3D Digital Clothing Design of Chu-style Lacquerware Patterns Based on Style3D Technology

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ABSTRACT

This study investigates the application of Chu-style lacquerware patterns in modern clothing design using Style3D technology, aiming to explore innovative ways of integrating traditional cultural elements into contemporary fashion. By extracting and analysing the elements of animal, plant, and natural scenery motifs from Chu-style lacquerware, and utilising 3D digital technology for redesign and modelling, unique designs that blend traditional characteristics with modern fashion have been achieved. The results indicate that Style3D technology effectively enhances the visual presentation and production efficiency during the design process, offering new possibilities for the digital inheritance of traditional culture and personalised clothing customisation.

INTRODUCTION

In recent years, as attention to cultural heritage and innovation has increased, the application of traditional patterns in modern clothing design has become an important topic of interest in both academic and industrial fields. Internationally, digital design technologies in the clothing sector have gradually matured, with many studies and design practices using 3D technology to achieve rapid responses from design to production, thereby enhancing the level of personalised clothing customisation and design efficiency [1,2]. For example, in Europe and Japan, fashion designers integrate traditional cultural elements with modern digital technology through virtual simulation and 3D modelling, achieving a modern transformation of traditional patterns [3]. The application of Style3D technology in modern fashion design is becoming increasingly widespread. Through digital modelling, virtual rendering, and intelligent material processing, it enhances workflow efficiency and strengthens supply chain coordination. Recent studies have shown that digital twin creation tools such as Style3D and CLO3D play a pivotal role in virtual prototyping and the broader digital transformation of the

apparel industry [4]. However, current international research on Chinese traditional lacquerware patterns in digital clothing design is relatively limited, especially lacking in-depth exploration and systematic application of Chu culture lacquerware patterns. In this study, the term "Chu-style lacquerware" refers to lacquered artefacts originating from the Chu culture during the Warring States period, characterised by ornate motifs including mythical creatures, abstract flora, and celestial symbols.

In China, in recent years, some scholars and designers have attempted to redesign and apply traditional patterns through digital means. However, most of the research has focused on two-dimensional design or basic 3D display, lacking in-depth application of three-dimensional digital modelling and systematic exploration of cultural connotations [5]. Scholars such as Chen Zhenyu have conducted in-depth research on Chu-style lacquerware patterns, summarising the characteristics and cultural value of motifs such as animals, plants, and natural scenery. However, the complex forms and intricate artistic expressions of traditional lacquerware patterns pose numerous technical challenges during the digital conversion process, such as detail representation and the overall coordination of motifs. Therefore, how to effectively use 3D digital technology to achieve the recreation of Chu-style lacquerware patterns in clothing design has become a significant gap in current research.

This study, based on Style3D technology, focuses on the application of Chu-style lacquerware patterns in modern clothing design, aiming to explore the digital heritage and innovation pathways of traditional cultural elements. Firstly, we extract and analyse different themes of Chu-style lacquerware patterns, including animals, plants, and natural scenery, summarising their shape characteristics and cultural connotations [6,7]. Subsequently, through the Style3D platform, the motifs undergo three-dimensional digital redesign and clothing modelling, emphasising the combination of aesthetic expression and practicality of the patterns in modern clothing. The expected outcome is to develop a Chu-style lacquerware pattern clothing design scheme that integrates traditional culture with modern fashion, enhancing the application value of traditional elements in modern clothing, and providing theoretical and practical support for the digital transformation and personalised customisation of the fashion industry [8].

The significance of this study lies in the application of Style3D technology, which not only improves design efficiency and the visual effect of clothing but also effectively promotes the heritage and innovation of traditional culture in modern society, contributing to the deep integration of traditional patterns with modern clothing design [9].

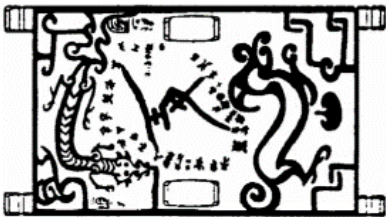## ANALYSIS OF ELEMENTS OF CHU-STYLE LACQUERWARE PATTERNS

Analysis of Animal Patterns

Animal patterns in Chu-style lacquerware are known for their richness in species and diversity of expression techniques, commonly including motifs of dragons, phoenixes, snakes, mythical beasts, and the golden crow. These motifs combine realism with exaggerated deformation, forming an artistic style that is distinctive in both ethnic and era characteristics [6]. According to CHENG Dan's research in "Aesthetic Connotation of Chu Lacquer Art," animal motifs in Chu-style lacquerware often use symmetrical composition to convey a solemn and mysterious atmosphere, which is particularly prominent in lacquerware from Chu culture [6].

The composition characteristics of animal patterns are primarily symmetrical, emphasising visual balance and harmony. For example, the "Twenty-Eight Constellation Clothing Chest" from the Tomb of Marquis Yi of Zeng is decorated with the names of the twenty-eight constellations arranged in a "斗" shape, and the green dragon and white tiger patterns on the lid are drawn based on a left-right symmetrical composition (Table 1a). This layout not only reflects Chu culture's understanding of cosmic order but also imbues the decorative pattern with a solemn aesthetic.

