatic Envoys’ and remarked that it was his favourite artwork [68]. This artwork holds significant political and artistic allure, as evidenced by its appreciation by prominent figures such as President Bill Clinton.

3.1. Overall Plan

This paper analyses the ceremonial attire depicted in the Tang Dynasty tomb mural ‘Diplomatic Envoys’ from two dimensions. Firstly, it examines the attire etiquette of the Tang Dynasty’s local diplomats and foreign envoys in a cross-cultural diplomatic context. Secondly, it explores the digital simulation and recreation of the two-dimensional clothing of the mural into three-dimensional representations. The research in the first dimension includes not only visual materials, such as two-dimensional tomb mural images and three-dimensional stone carvings from the same social scene, but also textual records from official historical literature. The foundation of this process is the integration and analysis of visual and literary data. Software such as Adobe Illustrator, Clothing CAD, and CLO Standalone OnlineAuth are then used for the three-dimensional virtual simulation and recreation, with the aim of achieving the most realistic restoration results. The implementation process is illustrated in Figure 1.

This study on restoration relies on archaeological and literary sources to accurately reconstruct clothing. The artwork is two-dimensional, making it challenging to determine the full appearance of three-dimensional clothing for virtual reconstruction. However, from the Tang Dynasty, numerous three-dimensional preliminary sketches, known as ‘Fenben’ in Chinese, have been preserved. Figure sculptures among them can serve as valuable auxiliary research materials. However, the details in these sculptures may have become indistinct due to the passage of time. Official classical literature provides detailed descriptions of ceremonial clothing, which can corroborate the reconstruction. To prevent traditional cultural treasures from being lost in the torrent of history, a combination of two-dimensional images, three-dimensional images, and textual details is used to virtually simulate and reconstruct ancient diplomatic attire. Once the restoration is complete, the data will be able to withstand the test of time and other external factors, ensuring their preservation for future generations.
3.2. Analysis of Mural Scene

As is well known, during the Tang Dynasty, China was a powerful and open empire that welcomed envoys and diplomats from various foreign nations. Diplomacy played a crucial role in consolidating the nation’s political power. The Tang Dynasty produced a rich array of paintings depicting diplomatic themes, such as the painting ‘Emperor Taizong Receiving the Tibetan Envoy’ by Yan Liben. This artwork depicts a scene of a marriage between rulers of different lands, featuring a foreign envoy and a Tang monarch. Additionally, other artistic works also depict the attire worn by foreign dignitaries, such as the Gathering of King, Stone-Carving Statues of Chiefs of Tribes of 14 Countries at the Zhaoling Mausoleum, and the Stone Statues of 61 Foreign Officials at the Qianling Mausoleum. These artworks are valuable resources for studying the attire of foreign emissaries. However, the mural painting the ‘Diplomatic Envoys’ not only highlights the characteristics of foreign attire but also portrays those of native clothing worn by the Tang officials. The coexistence of these different clothing styles creates a visual contrast and reflects the cultural exchange and tolerance of the era. This mural serves as crucial material for studying the attire, rituals, and diplomatic scenes of the Tang Dynasty’s officials’ class.

Li Xian, who was moved to the Qianlong Mausoleum in the second year of the Reign Shenlong (706) from Bazhou (present-day Baizhong, Sichuan province) and was posthumously conferred the title of Crown Prince Zhanghuai in the second year of the Reign Jingyun (711), is the person buried in the tomb. The mural in the tomb, the ‘Diplomatic Envoys’, is divided into two parts: the east wall and the west wall. It depicts the arrival and mourning of foreign envoys. It not only shows Chinese officials receiving foreign envos during the Tang Dynasty but also portrays foreign envoys waiting in respect, showcasing the grandeur of Tang Dynasty diplomacy.
The mural in Crown Prince Zhuanghuai’s tomb follows a specific pattern and fixed spatial arrangement. The east wall of the tomb chamber features the ‘Diplomatic Envoys’ and a painting of the Azure Dragon, while the west wall displays the ‘Diplomatic Envoys’ and a painting of the White Tiger [69]. According to traditional Chinese directional symbolism, the Azure Dragon represents the east, while the White Tiger represents the west. The Office of Foreign Affairs, also known as the Honglu Temple at that time, was responsible for managing diplomatic affairs. Its duty was to distinguish the ranks and positions of foreign monarchs and dignitaries from various regions and treat them as honoured guests when they met the monarchs of the Tang Dynasty ([70] p. 1885). The eastern section of the ‘Diplomatic Envoys’ likely depicted envoys from eastern regions, while the western section of the ‘Diplomatic Envoys’ likely depicted envoys from western countries [71,72]. This conclusion is drawn from the use of traditional Chinese orientation symbolism and the consideration of academically recognised textual research on the countries of origin of the envoy.

3.3. Analysis of Reconstruction Objects

The study of ceremonial costumes in the ‘Diplomatic Envoys’ comprises two dimensions: the research of the Tang diplomats’ costumes and the research of costumes worn by foreign envoys coming to China. The ‘Diplomatic Envoys’ are divided into two parts: the east wall and the west wall. The objects of study on the east wall of the ‘Diplomatic Envoys’ are labelled A, B, C, D, E, and F from left to right, as shown in Figure 2. The objects on the west wall of the ‘Diplomatic Envoys’ are labelled G, H, I, J, K, and L from left to right, as shown in Figure 3.

![Figure 2](image2.jpg)

Figure 2. The east wall of the tomb of Crown Prince Zhanghuai.

![Figure 3](image3.jpg)

Figure 3. The west wall of the tomb of Crown Prince Zhanghuai.

