

Abstract

This study focuses on the costume culture depicted in Tang Dynasty Dunhuang murals, exploring its digital translation and integration into contemporary fashion design. It aims to address the research question of how ancient mural art can merge with digital fashion design. A combination of iconographic analysis, practice-based research, and 3D digital reconstruction was employed to systematically examine and reinterpret the form, color, and structure of Dunhuang mural costumes. The findings reveal that these costumes feature flowing lines, balanced silhouettes, and vivid color palettes, reflecting the Tang Dynasty's aesthetic ideals of grandeur, vitality, and harmony with nature. Through digital reconstruction and creative experimentation, the study successfully transforms traditional Dunhuang costume elements into digital fashion works that embody both cultural depth and modern aesthetics. The innovation of this study lies in introducing a digital fashion design perspective to systematically analyze the aesthetic structure of Dunhuang mural costumes, establishing a translation pathway from traditional imagery to digital fashion, and demonstrating that the fusion of traditional aesthetics and digital technologies not only broadens the expressive language of contemporary fashion design but also contributes to the preservation, inheritance, and global dissemination of cultural heritage.

Keywords: Dunhuang mural painting, Tang dynasty, costume, digital costume design

Introduction

The Mogao Caves in Dunhuang stand as a rich artistic and cultural heritage site, reflecting the exchange of civilizations along the ancient Silk Road (Zhao, 2015). The costumes depicted in Dunhuang murals hold high aesthetic and artistic value in terms of structure, color, and composition (Chang, 2001). With advancements in technology, especially in the era of the metaverse, 3D digital tools are increasingly applied in design and creative fields. The integration of traditional costume elements with digital technology enhances design efficiency and consumer engagement, while also enriching the narrative of contemporary fashion through the fusion of science and aesthetics.

Previous studies have primarily explored traditional and ethnic patterns in fashion design (Gu, 2021). However, few have addressed the interdisciplinary application of 3D digitization in Dunhuang costume design. This study adopts image analysis as a theoretical foundation and explores the formal aesthetics of Tang Dynasty mural costumes—focusing on form, composition, and color. It digitally reconstructs and innovatively applies these elements, using interactive digital technologies to create an immersive 3D animation display. The aim is to provide a new model for the preservation, innovation, and dissemination of traditional Chinese costume culture.

An overview of the mural costumes of the Tang dynasty at Dunhuang

Dunhuang, home to the world's largest and most artistically valuable collection of ancient murals, is a cultural and artistic treasure and a key component of cave art (Ma, 1996). While primarily Buddhist in content, its murals vividly depict a wide range of figures in elaborate and colorful attire, especially the elegant and richly detailed women's costumes from the Tang Dynasty. These serve as important visual references for studying Tang women's fashion. Tang costume culture, known for its vibrant colors, diverse styles, and refined aesthetics (Shen, 1997) embodies a blend of freedom and elegance, emphasizing line, form, and subtle beauty. The aesthetic charm of Dunhuang dress reflects the harmony of Eastern art and holds lasting relevance in contemporary Chinese aesthetics.

The aesthetic characteristics of Dunhuang Tang dynasty mural paintings

Dunhuang mural paintings have made outstanding achievements in the history of culture and art in the world with their exquisite painting skills, lifelike figures and delicate composition (Samara, 2008). Aesthetics researchers at home and abroad have highly praised Dunhuang art, and so has the beauty of the costumes in the Tang murals at Dunhuang. The enlightened political culture of the Tang Dynasty promoted the exchange and fusion of Chinese civilisation and foreign cultures, and shaped the unique clothing style of the Tang Dynasty. This unique fashion has profoundly influenced the style of dress, life philosophy and aesthetic orientation of the Tang people. Dunhuang Tang dynasty mural dress aesthetic characteristics are mainly manifested in the dress modeling linear beauty, colour harmony and the beauty of the form of dress and other aspects.