Another example is the dragon and phoenix lacquered lid, where the dragon and phoenix motifs carved on the top also adopt a symmetrical layout (Table 1b). This design makes the overall composition more orderly, giving a sense of stability and grandeur. Additionally, the layout of animal patterns on the main coffin is also notable for its symmetrical sequence (Table 1c), with dragon and phoenix patterns painted on both the lid and side panels, forming eighteen symmetrical groups symbolising life cycle and harmony between heaven and earth. The symmetrical layout of Chu-style lacquerware not only visually presents the characteristics of order and precision but also implies reverence for nature and the cosmic order, reflecting the unique aesthetic and spiritual pursuit of Chu culture [10].

Table 1. Chu-style Lacquerware Animal Patterns

Number	Illustration	Composition Characteristics
(a)		"Twenty-Eight Constellation Clothing Chest" with the names of the twenty-eight constellations arranged in a revolving "斗" shape, and the symmetrical Azure Dragon and White Tiger patterns on both sides

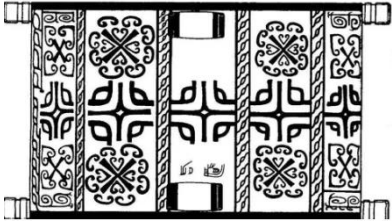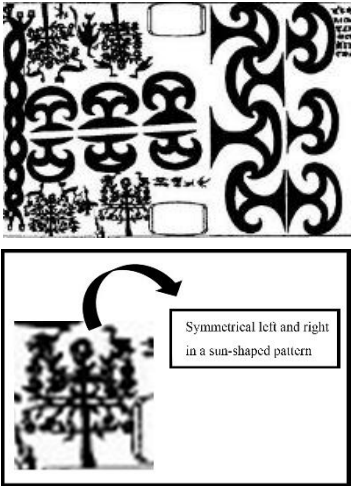| Number	Illustration	Composition Characteristics
(b)		Symmetrical dragon and phoenix patterns on the top of the lacquered bean with dragon and phoenix motif
(c)		Symmetrical designs of phoenix and dragon motifs on the lid of the main coffin of the Tomb of Marquis Yi of Zeng, featuring symmetry in both composition and layout

Overall, the animal patterns in Chu-style lacquerware combine realism with exaggerated deformation in their forms, paired with symmetrical composition, which expresses rich symbolic meaning and aesthetic logic. These animal motifs hold high potential for recreation in modern clothing design, adding a unique visual effect to the designs while also conveying a profound historical and cultural heritage, injecting new inspiration and vitality into modern fashion design.

The symmetrical designs of these animal motifs provide a good reference for applying patterns in modern clothing design. By combining traditional symmetrical composition with modern design elements, designers can create clothing works that blend traditional charm with a modern style. This fusion aids in the transmission and development of traditional culture in a modern context.

Analysis of Plant Patterns

Plant motifs in Chu-style lacquerware represent a relatively small proportion of the motifs found in lacquerware excavated from Chu culture. The plant motifs mainly include the Fusang tree and some floral patterns, which are presented in an abstract, story-like form [6]. The plant patterns in Chu-style lacquerware are rich in content and often use balanced composition techniques to create a sense of freedom, diversity, and dynamism.

Table 2. Chu-style Lacquerware Plant Patterns

Number	Illustration	Composition Characteristics
(a)		In the "Hou Yi Shoots the Sun Clothing Chest" from the lacquerware, the deformed floral motifs of different sises are paired symmetrically under a balanced composition.
(b)		The branches of the Fusang tree and the phoenix bird motifs are symmetrically arranged based on the sun-shaped pattern.

Compared to animal motifs, which emphasise symmetrical composition, plant motifs in Chu-style lacquerware are more inclined to use balanced composition. The balanced composition is reflected in the combination of elements such as size, quantity, contrast, and harmony, creating psychological and visual balance. This approach breaks the constraints of symmetry, presenting an asymmetric, irregular, and free balance aesthetic. For example, in the floral patterns on the lid of the "Hou Yi Shoots the Sun Clothing Chest" unearthed from the Tomb of Marquis Yi of Zeng, the design cleverly uses balanced composition. The lid features complete deformed floral shapes of different sises, paired symmetrically, which not only showcases the aesthetic characteristics and unique charm of plant patterns but also reflects the cultural ideology of that era (Table 2a). Further examining the Fusang tree motif on the "Hou Yi Shoots the Sun Clothing Chest," each set of tree motifs includes a sun-shaped pattern, presenting symmetrical characteristics. However, there are differences between the tree motifs in terms of size and direction, showing that plant patterns in Chu-style lacquerware are influenced by symmetrical composition but tend to present a more balanced style (Table 2b).

The composition of plant patterns in Chu-style lacquerware is mainly influenced by symmetrical arrangements, presenting a unique form of incomplete balance, integrating an abstract and metamorphosed form of expression, which conveys rich symbolic meaning and aesthetic logic. These plant motifs can provide abundant inspiration for application in modern clothing design, not only

adding fresh visual appeal to the design itself but also representing the long-standing cultural heritage of Chu culture through the motifs.
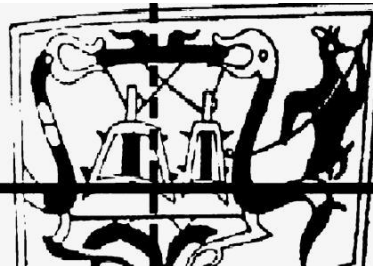
These plant motifs, with their balanced composition, can provide distinctive printed styles for modern clothing pattern design. By combining balanced composition with abstract metamorphosed plant patterns, designers can create clothing pieces with a strong artistic appeal of Chu culture, contributing to the transmission and innovation of traditional culture.
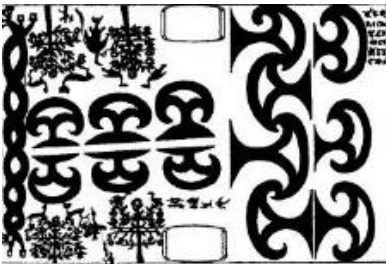
Analysis of Natural Scenery Patterns

Natural scenery motifs in Chu-style lacquerware are decorations that are inspired by elements of nature, including themes such as sun, moon, stars, mountains, water, clouds, and thunder [5]. Natural scenery patterns in Chu-style lacquerware are influenced by their characteristic forms, often appearing as continuous motifs. During the decorative process, they are expressed through two-dimensional continuous patterns, featuring unique designs and a strong sense of ornamentation.