Objects A, B, and C: The murals on the east and west sides of Prince Zhanghuai’s tomb depict the scenes of the reburial of Li Xian, then Prince of Yong, by Emperor Zhongzong of the Tang Dynasty. This ceremony was supervised by officials from the Honglu Temple.
According to the Old Book of Tang: Record of Officials, there was a third-rank minister called a ‘Qing’ and two fourth-ranked vice ministers called ‘Shaoqing’ under the Honglu Temple. The role of a ‘Qing’ involved overseeing matters related to receiving and entertaining guests, managing ceremonial and funeral matters, and leading the departments of ‘Quke’ and ‘Siyi’ in work and arranging positions for them. The two vice ministers were responsible for receiving foreign envoys in the capital and treating them according to their ranks. They also participated in funeral rites, including mourning and condolences for emperors, crown princes, and other high-ranking officials [70]. The depictions in the murals align with the documentation in terms of the number of individuals, the scene, and the background. The murals depict three officials from the Honglu Temple. One of the officials held the rank of Qing at the third level and was responsible for managing ceremonial matters for guests and funeral ceremonies. The other two officials were responsible for managing the reception of foreign envoys during mourning and condolences. All three Tang officials wear black gauze caps adorned with long ribbons and red official robes with floor-length sashes [73]. At the same time, they effectively present various angles of the official attire worn by the Tang Dynasty diplomats, providing valuable references for 3D reconstruction.

As per the New Book of Tang: Records of Chariots and Clothing, officials ranked at a fifth level or higher were obligated to wear court dress, also known as ‘Jiufu’ or ‘Chaofu’, during important ceremonies such as sacrifices, court meetings, banquets, and court worships. The literature also provides specific details on attire, including wearing a scarf, followed by a cap or crown and a hairpin. The required attire consisted of a red silk outer robe, a white silk one-piece shirt, black collars and sleeves, and decorative lace trimmings on the edges. Additionally, white skirts and innerwear, a leather belt decorated with gold hooks, curved collars, white socks, black leather boots, and accessories such as a sword and a sachet on the waist were suggested [74]. Based on additional documentation, during the first year of the Reign Xianqiang (656), third-rank officials were required to wear purple clothing with belts adorned with gold and jade. Fourth-rank officials were to wear crimson clothing with gold accessories, and fifth-rank officials were to wear light red clothing with gold-adorned belts [74]. It can be inferred from this information that the three Tang officials from the Honglu Temple held positions of at least fourth grade or above [75]. Figure 4a illustrates the clothing style.

Object D: The individual is dressed in a shirt, an open-necked purple robe, a thin white belt, and black boots, with folded hands in front of the chest. The clothing style is depicted in Figure 4b. Based on the traditional Chinese orientation symbolism, this person is likely a Khitan [71]. The New Book of Tang: Biographies of Khitans records frequent communication between the Khitan and the Great Tang Empire. The envoy in the mural is depicted with a shaved head, a hairstyle known as ‘Kunfu’ (髡发) in Chinese. This hairstyle features no hair on top and is evidenced in physical artifacts such as murals and figurines from tombs of the Liao Dynasty. For example, the Zhang Wenzao tomb mural [76], shown in Figure 5, depicts this hairstyle. Additionally, the crossed-arm gesture (叉手礼仪) serves as further evidence. The crossed-arm gesture can be observed in the mural on the west wall of the Baoshan M1 tomb chamber and in the tomb entrance mural. These two murals depict Khitan male attendants in the same pose [77], as shown in Figure 6. Moreover, other tomb murals of the Liao Dynasty, such as the Guanshan M5 [78] and the tomb of the Seven Sages of Jianping [79], also portray the Khitan people making the same gesture. However, it is important to note that, during the Liao period, the Khitan people mainly wore round collars. Is it possible that the turndown collar depicted in the murals represents the clothing style of the Tang Dynasty, which preceded the Liao Dynasty (907–1125)? The answer is nearly affirmative. According to the New Book of Tang, after the reign of Emperor Zhongzong, men’s clothing and footwear began to share formal characteristics with those of northern minorities such as the Xi and the Khitan (p. 531). Therefore, some scholars hold the view that the right-lapelled robes were the attire of the Khitan people [71]. In conclusion, the envoy was Khitan.
Figure 4. Costume styles of the mural figures in the 'Diplomatic Envoys' (drawn by the authors).

Figure 5. Khitan hairstyle [71].
Object E: According to the official archaeological excavation report, this individual is depicted wearing a feathered hat with two bird feathers upright on top. The front of the hat is adorned with vermilion colour, while the sides are adorned with green. The hat is fastened below the jaw by two bands hanging down from both sides, exposing the ears. The individual is dressed in a long white robe with a prominent red collar. The robe’s lapels are adorned with red floral patterns. The individual is dressed in a robe with wide sleeves that cover both hands, which are clenched in a gesture of respect. A white belt is tied around the waist, and yellow boots are worn. The robe has two layers with triangular ends at the waist, characterised by two hanging straps. The clothing structure is similar to that of the statue of the Southern Barbarian King located at the southeast corner of the eastern side of the Zhuque Gate outside the Qianling Mausoleum in Shaanxi, as shown in Figure 7. This three-dimensional statue is a crucial reference for reconstructing the clothing in three dimensions. In 2002, a pedestal inscribed with ‘Prince Jin Zhende of Lelang Commandery, Silla’ was excavated from the Northern Sima Gate of the Zhaoling Mausoleum. This discovery has resolved a long-standing mystery in the academic community. The pedestal can be correlated with a fragment discovered in 1982, where the figure is similarly depicted wearing a three-layered robe that drapes to the ground. The lower layer is the longest and widest, covering only the tips of the feet. The middle and outer layers gradually shorten and are cinched with a long ribbon in front of the abdomen. The feathered crown is a typical headdress of Silla. Archaeological analysis suggests that the envoy wearing the bird feather crown is likely an envoy from Silla. According to the Old Book of Tang: Biographies of Eastern Barbarians, in the third year of the Tian Shou era (692 AD), Empress Wu Zetian of the Tang Dynasty expressed condolences and dispatched envoys to Silla to mourn the passing of the Ming Emperor and participate in the coronation ceremony of the new king (p. 5337). This record presents the close official communication between the Great Tang Empire and Silla. The Old Book of Tang: Biographies of Baekje states that officials wore red clothes, while the Biographies of Goryeo, in the same book, describe their attire as consisting of upper outer garments with tube-shaped sleeves, loose trousers, white belts, and yellow shoes. The clothing of Silla was also similar to that of Korea and Baekje. Therefore, the clothing styles of Korea and Baekje can serve as a reference during restoration. This provides a useful reference for restoration purposes. The painting scroll ‘Tribute Bearers’, which is housed in the China National Museum and depicts envoys from Baekje, is shown in Figure 8. To summarise, the style characteristics of the attire can be determined, as illustrated in Figure 4c.