The linear beauty of dress in Dunhuang Tang dynasty mural paintings

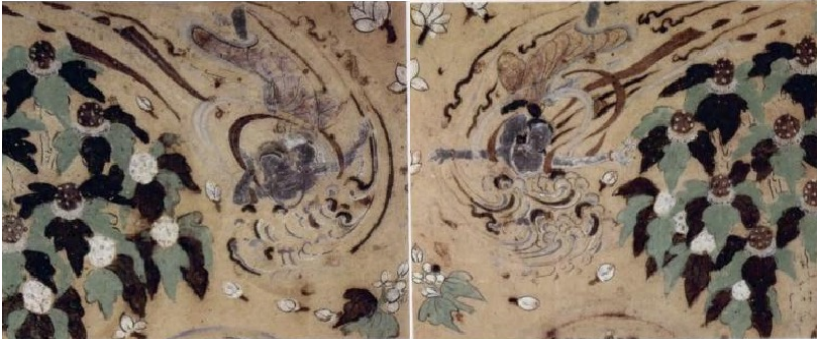
Professor Wu (2018) noted that traditional Chinese painting emphasizes subtle beauty, often portraying the human figure metaphorically through flowing garments and graceful gestures rather than direct representation. In Dunhuang's Tang Dynasty murals, lines not only depict clothing but also convey movement and rhythm, reflecting the Eastern aesthetic of "line-based modeling."

For instance, in Cave 401, the Bodhisattva is depicted with a high-waisted skirt and flowing shawl, adorned with vibrant ornaments. The vertical lines elongate the figure, while the fluttering ribbons and jewelry create a sense of graceful motion. This visual stretching reflects the Tang ideal of a slender, upright form.

Flying Apsaras are another embodiment of linear beauty. In Cave 57, they appear with bare upper bodies and long skirts, trailing vivid red ribbons. Their elegant poses and dynamic silhouettes, combined with swirling auspicious clouds, form vivid compositions. Using the "outline and color" painting technique, the murals express fluidity and rhythm, symbolizing vitality, joy, and the aesthetic power of Dunhuang's flying figures as figure 1.

Figure 1

Mural detail: flying apsara in cave 57, Dunhuang



Note. Adapted from “Tianjin: Tianjin,” by W Duan, (Ed.) *The Complete Collection of Dunhuang Frescoes in China* (p. 16), 1996, People’s Fine Arts Publishing House. Copyright 1996 by Tianjin People’s Fine Arts Publishing House. Adapted with permission.

The colourful beauty of Dunhuang Tang dynasty mural dresses

The use of color in Dunhuang Tang Dynasty mural costumes is a vital expression of Tang costume aesthetics. Among various dynasties depicted in the grottoes, Tang murals stand out for their rich, vivid palettes (Pan, 1957). Dominated by red, green, and cyan, the costumes adopt flat coloring techniques, combining vibrant hues with elegant lines to create a harmonious and majestic visual effect.

What makes Tang color application unique is the sophisticated use of contrast. In Cave 321 as figure 2, for example, the bodhisattva’s robe and mantle use large color blocks in single tones, while surrounding Guanyin figures are dressed in layered combinations of blue, green, vermilion, and white. The contrast between small and large color fields brings visual tension yet maintains unity (Arnheim, 1998). This balance between harmony and clash reflects both the aesthetic ideals and visual richness of Tang-era fashion, highlighting the dynasty’s mastery of color artistry.

Figure 2

Mural detail: The expression in cave 321, Dunhuang



Note. Adapted from “Tianjin: Tianjin,” by W. Duan, (Ed.) *The Complete Collection of Dunhuang Frescoes in China* (p. 95), 1996, People’s Fine Arts Publishing House. Copyright 1996 by Tianjin People’s Fine Arts Publishing House. Adapted with permission.

Formal beauty of Tang dynasty costumes in Dunhuang mural paintings

Dunhuang murals from the Tang Dynasty reveal refined formal beauty in costume design. In Cave 331, four tribal chiefs are seated symmetrically, their garments forming a balanced visual harmony through staggered positioning and mirrored colors, reflecting the Chinese aesthetic ideal of dynamic equilibrium. Repetition is seen in Cave 130, where Madame Dudu and her daughters wear cross-collared robes with recurring floral patterns (Liu, 2022), echoed by attendants in similar motifs, enhancing the visual rhythm and layering. Cave 375’s female donors as figure 3, arranged in staggered heights, mimic musical notes, embodying rhythmic beauty through compositional variation. Lastly, in Cave 220, a Bodhisattva’s attire showcases layered elegance using ikat-dyed textiles, translucent capes, and flowing silk belts. The use of overlapping elements and contrasting background colors enhances depth and hierarchy, reflecting both material sophistication and visual harmony in Tang costume design.