Natural scenery patterns are considered auxiliary motifs, and their composition is still influenced by the animal and plant patterns of Chu-style lacquerware, showing a balanced composition under symmetrical influence. For example, in the "Bell Striking with Chimes" motif on the mandarin duck box, the strange birds and chime bells serve as special auxiliary motifs (Table 3a). The overall composition is balanced; however, while the two strange birds and two chime bells are symmetrically composed, the shape, size, and colour areas of these patterns vary. Notably, the position of the chime bell is located at a corner, actually using a method of golden ratio division. Its characteristic is that even if a rectangle is removed, the remaining rectangle still maintains the same golden ratio of length to width. This composition design achieves a balance between the primary motifs of the golden ratio and the auxiliary natural scenery patterns.

Table 3. Chu-style Lacquerware Natural Scenery Patterns

Number	Illustration	Composition Characteristics
(a)		Overall balanced composition, but the two strange birds and two chime bells are arranged with a balanced shape according to the golden ratio division.

Number	Illustration	Composition Characteristics
(b)		The mushroom-shaped cloud motifs on both sides differ in size and direction, but still maintain a balanced form under the influence of symmetry.

Another example is the mushroom cloud patterns in the "Hou Yi Shoots the Sun Clothing Chest" (Table 3b). The mushroom-shaped cloud patterns on the left and right sides differ significantly in size, highlighting the dynamic and flexible nature of balanced composition. However, upon closer examination, the pattern maintains a symmetrical form, allowing the design to move away from a completely rigid layout towards a more sophisticated one that better fits people's visual habits and psychological needs.

Natural scenery patterns, as auxiliary motifs in Chu-style lacquerware, occupy a certain proportion, but compared to animal and plant patterns, they appear as secondary motifs, serving as auxiliary decorations in the overall pattern layout. There are many types of natural scenery motifs in Chu-style lacquerware, with varied occurrence patterns, and their unique balanced composition and band-like combination make them suitable for use as auxiliary motifs in parts of clothing design, such as cuffs, collars, hems, and pockets. Additionally, these motifs themselves exhibit the abstract thinking and artistic creativity of Chu culture, significantly enhancing the cultural attributes and artistic expressiveness of clothing design works.

APPLICATION OF CHU-STYLE LACQUERWARE PATTERNS IN FASHION DESIGN

Realistic Depiction of Animal Motifs

The animal motifs in Chu-style lacquerware are renowned for their rich variety and diverse forms of expression, with common motifs including dragons, phoenixes, tigers, snakes, and other mythical creatures. These motifs combine realistic representation with exaggerated deformation, resulting in a unique artistic style that features both ethnic and period-specific characteristics.

Realistic depiction plays a key role in animal motifs, as designers meticulously replicate these traditional patterns and incorporate them into modern fashion design. Unlike Western designers, who often employ direct application, Chinese designers infuse deeper spiritual meaning from Eastern culture into realistic representations. In Guo Pei's 2019 Spring "Legend of the East Palace" collection, the dragon motif is vividly presented, along with various forms and colours, showcasing the profound

philosophy of Yin-Yang and the Five Elements in Chinese culture (Figure 1). The dragon motif in this collection evolves from primal to sublime, inheriting the unrestrained posture of the Han Dynasty dragon, while being endowed with richer emotions and dynamic expressions. The colours of the dragon motif—black, green, gold, silver, and red—appear in different parts of the clothing, symbolising the deep and mysterious Yin-Yang and Five Elements philosophy.

Figure 1. Guo Pei's "Legend of the East Palace"

In these designs, the realistic portrayal is not limited to the recreation of traditional patterns' forms and details but also extends cultural symbols to provide a deeper cultural expression for clothing. The realistic depiction of animal motifs conveys respect for traditional culture and, through precise reproduction and meaningful combinations, creates visually compelling and story-rich effects. These animal motifs not only add unique visual elements to fashion design but also integrate history, culture, and modern design language, endowing contemporary fashion with cultural depth and artistic significance.

The representation of mythical beasts such as dragons, phoenixes, and vermilion birds is not just a transfer of decorative elements but also a profound interpretation of Chu culture's understanding of nature and the cosmic order. These motifs, with their symmetrical arrangements and dynamic exaggerations, reflect Chu culture's pursuit of order and harmony. The realistic depiction in these motifs emphasises intricate detail and cultural connotation, allowing the designs to carry both decorative appeal and profound spiritual and cultural heritage.

The realistic portrayal of animal motifs enhances the decorative and artistic expressiveness of modern fashion design while delving deeply into traditional cultural elements, imbuing contemporary designs with a richer cultural essence and distinctive spiritual resonance.