Object F: The envoy is depicted wearing a fur hat, a grey fur outer garment with a round collar, fur pants, yellow leather boots, and a black belt, with both hands held within the sleeves. Experts have deduced that this envoy is likely from the Mohe people, a northeastern minority group, and represents the kingdom of Bohai, also known as Pohai. The ethnic group referred to as ‘Wuji’ during the Southern and Northern Dynasties period was known as ‘Mohe’ during the Tang Dynasty. According to Northern History: Biographies of Wuji, ‘Men wore pigskin robes and the tails of tigers and leopards were into their headwear’. Clothing similarities between the mural and the Mohe people’s clothing
are notable. Men wore pigskin robes and fur hats made from animal skins due to the cold climate of the Mohe region. An analysis of a figure depicted on a piece of damaged paper pasted on red silk within a helmet from the South Warehouse of the Shōsōin Treasure House, exhibited at the Nara National Museum in Japan, suggests that the clothing style of the figure matches the shoulder attire of Object F in the painting the ‘Diplomatic Envoys’, as shown in Figure 9 [86].

Figure 7. The king statue of Qianling in Shaanxi Province.

Figure 8. ‘Tribute-Bearing Envoys Painting Scroll’ depicts envoys from Baekje.

The addition of felt pieces on both sides of the fur hat is an interesting detail. The Mohe people combined their clothing with Tang Dynasty attire, as evidenced by the literature and visual materials. However, due to climatic factors, suitable fur and fabric materials specific to their ethnicity were necessary. Several Mohe stone figurines have been discovered in Tang Dynasty tombs excavated in Liaoning, China. The stone figurines shown in Figure 10 are dressed in Tang Dynasty clothing and have braided hair [87]. One of the male stone figurines is wearing a round-collared, right-lapelled robe, a belt around
the waist, and pointed boots. The robe he is wearing bears a resemblance to the round-collared robe worn by the Mohe envoy in the ‘Diplomatic Envoys’. The appearance of the attire in the mural helps to reconstruct the clothing of the character and confirms the blending of the Tang Dynasty’s round-collared robe style with the attire of northeastern ethnic groups. In conclusion, Figure 4d illustrates the style characteristics of this attire.

![Figure 9. Figure of characters in red silk helmet ink painting.][1]

Object F: The envoy is depicted wearing a fur hat, a grey fur outer garment with a round collar, fur pants, yellow leather boots, and a black belt, with both hands held within the sleeves. Experts have deduced that this envoy is likely from the Mohe people, a north-eastern minority group, and represents the kingdom of Bohai, also known as Pohai of the Tang Dynasty’s round-collar robe style with the attire of northeastern ethnic groups.

![Figure 10. Mohe male stone figurine unearthed from Tang Tomb on Huanghe Road, Chaoyang City, Liaoning Province.][2]

Object G: With deep-set eyes, a prominent nose, a beard along the jawline, and wearing a pointed felt hat with an inwardly rolled brim (also known as a ‘Hu hat’), this individual is dressed in a red robe with a large turned-up collar and narrow sleeves. He is wearing a red inner layer, a white belt around the waist, and black knee-high boots and is holding a wooden tablet. Based on the attire of this envoy, it is highly likely that he is of Sogdian origin. During the 6th to 8th centuries, the Sogdians established city-state kingdoms, with Sogdina, also known as Kangju, being one of the most prominent. They played a crucial role in connecting the east and west in trade, serving as intermediaries between the Central Asian region and China during the peak of communication between the two regions. The Tang Dynasty referred to them as the ‘Hu people’. The Sogdian people and other Central Asian ethnic groups in the surrounding regions adopted the tradition of wearing pointed-brim hats, also known as ‘conical hats’. Historical data are available on the clothing worn by the Sogdian people.

This paper presents an analysis of the data collected from pottery figurines discovered in Sogdian tombs. For example, the Tang tricolour-glazed figurine found in the An Pu couple tomb and now housed in the Luoyang Museum depicts a man wearing a pointed felt hat, an open-necked robe, and long boots. The facial features and clothing of the figure in this image are similar to those of the envoy depicted in a painting from the same tomb,
referred to as the ‘Diplomatic Envoy’, which is also housed in the Luoyang Museum (see Figure 11). Additionally, a Sogdian figurine riding a horse was found in the same tomb. The lapelled robe worn by the figurine has a split side swing, as depicted in Figure 12. Furthermore, the tomb of Su Sixu from the Tang Dynasty contains murals depicting a Huteng Dance, which includes Sogdian people. The research object of this paper bears a resemblance to the attire depicted in Figure 13 [89], which features a pointed hat with the rim inwardly rolled. The style characteristics of this attire are confirmed in Figure 4e.

Figure 11. Figurine of a male wearing a hat, housed in the Luoyang Museum [90].

Figure 12. Figurine of a Hu riding a horse, housed in the Luoyang Museum [91].

Object H: This individual has a long face, large eyes, a high topknot, and his hair is tied at the back of the head. The person is dressed in a black robe with a round collar and narrow sleeves, along with a waistbelt and black knee-high boots. A notable characteristic is the use of vermilion colour on the forehead, cheeks, nose bridge, and lower jaw. The person stands with hands folded with the sleeves and wears a headband typical of Tibetan headwear. According to the New Book of Tang: Tibetan Empire, ‘The people of Tibet wore clothing made of felt fabric and had a preference for applying red ochre on their cheeks’ [74]. This aligns with the described characteristics. Additionally, the Old Book of Tang: Biographies of Tibetans states that they wore black clothing during funeral scenes. Thus, it can be inferred that the figure portrayed on the west wall, dressed in a black robe with a round collar, narrow sleeves, and black knee-high boots, is a Tibetan envoy [92].
Tibetan clothing is well documented, particularly in relation to ‘Fan Jin’ textiles. The Sogdian people from Central Asia who migrated to Tibet established their own silk-weaving industry. When discussing Tibetan envoys to the Tang Dynasty, it is worth noting Yan Liben’s painting of Emperor Taizong, Receiving the Tibetan Envoy. The painting depicts the Tibetan ambassador, Dazhang Luodongzan, Gar Tongtsen Yulsung, wearing a round-collar silk robe known as the ‘Fanke Jinpao’ in Chinese. This painting is currently held in the Palace Museum and is illustrated in Figure 14. There are extant artifacts that serve as references for the reconstruction of the round-collar silk robes of Tibet, as shown in Figure 15. Additionally, a robe with linked pearl patterns, discovered in the Caucasus region, features a right-lapel design with dividing lines at the waist, which aligns with the attire of the characters in the mural. Moreover, the region of origin and usage context are consistent, making it a valuable reference for reconstruction. In summary, the style characteristics of this attire can be confirmed, as illustrated in Figure 4f.