Figure 3

Mural detail: female donner in cave 375, Dunhuang



Note. Adapted from “Tianjin: Tianjin,” by W. Duan, (Ed.) *The Complete Collection of Dunhuang Frescoes in China* (p. 1), 1996, People’s Fine Arts Publishing House. Copyright 1996 by Tianjin People’s Fine Arts Publishing House. Adapted with permission.

Objectives of the study

1. To analyze the aesthetic characteristics of Dunhuang mural paintings and explore their artistic value through iconographic and visual research methods.
2. To establish a theoretical and practical foundation for the 3D digital reconstruction and innovative application of traditional costume aesthetics.
3. To investigate the interdisciplinary innovation potential of integrating aesthetics, cultural heritage, and digital design tools, and to advance practice-based research in fashion design.

Materials and methods

Digital Innovation in Modern Fashion: 3D Applications of Dunhuang Mural Costume Elements

With the rise of the “China-Chic” trend, modern designs increasingly incorporate traditional Chinese elements (Liu, 2021). By combining traditional Tang Dynasty costumes with modern technology, the culture of Dunhuang

traditional attire is reinterpreted and presented through digital means. This approach enables the inheritance and innovation of Dunhuang costume culture in the context of the big data, internet, and smart era.

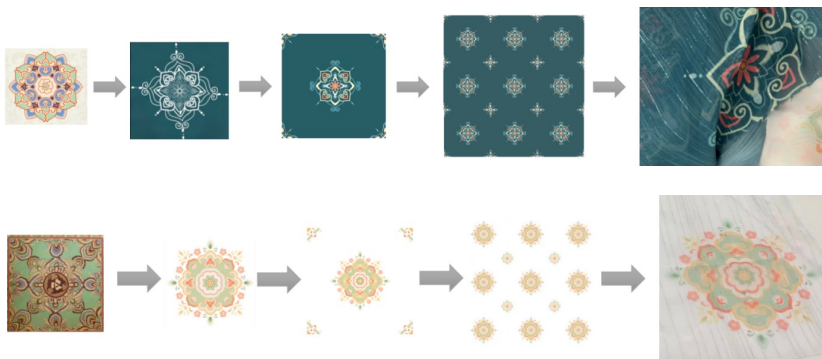
Pattern design

Through extensive preliminary research and digital collection of Dunhuang Tang Dynasty mural costumes, the composition styles, filling elements, and common colors of four-directional continuous patterns were summarized. Traditional Tang patterns were vectorized using digital graphic design software, enabling their redesign and recreation.

As a representative Buddhist motif, the “Baoliang Flower” frequently appears in Dunhuang mural costumes and caisson ceilings (Chang, 2004). This study extracted the Baoliang Flower from the center of a caisson pattern and selected a single petal as the basic design unit for iterative and innovative pattern creation. The petal was symmetrically or evenly arranged based on its shape to form radiating and converging compositions, culminating in a continuous four-directional pattern. Multiple patterns were combined into a cohesive design and printed as test samples as figure 4.

Figure 4

Redesign and re-creation of traditional Tang dynasty patterns



Digital 3D costume design

In the silhouette design, the linear aesthetics of Dunhuang Tang Dynasty mural costumes are reinterpreted with streamlined forms and high-waisted structures as core style elements. Digital tools and CAD software are used for pattern development, combining soft, simplified lines with a sense of structure and flow. Baoxiang flower motifs are integrated into garment details, while interlacing and stacking techniques add depth. Contrasts between shoulders, sleeves, and the lower body enhance visual impact.

Classic Dunhuang colors—pale green, ochre, and turquoise—are applied with balanced tone variations and block proportions. Custom four-directional Baoxiang patterns enrich the design, echoing the layered and rhythmic beauty of the murals. Final designs are 3D-simulated for stitching and fitting, with adjustments to materials and styling before physical production as figure 5.

Figure 5

Digital fashion design



Digital character and 3D scene modeling design

The default models in digital clothing software often have overly homogenized facial features, making them unsuitable for showcasing this collection. Therefore, 3D virtual simulation and virtual reality technologies were employed to design the facial features of digital character models, choreograph digital model dance movements, and create digital scene designs.