Narrative Design of Plant Motifs

The plant motifs in Chu-style lacquerware can also integrate decoration and cultural connotation through narrative design techniques, making them not just visual elements but also carriers of profound emotions and cultural stories. Narrative design is not simply a replication of traditional figurative patterns, but an abstract treatment, symbolic expression, and narrative construction of plant motifs, which imbues these motifs with new life and richer cultural connotations.

In Xia Zichen's 2019 Spring/Summer collection (Figure 2), the designer borrowed elements from plant motifs such as Western lotus, dragon, and phoenix, transforming and reconstructing them to retain their unique characteristics while incorporating modern artistic expression. Smooth and gentle lines were used to reshape plant elements, resulting in rhythmic artistic effects that evoke the profound aesthetic appeal of Eastern culture. These motifs not only enhance the visual beauty of the garments but also allow viewers to perceive the cultural narratives and historical significance embedded within.

Figure 2. Xia Zichen's "Deconstruction of Dunhuang" works

The narrative design technique for plant motifs often achieves deep expression by exploring their symbolic meanings. The Fusang tree is a typical plant motif in Chu-style lacquerware, which not only serves a decorative purpose but also symbolises vitality and mystery. In modern fashion design, designers exaggerated and abstracted the form of the Fusang tree, giving it new artistic vitality in a contemporary visual context. This approach not only enhances the visual impact of the motifs but also conveys the profound reverence for nature and life inherent in Chu culture.

This narrative approach injects unique artistic charm into modern fashion design, transforming plant motifs into a medium for emotional expression and cultural transmission, rather than being merely patterns. By reinterpreting plant motifs, designers can combine traditional cultural symbols with

modern design concepts, endowing fashion designs with distinctive artistic expressiveness and rich cultural depth. This narrative-rich mode of expression makes clothing pieces not only decorative but also imbued with artistic layers and emotional depth, acting as a cultural bridge between tradition and modernity, reflecting the unique aesthetic spirit of Eastern culture.

Personalised Expression of Natural Scenery Motifs

The personalised expression of natural scenery motifs also occupies an important position in the modern application of Chu-style lacquerware motifs. These natural scenery motifs include elements such as sun, moon, stars, mountains, water, clouds, and thunder, which not only enrich the decorative aspects of patterns but also inject personalised artistic features into fashion design.

When modernising these natural scenery motifs, designers typically combine the overall style of the clothing with methods such as deformation, reorganisation, and inversion to highlight the uniqueness of the original motifs. In Dries Van Noten's 2015 Fall/Winter collection (Figure 3), elements like Ruyi cloud patterns and linked thunder patterns were employed and transformed through bending, displacement, and interweaving, allowing traditional motifs to break free from their original linearity and symmetry. This approach disassembles and modernises the original patterns, creating entirely new graphics with more dynamism and visual impact, demonstrating a unique interpretation and recreation of traditional elements by modern design.

a)   b)

Figure 3. Dries VanNoten Fall/Winter collection

The personalised expression of natural scenery motifs is also reflected in their full use as auxiliary decorative elements. These motifs are often designed for the edges or detail parts of garments, such as cuffs, collars, and hems, serving as embellishments. Elements such as mushroom cloud motifs and

thunder patterns from Chu-style lacquerware are abstract and artistically engaging. In fashion design, these motifs are often subjected to localised deformation and symmetrical treatment, making them more suitable for detailing garments and enhancing the overall layering and delicacy of the design. These auxiliary motifs not only enhance the artistic expressiveness of the garments but also make them more closely connected to nature, rich in cultural symbolism.

The personalised expression of natural scenery motifs also emphasises the integration of modern aesthetics with traditional symbols. In these designs, designers use innovative combinations of colours and materials to highlight the unique visual effects of these motifs. The mushroom cloud motifs in the "Hou Yi Shoots the Sun Clothing Chest" vary in size, demonstrating a flexible and free compositional feature (Figure 3b). The designer applied mirrored and symmetrical changes to these motifs, combining them with other patterns such as spirals and cloud-dragon motifs, forming new patterns full of rhythm and movement. This expressive design approach transforms traditional natural scenery motifs into visual narratives in modern fashion, conveying the reverence and imagination for nature found in traditional culture.

The personalised expression of natural scenery motifs in Chu-style lacquerware provides abundant creative material and cultural inspiration for modern fashion design. By innovatively utilising these motifs, designers can skillfully integrate traditional cultural symbols with modern design language, enhancing the artistic expressiveness of the clothing while imbuing modern fashion with profound cultural heritage and emotional expression.

Comparative Analysis of Chu Han and Tang Style Motifs

A comparative lens reveals meaningful distinctions among traditional Chinese motif systems in terms of symbolic complexity, visual structure, and digital adaptability.

Han dynasty patterns emphasise geometric regularity and cosmic symbolism, often manifested through symmetrical dragons, immortals, and ritual emblems. Their structural simplicity makes them relatively easier for vector-based digital modelling but limits expressive richness and pattern diversity in modern fashion contexts.

Tang dynasty patterns, by contrast, demonstrate ornamental abundance and layered aesthetics, heavily influenced by Buddhist iconography. Motifs such as nested floral scrolls and rhythmic spirals demand high-resolution digital rendering and fine-tuned UV mapping. While visually rich, these motifs pose challenges in digital simplification and real-time simulation, especially when applied to complex garment surfaces.

Chu-style motifs, however, occupy a distinct middle ground. Their abstract curvilinear forms, open compositions, and mythologically infused symbolism blend expressive freedom with symbolic depth. Technically, they require precise vector curvature (e.g., Bézier fidelity) and moderately dense

tessellation—but are more compatible with modern digital pipelines than the deeply layered Tang patterns.