Figure 13. Figurine of a Hu riding a horse, housed in the Luoyang Museum.

Figure 14. Tibetan envoy Ludongzan.
Figure 14. Tibetan envoy Ludongzan.

Figure 15. Brocade robe unearthed from the region of Caucasia [93].

Object I: The individual has a broad, round face with high cheekbones and hair combed behind the shoulders. He is wearing a yellow robe with a round collar, right lapel, and narrow sleeves, which is fastened with a waistbelt. A short, dagger-like object is hanging from the belt. His hands are respectfully placed over his chest, and he is wearing knee-high black boots. Scholars have suggested that this figure may be an envoy from the Gaochang Kingdom, also known as Gocho, based on a record in the New Book of Tang: Biographies of Gaochang. This record documents the practice of braiding hair and letting it hang down behind the body in this region [92]. However, it is worth noting that Crown Prince Zhanhuai was reburied in the second year of the Shenlong era (706), but the Gaochang kingdom had already been conquered by the Tang Dynasty by the 14th year of the Zhenguan era (640). Therefore, it is unlikely that the murals portray an emissary from an extinct state, as they were not painted until 50 years after the state’s demise. Some scholars suggest that this figure may be Turkic [72]. The authors agree with this deduction for the following reasons: firstly, the custom of braiding hair and letting it hang down behind the body was not exclusive to the Gaochang people but was also shared by the Turkic people as a display of hair decoration. According to Zhoushu: Biography of Turkic, the Turkic people ‘had the custom of dishevelled hair’ [94]. In the third year of the Zhenguan era (629 AD), during the reign of Emperor Taizong of the Tang Dynasty, the Buddhist monk Xuanzang departed from Chang’ an (present-day Xi’an, Shaanxi Province). Upon arrival in Suiye City (present-day southwest of Tokmok City in Kyrgyzstan), also known as Suyab, he observed that the Khan was dressed in a green ghatpot robe and his hair was wrapped with a 10-inch silk ribbon starting from the forehead and hanging down behind. Over 200 high-ranking officials, dressed in long robes and with braided hair, stood around the Khan [95]. According to this historical account, Turkic officials wore braided or woven hair and did not adorn their heads. The mural portrays a backward braided hairstyle found in many Turkic stone statues that have been unearthed.

Additionally, the most notable feature of this figure is the dagger-shaped object worn around the waist. Research has revealed a comparable figure in Turkic stone figures dating from the 6th to 7th centuries at Qiaoxia Cemetery in Ahele Township, Xinjiang, as shown...
in Figure 16 [96]. Similarly, stone statues from the same era, such as the Sarekuobu Turkic stone figures in Zhaosu, the Ili region, wear short daggers hanging from their waists, as shown in Figure 17 [97]. To summarise, this figure is likely a Turkic envoy. In 2011, the Shoroon Bumbagar relics in Bulgan Sum, Central Province, Mongolia, were excavated, and the tomb of a Turkic noble from the 7th century was discovered. The tomb contains partially damaged murals and various figurines depicting different human forms. Scholars have analysed the clothing styles of male Turkic figures represented in these artifacts. It is clear that, in addition to the traditional left- and right-lapel attire, round collars and lapels were also commonly used in Turkic clothing, as shown in Figure 18 [98]. This figure depicts a round-collared long robe that provides a crucial reference for the reconstruction of the mural the ‘Diplomatic Envoys’. In conclusion, the style characteristics of this attire can be confirmed, as illustrated in Figure 4g.

Figure 16. Stone statue at Xiaqiao cemetery.

Figure 17. Stone statue in Sarekuobu.

Figure 18. Line graph of early Turkic male clothing unearthed from Shoroom Bumbagar tomb.

Objects J, K, and L: It is likely that the other three Tang Dynasty officials depicted on the west wall of the ‘Diplomatic Envoys’ painting were also involved in diplomatic ceremony and event management, given their positions in relation to the officials on the east wall.
However, their attire is noticeably less splendid than that of their counterparts. Scholars have identified them as ‘officials from the Tang dynasty’s Office of Foreign Affairs (the Honglu Temple).’ [92]. According to the Old Book of Tang: Records of the Imperial Carriage and Clothing, officials below the sixth rank held tablets made of bamboo or wood, known as ‘Huban’, with round tips and flat bottoms ([70] p. 1952). Two of the three officials hold court tablets featuring round tips and flat bottoms, indicating that they were likely officials of the Dianke Shu, a branch responsible for minority affairs under the Honglu Temple. Specifically, they may have held the positions of Dianke Ling (典客令), a deputy lower seventh rank, and Dianke Cheng (典客丞), a deputy lower eighth rank. This information is supported by the Old Book of Tang, where the Records of Official Positions states that the Dianke Ling was responsible for managing foreign envoys from friendly nations, while the Dianke Cheng had two individuals who were required to participate in and prepare for matters related to worship, tributary missions, banquets, receptions, and other diplomatic affairs. They were expected to receive the guests according to their status and perform their duties well [70]. However, the figures in the murals wear red clothing, which was reserved for officials of the fifth rank or higher. This rule did not apply to the regulations for officials of the lower seventh rank and below.

As the Honglu Temple did not establish a fifth-rank official position, the attire and colour worn by these three Tang officials can be seen as an example of ‘exceeding the proprieties’ [99]. The clothing’s style characteristics are summarised in Figure 4h.