Figure 6

Line drawings of female portrait in Tang dynasty



In the digital facial design process, the author referenced Dunhuang Tang Dynasty murals, literature, and film to create costume renderings and facial illustrations as figure 6, blending traditional character modeling with modern aesthetics. This resulted in a creative yet practical design grounded in artistic exploration.

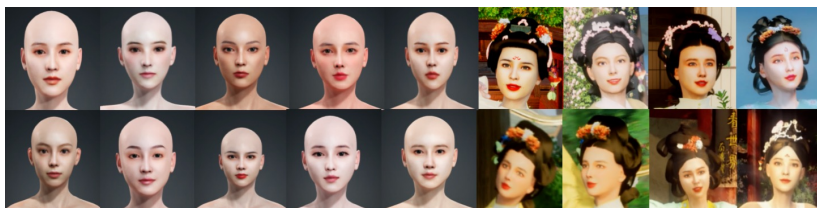
Starting from hand-drawn research sketches, 3D modeling software was used to build facial structures, including skull, contours, and features with accurate proportions. Detailed sculpting enhanced realism through refined skin texture and pores. Lighting and rendering tests followed, adjusting materials for optimal effects across various environments as figure 7.

Further innovations were applied to makeup, hairstyles, and headpieces, integrating Tang aesthetic elements with modern design. The result strikes a balance between historical elegance and contemporary appeal, preserving the essence of Tang beauty without rigid traditionalism .

Using 3D virtual modeling technology, Tang Dynasty architecture and life scenes were recreated in a 360-degree immersive format. The process began with collecting reference materials—images, videos, and texts—to ensure historical accuracy. Preliminary sketches defined the layout, color palette, and visual style. Software such as Blender, Maya, or 3ds Max was then used to construct the scene with precise proportions and Tang-inspired elements. Finally,

Figure 7

Facial and makeup design for virtual digital Human models

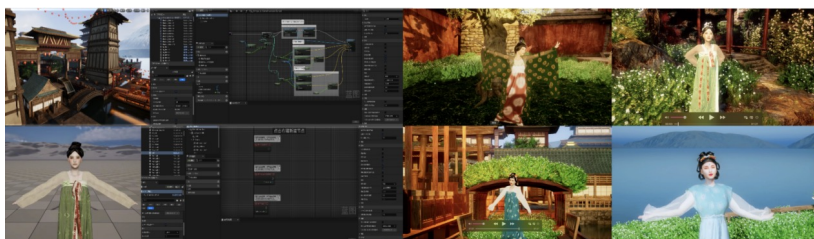


digital tools simulated character dance movements and integrated costume designs, resulting in a dynamic 3D presentation of Tang Dynasty life and fashion as figure 8.

From designing traditional Tang Dynasty costume patterns to creating character portraits, choreographing dance movements, constructing virtual scenes, and performing digital post-production synthesis, the process employed digital design language to innovate and preserve cultural heritage. This research pathway demonstrates the innovative application of digital costume design, offering a digitalized solution for applying Dunhuang Tang Dynasty mural costume elements to modern fashion design.

Figure 8

Digital 3D virtual scene modeling and dynamic display of 3D costumes



Data Analysis

This study adopts a qualitative research methodology that combines image analysis with practice-based design to systematically explore the aesthetic features of Dunhuang mural costumes and their application in digital fashion. The data analysis is composed of two interrelated components: visual data interpretation and digital design experimentation.

Visual analysis of Dunhuang mural costumes

The study collected over one hundred high-resolution mural images from the Mogao Caves, primarily from the Tang Dynasty period. Using image analysis techniques, the visual data was categorized and examined through three major aesthetic dimensions: line composition, structural form, and color language.

1. Line Composition: The costume outlines in the murals often adopt flowing curves, expressing grace and dynamism, frequently seen in representations of flying deities or celestial maidens.

2. Structural Form: High waistlines, wide sleeves, and ribbon-like extensions are common elements, reflecting symbolic associations with Buddhist cosmology and idealized bodily proportions.

3. Color Language: The dominant hues include vermilion red, malachite green, ochre, yellow, and peacock blue—mineral pigments that reflect both technical dyeing practices and religious symbolism of the period.

Practice-based 3D digital design process

The extracted aesthetic elements were translated into digital design using platforms such as CLO3D and Blender. A series of 3D garment reconstruction experiments were carried out, including the following phases:

1. Base Garment Modeling: Building 3D garment structures based on historical Tang Dynasty silhouettes.

2. Pattern Reinvention and Translation: Reinterpreting traditional mural motifs into innovative and contemporary pattern designs.