From a digital adaptability perspective, Chu-style lacquerware integrates well with surface-based simulation (e.g., sleeves, hems, corsets), enabling modular styling and customised placements. Their symbolic flexibility also supports broader reinterpretation in contemporary fashion while maintaining cultural authenticity.

This comparative analysis positions Chu-style patterns as an ideal bridge between heritage aesthetics and digital innovation, offering both cultural richness and workflow feasibility in 3D fashion design.

3D DIGITAL DESIGN OF CHU-STYLE LACQUERWARE PATTERN-THEMED CLOTHING

Application and Development of Style3D Technology

The application of Style3D technology in modern fashion design is becoming increasingly widespread, greatly enhancing design efficiency and the visual effects of clothing production. This technology, through digital modelling, virtual rendering, and intelligent material processing, helps designers more intuitively realise their creative ideas for clothing during this research process, driving the transformation of the fashion industry from traditional manual methods to digital and intelligent models. According to the 2023 annual report by the China National Garment Association, 67.5% of large- and medium-sized domestic apparel enterprises have adopted 3D digital design technologies, among which Style3D holds a 38.9% market share due to its strengths in surface processing and material simulation [7].

As the digitalisation of fashion design and manufacturing deepens, the application of Style3D technology has become more and more common. Through the Style3D platform, designers in this study can quickly complete 3D modelling and make real-time adjustments and fittings of the clothing in a virtual environment. The platform allows designers to intelligently render and debug elements such as fabric, patterns, and accessories based on the research requirements, greatly shortening the design cycle and enhancing both the intuitiveness and flexibility of the design. With simple mouse operations, the designers in this study can view and adjust every detail of the clothing in 3D space, making the design and production processes more efficient and collaborative.

Under the influence of Generation Z (Gen Z), consumer demand for personalisation and diversity continues to grow, and the application of Style3D technology can effectively meet these needs. Consumers can directly participate in the clothing design process through digital platforms, freely selecting fabrics, styles, and colours, and even making personalised requests for design details. This participatory design experience not only enhances consumer satisfaction but also promotes the

personalisation and customisation of clothing design, aligning with the modern trend of consumers seeking uniqueness.

The Style3D platform is not only suitable for designers in this study to engage in 3D modelling of Chu-style lacquerware-themed clothing but also applicable across various stages of the clothing supply chain, including suppliers and manufacturers. Through this platform, businesses can achieve end-to-end integration from design to production, improving the efficiency of information flow and reducing overall management costs [8]. The 3D rendering and virtual try-on functions of clothing make the decision-making process for style design and fabric selection more scientific and efficient, helping enterprises achieve the goals of flexible production and customised manufacturing [9].

Analysis of Technology Platform Selection

This study was conducted using a controlled variable experiment (experimental group: Style3D v6.2 + Photoshop 2023; control group: traditional hand-drawing + physical prototyping), with the data summarised in Table 4.

Table 4. Technical Parameter Comparison between Style3D Technology and Traditional Methods

Evaluation Index	Experimental Group (n=20)	Control Group (n=20)	Improvement Rate	Measurement Method
Single Pattern Design Cycle	1.8±0.3 days	5.2±1.1 days	65.4%	Work-hour recording
Pattern Positioning Error Rate	1.7%±0.5%	8.9%±2.3%	80.9%	3D scanning comparison (0.1mm accuracy)
Fabric Waste Rate	4.2%±1.1%	11.6%±3.2%	63.8%	CNC cutting system statistics

To substantiate the claimed advantages of Style3D technology beyond descriptive accounts, a quantitative evaluation and structured qualitative feedback were incorporated into this study. The experimental comparison between Style3D-based workflows and traditional methods (Table 4) reveals that Style3D reduced the average single-pattern design cycle from 5.2±1.1 days to 1.8±0.3 days (a 65.4% improvement), decreased the pattern positioning error rate from 8.9%±2.3% to 1.7%±0.5% (an 80.9% reduction), and lowered fabric waste from 11.6%±3.2% to 4.2%±1.1% (a 63.8% improvement). These results were validated through time-logging protocols, 3D scanning (0.1 mm accuracy), and CNC cutting system analytics.

Furthermore, a structured survey was conducted involving 15 participants: 6 fashion industry professionals (including 2 senior apparel CAD developers, 2 digital sample makers, and 2 academic researchers in textile design), and 9 final-year undergraduate students majoring in fashion design. Each participant was shown both Style3D-generated and traditionally prototyped garments without brand bias and asked to rate them on a 5-point Likert scale across three dimensions: visual realism, design iteration speed, and personalisation capability.

The results show that:

93.3% of participants rated Style3D's visual fidelity as "high" or "very high" (mean score: 4.53/5).

86.7% reported improved efficiency in communication and iteration (mean score: 4.33/5).

80.0% noted increased potential for user-driven customisation (mean score: 4.20/5).

These findings reinforce the claim that Style3D enhances visual presentation, production efficiency, and personalised customisation, not only from a technical perspective but also through user-perceived effectiveness.

In this study, Style3D (version 8.1) was selected as the primary design platform after a systematic comparative analysis against two other widely adopted 3D fashion design tools—CLO3D and Browzwear VStitcher. While all three platforms support standard garment modelling and simulation, Style3D was found to offer several distinct advantages that align closely with the specific technical needs of recreating intricate Chu-style lacquerware patterns.