3.4. Human Body Proportions and Garment-Making

After consulting specialised archaeological reports and other resources, it has been discovered that the murals, currently housed in the Shaanxi History Museum in Shaanxi Province, China, depict envoys with incredibly lifelike facial features, detailed clothing, and accurate proportions [75]. This aligns closely with the actual situation. However, the measurements for the east wall of the 'Diplomatic Envoys' are more detailed than those for the west wall of the same painting. The eastern wall mural’s official measurements are 185 centimetres in height and 247 centimetres in width [100]. These measurements indicate that the figures on the east wall are life-sized, emphasising their realism [100]. The height of the characters on the east wall of the 'Diplomatic Envoys' can serve as a reference for determining the height of the characters on the west wall. Research suggests that, during the Tang Dynasty, the average height of males in the central plains of China was approximately 167.03 cm, with a range of variation from 162.40 cm to 173.40 cm [101]. Therefore, the image scale analysis method can be used to estimate the height and body proportions of the Tang Dynasty officials depicted in the mural to determine clothing pattern measurements. These measurements are a crucial reference for determining the heights of Chinese officials and foreign envoys in the painting. Finally, height-to-head height ratios of research objects are obtained by integrating information fragments and dividing body heights by head heights. The ratios are 8.16, 6.8, 7.5, 7.4, 7.5, and 7.6, respectively, which are consistent with the typical body proportions of Asian males. Through image scale analysis, we conducted two-dimensional measurements of the clothing depicted in the murals to determine the proportional relationship between human bodies and clothing. We then estimated concrete clothing measurements and details by referring to data on human bodies and clothing of the same type [102].

Taking Object C as an example, this Tang Dynasty official’s height was divided into seven units, with three units above the waistline and four units below the waistline, resulting in a calculated height of 170 cm. A line was then formed by connecting the head point, front neck point, and waist point to form a line, and the angle formed was measured to be approximately 180°, as shown in Figure 19, indicating an upright position. Thus, the proportion measurement method yields valid data and can be employed to measure clothing sizes relative to the human body. Using the proportion measurement method, accurate data for vertical clothing measurements, such as length, sleeve width, and ribbon width, can be calculated based on the known height and head-to-body ratio of the
individuals and by analysing the proportional relationships between different parts of the clothing. Other clothing-related measurements, such as waistband width, shoulder width, and sleeve length, can be estimated. The calculated clothing data for other individuals are presented in Table 2. In order to verify the accuracy of the data on the clothing of the mural figures, the authors sorted out the archaeological data of the unearthed objects of the same style of robes and used the physical data as evidence to ensure the accuracy of the prediction data of the ratio method. As shown in Table 3, these archaeological data are the first-hand data of the Tang Dynasty robes from the China Silk Museum, and it can be seen that the length range of the robes is between 120 cm and 140 cm and the length of the sleeves is between 150 cm and 200 cm, fluctuating up and down. It is obvious that the data are in the same range as the measurements of the restored objects wearing the robes. Thus, it can be seen that the clothing size of the mural figure measured by the proportional prediction method is in accordance with the size law of the clothing of the Tang Dynasty, so the reliability of the data is improved and the digital plate-making and modelling in the next phase are ready to be implemented. Based on the obtained data, CAD pattern-making software can be used to create pattern diagrams, as shown in Figures 20 and 21.

Table 2. Recovered clothing size.

<table>
<thead>
<tr>
<th>Category (cm)</th>
<th>Garment Length (cm)</th>
<th>Hem Width (cm)</th>
<th>Innerwear Length (cm)</th>
<th>Open Length between Cuffs (cm)</th>
<th>Cuff Opening (cm)</th>
<th>Neck Width (cm)</th>
<th>Collar Length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objects A, B, and C</td>
<td>120</td>
<td>76.25</td>
<td>99</td>
<td>190.98</td>
<td>74.38</td>
<td>9.5</td>
<td>117.46</td>
</tr>
<tr>
<td>Object D</td>
<td>135.07</td>
<td>84.2</td>
<td>63.5</td>
<td>174</td>
<td>14</td>
<td>3</td>
<td>40.19</td>
</tr>
<tr>
<td>Object E</td>
<td>86.47</td>
<td>85.45</td>
<td>63.5</td>
<td>209.58</td>
<td>64.41</td>
<td>10</td>
<td>127.22</td>
</tr>
<tr>
<td>Object F</td>
<td>134.56</td>
<td>90.82</td>
<td>63.5</td>
<td>202.02</td>
<td>25.54</td>
<td>2</td>
<td>32.68</td>
</tr>
<tr>
<td>Object G</td>
<td>131.56</td>
<td>76.48</td>
<td>74.37</td>
<td>196.72</td>
<td>24.94</td>
<td>4.5</td>
<td>40.19</td>
</tr>
<tr>
<td>Object H</td>
<td>138.06</td>
<td>92.38</td>
<td>63.5</td>
<td>195.14</td>
<td>32.86</td>
<td>2</td>
<td>37.76</td>
</tr>
<tr>
<td>Object I</td>
<td>153.94</td>
<td>104.87</td>
<td>63.5</td>
<td>186.4</td>
<td>19</td>
<td>3.5</td>
<td>35.69</td>
</tr>
<tr>
<td>Objects J, K, and L</td>
<td>105.06</td>
<td>76.25</td>
<td>99</td>
<td>190.98</td>
<td>70.78</td>
<td>9.5</td>
<td>117.46</td>
</tr>
</tbody>
</table>

Figure 19. Details of proportion measurement of Object C.
Table 3. Archaeological survey data of archaeological objects.