3. Digital Avatar Styling and Scene Construction: Creating digital human models and virtual environments, allowing traditional aesthetics to be revived and visualized through modern digital media.

The resulting digital garments met key criteria in terms of historical aesthetic fidelity, adaptability in contemporary fashion contexts, and technical feasibility for both digital display and potential real-world applications.

Interdisciplinary insights

The synthesis of data indicates a high potential for interdisciplinary innovation by integrating visual cultural analysis with 3D digital design tools. This cross-domain method not only contributes to the digital revitalization of traditional culture, but also opens new pathways for virtual fashion design, metaverse-based clothing, and narrative-driven cultural heritage expression.

The results affirm that Dunhuang mural costumes are more than static cultural relics—they serve as a vital source of inspiration for driving innovation in digital fashion.

Conclusion and Discussion

This study explores the costumes depicted in the Tang Dynasty Dunhuang murals of the Mogao Grottoes, focusing on their form, color, and structural features, and reinterprets them through digital fashion design. By integrating iconographic analysis, interdisciplinary design methods, and 3D digital reconstruction, this research contributes to the emerging discourse on digital heritage and fashion innovation. Specifically, it offers a new theoretical and methodological framework that translates traditional visual culture into digital fashion expression, thereby bridging the gap between historical art and contemporary design technology.

The study's primary contribution lies in establishing a systematic pathway for transforming Tang costume aesthetics into digital fashion practice. It demonstrates how the Tang ideals of rhythm, balance, and harmony between humanity and nature can be effectively re-contextualized within digital environments to produce design outcomes that merge cultural depth with technological creativity. In doing so, the research not only enriches the expressive vocabulary of digital

fashion but also provides a replicable model for the digital preservation and revitalization of cultural heritage.

From a practical perspective, this study provides valuable insights for the fashion industry, tourism sector, and digital heritage design. In fashion, the reinterpretation of Dunhuang costume motifs can inspire collections or digital fashion lines that evoke Eastern aesthetics for global markets. In tourism and cultural promotion, immersive digital reconstructions of Tang attire—integrated into museum exhibitions or virtual experiences—can enhance cultural storytelling and audience engagement. In the digital heritage field, this model supports the documentation, visualization, and reanimation of intangible cultural assets through creative technologies.

However, several limitations and critical challenges must be acknowledged. First, cultural interpretation risks vary across contexts; the aesthetic meanings of Dunhuang imagery may shift when translated into digital or globalized fashion forms, potentially leading to cultural simplification or misrepresentation. Second, while 3D digital reconstruction enables visual accuracy, it still faces technical constraints in fabric simulation, texture authenticity, and the translation of spiritual symbolism into digital form. Third, the integration of cultural authenticity with commercial viability remains an ongoing tension within the digital fashion industry, requiring further critical dialogue between designers, historians, and technologists.

Despite these challenges, the study's innovative approach provides a foundation for future research that connects traditional art and emerging technology. By demonstrating how ancient Tang costume aesthetics can evolve through digital re-creation, this research highlights the potential of cultural heritage as a living, adaptive resource for global creative industries. It invites continued exploration into how digital fashion can serve not only as a tool of artistic innovation but also as an active medium for cross-cultural communication, education, and sustainable cultural transmission in the 21st century.

Recommendations

1. Strengthen interdisciplinary collaboration

Future research and design practices should promote deeper collaboration among disciplines such as art history, fashion design, computer graphics, and cultural heritage preservation. Cross-disciplinary synergy can enrich design methodologies and broaden the influence and dissemination of traditional cultural revitalization.

2. Expand applications in virtual fashion and cultural tourism

It is recommended to apply digitally reconstructed Dunhuang-style garments to platforms such as virtual museums, AR/VR exhibitions, digital fashion shows, and metaverse environments. These applications can create immersive cultural experiences and stimulate new commercial and educational potential.

3. Advocate for sustainable digital practices in cultural design

In response to global sustainability goals, it is advised to enhance the use of virtual simulation technologies in the digital reinterpretation of traditional costumes. This approach helps reduce material waste and physical sampling, improves resource efficiency, and maintains respect for the cultural essence of the designs.

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