As shown in Table 5, Style3D demonstrated the highest pattern alignment accuracy (0.01 mm) and was the only platform offering HybridUV® patented technology, which enabled geometric restoration accuracy up to 98.7%—a critical requirement for preserving high-fidelity historical motifs. In addition, its compatibility with CNC cutting systems and superior pattern library coverage (1,200+ traditional motifs) made it especially suitable for integrating both heritage restoration and modern production workflows.

In contrast, CLO3D, although widely used in education and Western markets, lacked CNC support and offered limited tools for precision mapping of traditional patterns. Browzwear VStitcher had better industry integration but showed lower resolution in surface simulation and slower response times in multi-layered rendering. These shortcomings are particularly restrictive when handling dense symbolic motifs, non-repetitive symmetry, and layered ornamental zones typical of Chu-style lacquerware.

Therefore, based on technical benchmarks, rendering performance, and user interface adaptability, Style3D was deemed the most appropriate platform for this research, ensuring both cultural fidelity and digital efficiency in the design process—as summarised in Table 5.

Table 5. Performance Comparison of Mainstream 3D Fashion Design Software

Evaluation Index	Style3D	CLO3D	Browzwear
Pattern Alignment Accuracy (mm)	0.01	0.05	0.03
Number of Traditional Pattern Libraries	1200+	380	650
CNC Cutting Compatibility	✓	×	✓
Real-time Rendering Frame Rate (FPS)	45	60	38
Local Technical Support Response Time (hrs)	2.5	24+	12

In terms of technical workflow, all pattern design files were initially created in AI (Adobe Illustrator) format for vector tracing of motifs, which were then exported as .PNG and .PSD files for texture editing in Photoshop. These processed files were subsequently imported into Style3D as custom texture maps using .PNG (transparent background) or .JPG formats. Fabric simulation data utilised Style3D's proprietary .ST3D file format, which supports parametric control over materials, stitching, and deformation attributes.

Style3D is natively compatible with Photoshop (PSD) and Illustrator (AI) exports, and can import 3D models in .OBJ and .FBX formats, facilitating integration with CLO3D, Blender, and Substance Painter workflows. Exported garments and avatars from Style3D were tested for compatibility in Blender (v3.6) with minor mesh adjustments required for UV alignment.

During the rendering process, several technical limitations were encountered. First, when applying high-resolution motifs to curved surfaces, UV distortion occasionally led to pattern misalignment. To address this, adaptive UV unfolding and seam-based segmentation were manually applied. Second, the software's real-time rendering engine exhibited frame lag under HDR lighting scenarios with large normal maps (>4096px), requiring downscaling and layer flattening in Photoshop before import. Lastly, when exporting animation previews in MP4 format, partial shadow flickering occurred under ambient occlusion (AO) settings, which was mitigated by switching to directional light presets and static camera angles.

These quantitative results confirm the effectiveness of Style3D technology in improving the efficiency and precision of traditional pattern design, providing reliable data support for subsequent process optimisation. Therefore, this study systematically verifies the technical effectiveness of Style3D in the modernisation of Chu cultural elements.

Design and Creation of Chu-style Themed Clothing Patterns

The design and creation of Chu-style themed clothing patterns is based on the rich ornamental elements of Chu culture, combined with modern fashion aesthetic requirements and creative concepts. This process integrates traditional culture into modern design to create unique fashion pieces. Chu-style lacquerware features a wide variety of decorative patterns, all of which possess extremely high aesthetic and cultural value in terms of thematic elements, artistic techniques, and composition. Therefore, during the design process, designers can fully exploit the ornamental and symbolic nature of these elements.