<table>
<thead>
<tr>
<th>Number</th>
<th>Designation of Cultural Relic</th>
<th>Era</th>
<th>Garment Length (cm)</th>
<th>Open Length between Cuffs (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Small group pattern brocade robe</td>
<td>Tang Dynasty</td>
<td>140</td>
<td>130</td>
</tr>
<tr>
<td>2</td>
<td>Yellow silk robe</td>
<td>Tang Dynasty</td>
<td>130.5</td>
<td>234</td>
</tr>
<tr>
<td>3</td>
<td>Dark floral silk robe</td>
<td>Tang Dynasty</td>
<td>120</td>
<td>220</td>
</tr>
<tr>
<td>4</td>
<td>Fragments of a robe</td>
<td>Tang Dynasty</td>
<td>133</td>
<td>148</td>
</tr>
</tbody>
</table>

Figure 20. Clothing pattern diagram of characters on east wall of mural painting of the ‘Diplomatic envoys’. 
3.5. 3D Simulation Model Construction

After completing the calculations and the pattern-making steps, the next stage is to construct a 3D model layer by layer for the clothing of the mural figures. This will achieve a virtual simulation and restoration effect. The first step is to set up the grids and the lens, whose parameters are shown in Figure 22a, and then to import the model. Based on previous research, a virtual model’s height is set at 170 cm, and three-dimensional data are established according to the average Asian body proportions, which include a chest circumference of 87.5 cm, a waist circumference of 71.5 cm, and a hip circumference of 90.1 cm. Gravity, resistance, and other related simulation parameters are then set, as shown in Figure 22b. Next, the DXF version file is imported, and the format parameters are set, as shown in Figure 22c. The pattern piece is then placed on the designated point, adjusting the three-dimensional angle while avoiding any contact with the virtual model. Next, the sewing thread parameters are edited, and virtual stitching is performed, as shown in Figure 22d. After the first layer of the garment is frozen, the second layer of the garment is organised, and virtual sewing is performed. The process of virtually trying on the outer garment follows the same steps as previously mentioned, with further adjustments made as needed. Finally, the clothing is layered, adjustments are made, and colour is applied to the virtual clothing details using the Select and Move tool. The main process is illustrated in Figure 23.
A set of 3D virtual simulations and restorations of the mural clothing were performed following the same steps, as illustrated in Figure 24. Virtual simulation and restoration are common tools used in educational settings and virtual museum displays. Furthermore, file formats output from such virtual simulations, such as the OBJ format, can be directly applied in 3D gaming environments, such as character clothing in video games, making them widely applicable. Due to the convenience of a secondary application, the source file of the image can be uploaded and stored in iCloud, Google Cloud, and other web disks for easy distribution and download. At the same time, each garment is tagged for identification by period, category, colour, and other information. This information can later be used as supporting data for the development of the AI-restored model.
Figure 23. Flow chart of virtual restoration of mural painting clothing.

Figure 24. Clothing 3D virtual restoration diagram of mural painting of the ‘Diplomatic Envoys’. 

To ensure the credibility of virtual simulation restoration results, it is essential to establish a set of validated evaluation criteria. These criteria should cover four key evaluation indicators: overall clothing style design, clothing structural details, clothing fabric texture, and clothing fabric colour \([57]\).

4.1. Establishing an Analytic Hierarchy Process (AHP) Model

(1) Creating a judgement matrix:

\[
A = \begin{bmatrix}
    a_{11} & a_{12} & \cdots & a_{1n} \\
    a_{21} & a_{22} & \cdots & a_{2n} \\
    \cdots & \cdots & \cdots & \cdots \\
    a_{n1} & a_{n2} & \cdots & a_{nn}
\end{bmatrix}
\]

In the matrix, \(a_{ij}\) represents the degree of importance of \(A_i\) in relation to \(A_j\). If \(A_j\) is more important, \(a_{ij} > 1\). If both are equally important, \(a_{ij} = 1\).

(2) Evaluating the importance of matrix components (Table 4).

Table 4. Standards for relative importance ratio.

<table>
<thead>
<tr>
<th>Scale</th>
<th>The Meaning Conveyed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>By comparison, the two factors are of equal importance</td>
</tr>
<tr>
<td>3</td>
<td>By comparison, the former factor is slightly more important than the latter.</td>
</tr>
<tr>
<td>5</td>
<td>By comparison, the former factor is significantly more important than the latter.</td>
</tr>
<tr>
<td>7</td>
<td>By comparison, the former factor is intensively more important than the latter.</td>
</tr>
<tr>
<td>9</td>
<td>By comparison, the former factor is extremely more important than the latter.</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>The middle value between two adjacent factors in a judgement.</td>
</tr>
<tr>
<td></td>
<td>The reciprocals of the values mentioned above</td>
</tr>
</tbody>
</table>

(3) Calculating the weight vector for the metrics.

Steps for vector product normalisation method:

Step 1: Use the normalisation process for the matrix by applying the following formula:

\[
\bar{a}_{ij} = a_{ij} / \sum_{k=1}^{n} a_{ij}(i, j = 1, 2, \ldots, n)
\]  

(1)

Step 2: Sum up the elements within the matrix:

\[
\bar{w}_i = \sum_{j=1}^{n} a_{ij}(i, j = 1, 2, \ldots, n)
\]  

(2)

Step 3: Perform the normalisation process on \(\bar{w}_i\) in the above formula:

\[
w_i = \bar{w}_i / \sum_{i=1}^{n} \bar{w}_i(i = 1, 2, \ldots, n)
\]  

(3)

Step 4: Calculate the largest eigenvalue of the judgement matrix:

\[
\lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} \frac{(Aw)_i}{w_i}
\]  

(4)
(4) Consistency inspection: We perform a consistency inspection on the previously obtained vectors and eigenvalues. If the inspection is passed, it indicates that the judgment matrix is reasonable and has explanatory value. Next, determine the numerical index of (RI) (Table 5).

<table>
<thead>
<tr>
<th>N</th>
<th>RI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0.52</td>
</tr>
<tr>
<td>4</td>
<td>0.89</td>
</tr>
<tr>
<td>5</td>
<td>1.12</td>
</tr>
<tr>
<td>6</td>
<td>1.26</td>
</tr>
<tr>
<td>7</td>
<td>1.36</td>
</tr>
<tr>
<td>8</td>
<td>1.41</td>
</tr>
<tr>
<td>9</td>
<td>1.46</td>
</tr>
<tr>
<td>10</td>
<td>1.49</td>
</tr>
<tr>
<td>11</td>
<td>1.51</td>
</tr>
</tbody>
</table>

The following are the calculation methods for the consistency index (CI):

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1}
\]  

The RI value can be obtained by using the value of n. The consistency ratio (CR) can then be calculated using the formula CR = CI/RI. When CR < 0.1, it indicates that the consistency requirement has been met.