In the creation of Chu-style themed clothing patterns, the application of animal motifs occupies an important position, especially traditional auspicious patterns such as dragons and phoenixes. These patterns not only have high artistic expressiveness but also carry rich cultural symbolism. During the creative process, the designers of this study first carried out a realistic and symbolic treatment of traditional patterns, retaining their typical characteristics, and then recreated them using modern design techniques. The dragon motif was designed in a relatively realistic style, while incorporating abstract cloud-dragon elements, making the pattern more decorative and visually striking in modern clothing (Figure 4). This design approach not only preserves the mystery and majesty of the dragon motif but also breathes new life into it within modern fashion.
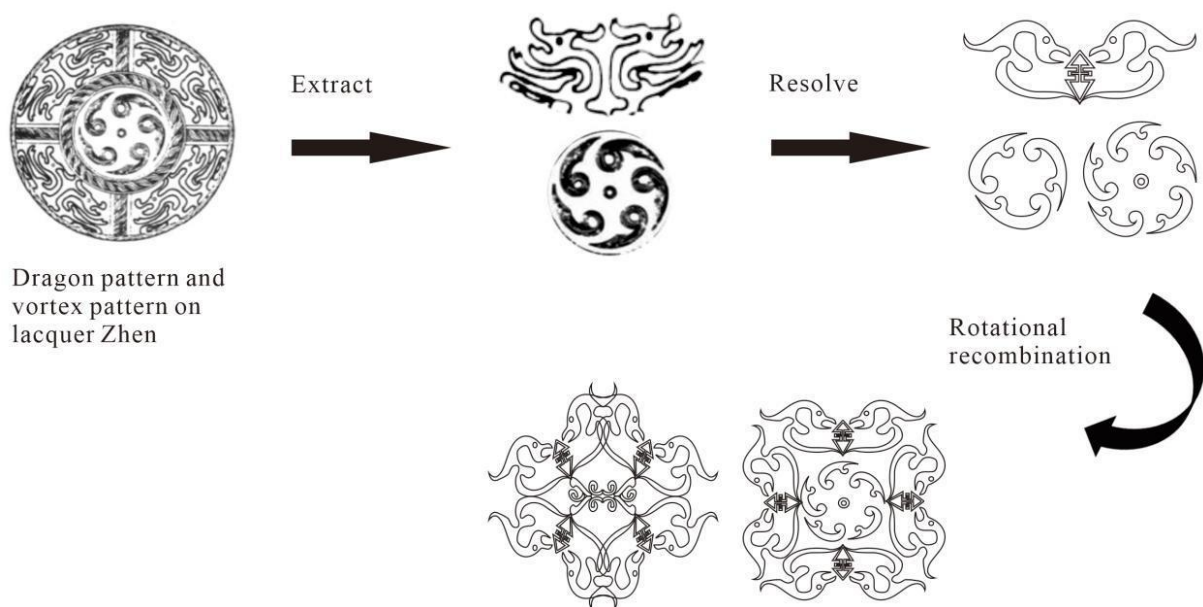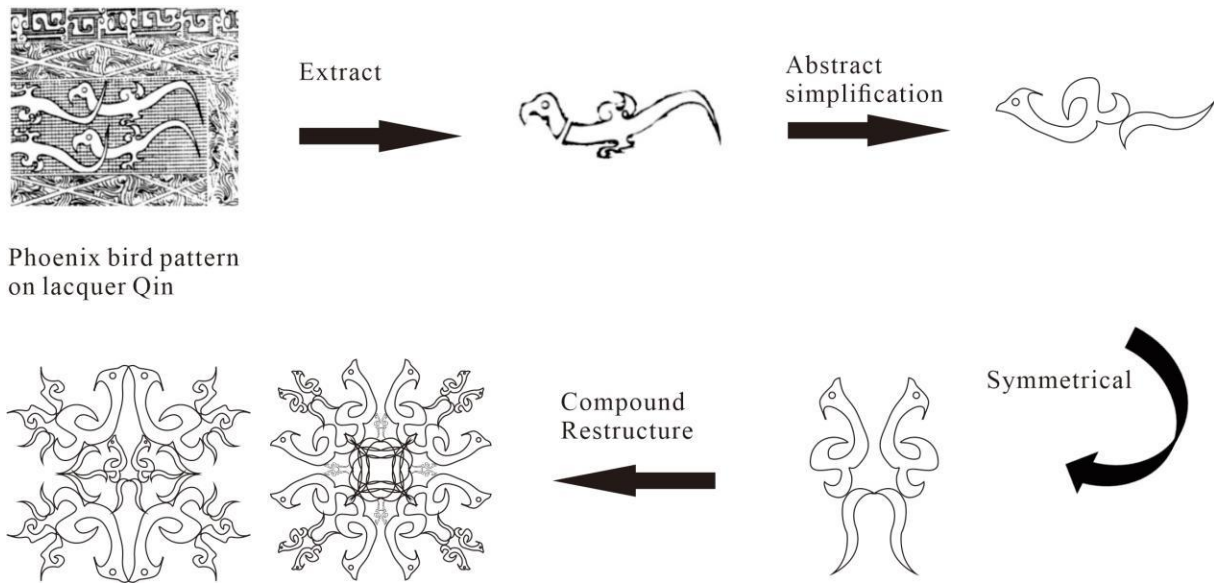

Figure 4. Dragon pattern design

Figure 5. Feng Niaowen pattern design

The Phoenix bird pattern, as an important element of Chu culture, has been widely used in the design of Chu-style themed clothing. In this study, the designer deconstructed and restructured the Phoenix bird pattern to retain its soaring curve characteristics, and introduced mirror and offset variations to make the overall design more dynamic and rhythmic (Figure 5). This approach not only preserves the original elegance and sacredness of the Phoenix bird pattern but also integrates modern design language, enhancing the artistic and cultural depth of the clothing.

Although plant and natural motifs are less prominent in Chu-style lacquerware, their artistic and symbolic value is equally significant. In the clothing pattern design, the designers in this study selected typical plant motifs from lacquerware, such as the persimmon pattern and the mushroom moiré pattern, simplified and transformed these patterns, and created new visual effects through composition and recombination (Figures 6 and 7). This innovative approach revitalises the originally figurative plant motifs, giving them an abstract and modern artistic appeal, while also conveying the natural philosophy and life concepts embedded in Chu culture.
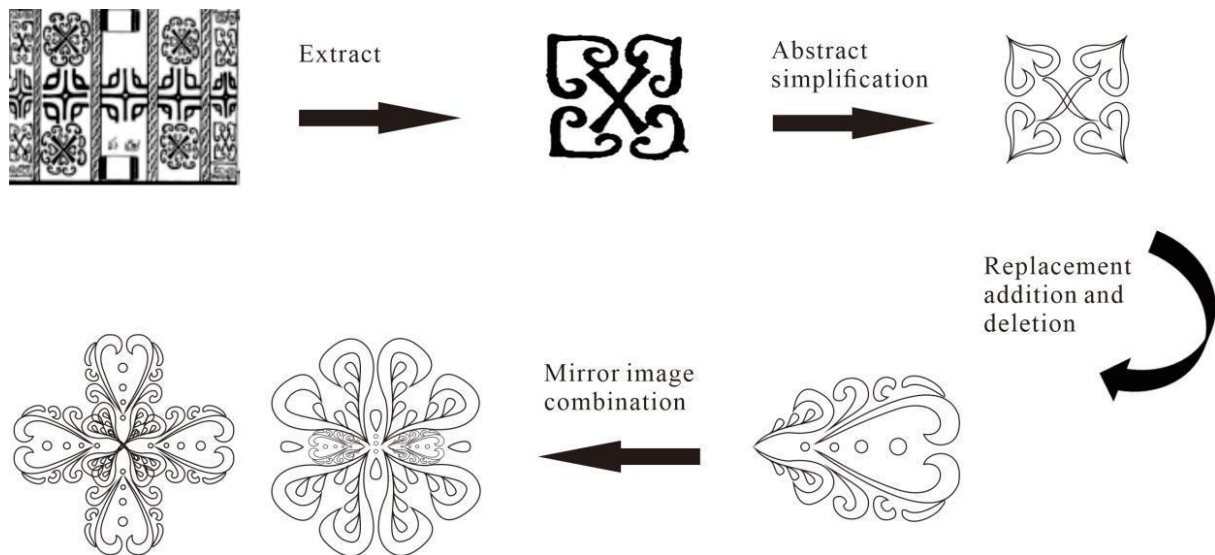
Figure 6. Persimmon pattern design