4.2. Construction of Discriminant Matrix and Calculation of Weights

A panel of eight clothing restoration research experts conducted interviews and compared four evaluation criteria based on their professional experience. They assigned scores to indicate the importance of each criterion within the system. After internal discussions and summarisation of the scoring results, the following pairwise discriminant matrices were produced (Table 6).

<table>
<thead>
<tr>
<th>Overall Clothing Style Design</th>
<th>Clothing Structural Details</th>
<th>Clothing Fabric Texture</th>
<th>Clothing Fabric Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Clothing Style Design</td>
<td>1.0000</td>
<td>4.1250</td>
<td>5.4167</td>
</tr>
<tr>
<td>Clothing Structural Details</td>
<td>0.2424</td>
<td>1.0000</td>
<td>2.2188</td>
</tr>
<tr>
<td>Clothing Fabric Texture</td>
<td>0.1846</td>
<td>0.4507</td>
<td>1.0000</td>
</tr>
<tr>
<td>Clothing Fabric Colour</td>
<td>0.2076</td>
<td>0.3261</td>
<td>2.8070</td>
</tr>
</tbody>
</table>

To begin, we calculate the maximum eigenvalue of the judgement matrix, denoted as \(\lambda_{\text{max}} = 4.2572\). In order to perform a consistency inspection on the judgement matrix, it is necessary to calculate the consistency index (CI):

\[
CI = \frac{\lambda_{\text{max}} - n}{n - 1} = \frac{4.2572 - 4}{4 - 1} = 0.0857
\]
The average random consistency index (RI) is 0.89. The random consistency ratio (CR) can then be calculated:

\[
CR = \frac{CI}{RI} = \frac{0.0857}{0.89} = 0.0963 < 0.10
\]

Thus, the analytic hierarchy process (AHP) results indicate satisfactory consistency, suggesting that the weight allocation is reasonable. The weight order is as follows: Overall Clothing Style Design > Clothing Structural Details > Clothing Fabric Colour > Clothing Fabric Texture (Table 7).

Table 7. The result of the weight order.

<table>
<thead>
<tr>
<th>Indicator Level</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Clothing Style Design</td>
<td>0.5763</td>
</tr>
<tr>
<td>Clothing Structural Details</td>
<td>0.2109</td>
</tr>
<tr>
<td>Clothing Fabric Texture</td>
<td>0.0788</td>
</tr>
<tr>
<td>Clothing Fabric Colour</td>
<td>0.1340</td>
</tr>
</tbody>
</table>

4.3. Fuzzy Comprehensive Evaluation Method

After determining the evaluation items, scales, and weights, a questionnaire survey was conducted to assess the level of approval for the restoration of the virtual clothing simulation of the mural characters. A five-level rating scale \( V = [V_1, V_2, V_3, V_4, V_5] = [\text{excellent, good, average, poor, very poor}] \) was used to evaluate each criterion (Table 8). Experienced individuals evaluated the criteria value system separately, and each survey participant assigned ratings to each criterion individually. The survey participants were undergraduate and graduate students with relevant knowledge in the fields of costume history research and archaeological clothing restoration. A total of 225 questionnaires were distributed, with 215 valid responses, resulting in an effective response rate of 95.5%. The degree of subordination of each criterion to a certain rating level was calculated by combining the scores given by each participant. The degree of subordination was determined by the proportion of individuals who agreed, with a particular rating level for the criterion. This process resulted in a single-factor fuzzy comprehensive judgement matrix. The calculation results are presented as follows:

Table 8. The score value of the evaluation result.

<table>
<thead>
<tr>
<th>Evaluation Levels</th>
<th>( V_1 ) (Excellent)</th>
<th>( V_2 ) (Good)</th>
<th>( V_3 ) (Average)</th>
<th>( V_4 ) (Poor)</th>
<th>( V_5 ) (Very Poor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Fuzzy relationship matrix corresponding to the criteria:

\[
R = \begin{bmatrix}
0.1442 & 0.7814 & 0.0698 & 0.0047 & 0.0000 \\
0.1302 & 0.8465 & 0.0140 & 0.0093 & 0.0000 \\
0.2977 & 0.5721 & 0.0186 & 0.0884 & 0.0233 \\
0.0977 & 0.8326 & 0.0512 & 0.0140 & 0.0047 \\
\end{bmatrix}
\]

Criterion B1 has a weight of \( W_{11} = [0.5763 \quad 0.2109 \quad 0.0788 \quad 0.1340] \). Criterion B1’s evaluation vector is calculated as \( B_1 = W_{11} \times R_{11} \).
\[ B_1 = \begin{bmatrix} 0.5763 & 0.2109 & 0.0788 & 0.134 \end{bmatrix} \circ \ \begin{bmatrix} 0.1442 & 0.7814 & 0.0698 & 0.0047 & 0.0000 \\ 0.1302 & 0.8465 & 0.0140 & 0.0093 & 0.0000 \\ 0.2977 & 0.5721 & 0.0186 & 0.0884 & 0.0233 \\ 0.0977 & 0.8326 & 0.0512 & 0.0140 & 0.0047 \end{bmatrix} = \begin{bmatrix} 0.1471 & 0.7855 & 0.0515 & 0.0135 & 0.0025 \end{bmatrix} \]

Overall evaluation score:

\[ F = VB^T = \begin{bmatrix} 5 & 4 & 3 & 2 & 1 \end{bmatrix} \begin{bmatrix} 0.1471 \\ 0.7855 \\ 0.0515 \\ 0.0135 \\ 0.0025 \end{bmatrix} = 4.0613 \]

The restoration result (between excellent and good) is considered ‘Good’ according to the maximum subordination principle, with an overall evaluation score of 4.0613.

5. Results and Discussion

This paper utilises the mature modern CLO3D clothing virtual fitting presentation software to apply traditional clothing in computer-interactive reverse engineering. The clothing of the Tang Dynasty tomb murals, which is mostly missing and is very important in modern research, has been digitally restored. Based on archaeological analysis, the condition, location, and proportion of the clothing are determined. A model of the clothing structure is made and presented using a clothing CAD tool for plate-making, and then the flat model is digitally reconstructed by means of conversion technology, with the addition of colours and textures. Based on this approach, a digital model of multi-ethnic clothing images is created for the Tang Dynasty cultural integration background. The model was developed by extracting the outline shape, style details, clothing colour, and texture of the figures in the murals. The feasibility of this method was verified through expert interviews and questionnaires. The creation of digital cultural clothing models can aid in the modern redesign and sustainable development of ancient clothing by presenting detailed structures and cultural symbols. This approach provided a more intuitive reflection of overall clothing-related information. It significantly shortened the clothing restoration period and offered valuable reference data for future restorations. Additionally, it reduced the risk of damage to cultural artifacts during restoration attempts. After modelling, the accuracy and feasibility of the restoration results are verified by the fuzzy hierarchical analysis model. The final comprehensive evaluation value is 4.0613, which is between excellent and good, so the restoration results are credible. The successful trial of this case study and application system helps to provide inspiration for the modern redesign and sustainable development and dissemination of ancient garments. Due to its easy transmission, replicability, and reproducibility, digitally modelled clothing has a wide range of applications in clothing, digital culture communication, film and television animation, museum exhibition halls, digital clothing redesign, and other commercial fields. In addition, at an educational level, it is difficult to allow the public to view the garments on display in all directions with the display cases removed, so the educational and dissemination objectives are difficult to achieve. However, with the popularity of digital clothing, this difficulty can be easily overcome: the public can observe every angle and detail of the garment, as well as the way it is worn, through the online halls of museums, cultural and educational displays, interactive human–computer experiences and other channels, and by touching the display or simulating the texture, etc. In this way, the purpose of cultural communication is effectively achieved. Furthermore, digital virtual clothing can be popularised in the classroom, where more detailed data and information are available for students to study, which is a potential educational application.

As is widely recognised, the modern clothing fashion industry utilises a range of technologies, including intelligent plate-making, intelligent fitting, virtual modification, and
other scientific and technological means. However, the restoration and protection of ancient cultural costumes are primarily carried out by experts in physics and chemistry, using textile archaeology-related technologies. The results of the restoration are typically communicated through visual aids such as photographs and text reports. This approach ensures objectivity and clarity in the presentation of the restored costumes. If fashion and archaeology are integrated, recovered clothing objects can be presented through virtual simulation using modern clothing market technology. This approach not only has the authority of clothing archaeology but also promotes sustainability in an accessible and comprehensive way. Undoubtedly, bringing people and objects closer to the public is the most effective and best way to interact with and understand them. This approach has also gained attention from the fashion and archaeology communities. It is expected that, in the future, research on the digital modelling and digital archaeology of clothing will deepen, and traditional cultural communication and innovative design methods will diversify. This research is of both theoretical value and practical significance.

6. Conclusions, Limitations, and Future Research

This study is based on the background of the intelligent era of Industry 4.0 and the current situation of the popularisation of digital technology and digital products, and it responds to the international trend of protecting and diversifying traditional culture. This paper discusses in depth the application ideas of digital technology in the restoration of traditional clothing. After examining the style, colour, detail, and other elements of clothing from the perspective of archaeology, it applies clothing CAD tools and CLO3D modelling tools to perform 3D virtual simulation restoration, result inspection, and verification of the costumes of characters in the etiquette scene of the Tang Dynasty’s ‘Diplomatic Envoys’ fresco. The construction of a 3D presentation and application system of traditional cultural clothing symbols is established. Successful experiments with this method can provide ideas for the protection and dissemination of other textile heritage and have distinct theoretical and practical significance. The theoretical significance of this study lies in protection and exploration, and the practical significance lies in inheritance and derivation.

For the protection of traditional costumes, it is essential to identify, verify, and differentiate the dress and identity of the figures in the mural. Correct archaeological information is the basis of cultural dissemination, which has profound theoretical research significance. In addition, in terms of heritage, it is worth noting that, in the trial process of technological application, it was found that the digitally restored physical garments have a high degree of matching with the original images. Furthermore, it is easy to copy, adjust, and modify the data in the digitally stored files. This allows the results to be presented quickly and more garment details to be observed. Traditional digital garment data are highly reproducible, editable, and visible. The storage and archiving of the data resources reduces the time cost of secondary design and application communication. For example, the data resources can be used in online museum displays, educational interactions, game animation, garment-making, and other communication channels, providing a valuable reference for cultural heritage that is of enormous practical significance.

This research has formed a new model of digital clothing archaeology that integrates archaeology and technology, establishes a research system of textual research, modelling and evaluation, and has the innovative consciousness of cross-border integration. However, this research still has some backwardness and limitations, and it is necessary to deepen the exploration in the future, by mainly focusing on two aspects. First, the paper also mentions that image presentation includes 2D, 2.5D, 3D, and VR and that user experience satisfaction is gradually changing from 3D visualisation to immersive VR. This paper has certain limitations in technical application and lacks the involvement of digital images, human–computer interactions, and user experience. Therefore, in future research on cultural heritage in the digital context, it is necessary not only to explore the application of 3D technology but also to expand the direction of experiential digital technology. Second, against the background of the rapid development of artificial intelligence generation
technology in the past two years, a major breakthrough has been achieved in image generation. Its software development logic is based on a huge prototype information database. By writing codes and the positioning of labels, automatic image generation technology is possible. It is worth considering the possibility of rapidly analyzing deteriorated images such as wall paintings and automatically identifying and generating restored images by collecting and programming large amounts of original archaeological data, since archaeological restoration is also a way of presenting the new appearance of cultural relics. If successful, this would be a major breakthrough in technical research and development.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/jtaer19020069/s1, Index matrix tables.

Author Contributions: Conceptualization, C.L. and R.C.; methodology, C.L. and R.C. software, C.L.; validation, C.L.; formal analysis, C.L.; investigation, Z.W.; resources, C.L.; data curation, C.L.; writing—original draft preparation, C.L.; writing—review and editing, R.C.; visualization, Z.W.; supervision, Z.W.; project administration, Z.W. All authors have read and agreed to the published version of the manuscript.

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