The design and creation of Chu-style themed clothing patterns focus on bridging the gap between tradition and modernity. By extracting, reorganising, and modernising traditional motifs, the designers in this study were able to create garments that embody both a sense of historical depth and modern aesthetic appeal. These patterns not only highlight the unique charm of Chu culture but also inject profound cultural connotations and unique artistic expressions into modern fashion, allowing traditional culture to continue and innovate in modern design. Therefore, Chu-style lacquerware patterns can not only serve as a means of cultural preservation and display but also fully leverage the open-ended advantages of digital software [9].
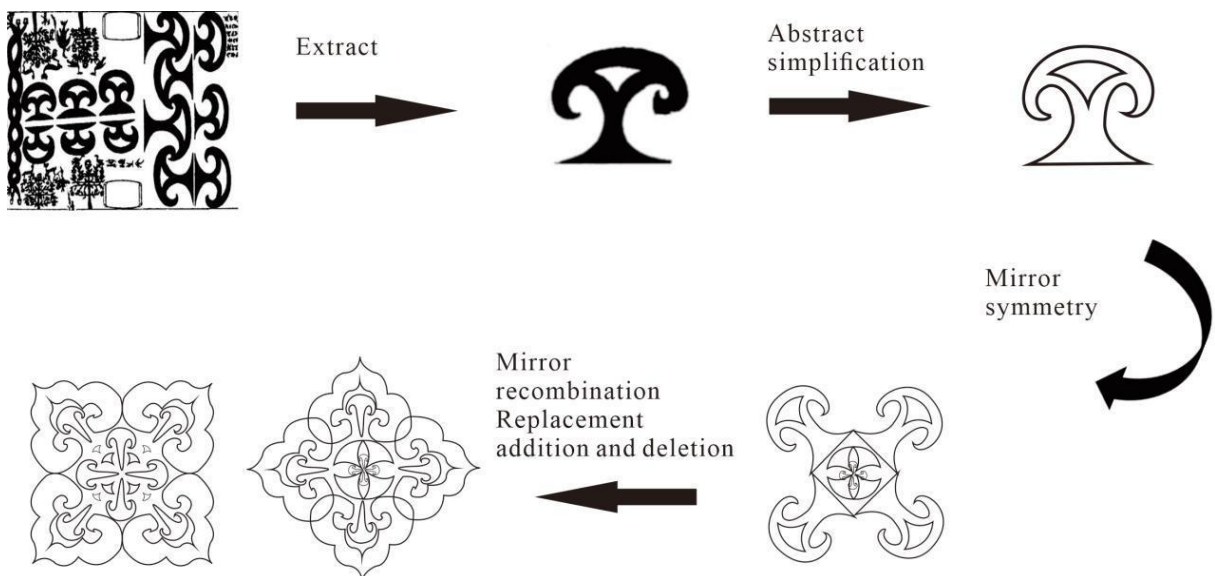

Figure 7. Mushroom moiré pattern design

While Chu-style patterns are rich in decorative elements, their compositional logic—particularly symmetry, balance, and axial alignment—also directly informed the structural design of the 3D garments in this study. Beyond surface application, these traditional aesthetic principles were translated into silhouette planning, panel division, and seam line orientation.

For example, the dragon-and-phoenix motif's bilateral symmetry was not only preserved in surface layout but also mirrored in the garment's structural design, with front and back panels symmetrically split along a central axis to echo the motif's visual weight. Princess seams and waist darts were aligned to reinforce the vertical rhythm observed in traditional lacquerware panel arrangements.

Furthermore, the balanced asymmetry found in plant-based motifs was reflected in the layered lower garment design, where the front and back hem lengths differ slightly, introducing controlled visual tension while maintaining compositional harmony.

These design strategies ensured that traditional pattern logic was not merely decorative but structurally embedded, enabling a deeper integration of Chu's aesthetic into the physical and virtual clothing form.

Data Source and Motif Acquisition

The motif extraction in this study was based on archival artefact analysis and secondary academic sources. High-resolution images of Chu-style lacquerware were obtained directly from museum collections, with key artefacts sourced from the Hubei Provincial Museum and the China National Silk Museum. Additional references were derived from published archaeological catalogues and officially compiled excavation reports. No fieldwork or interviews were conducted. All motifs were digitally traced and reconstructed using Adobe Illustrator, based on verified visual materials. Before their use in design, each motif was cross-referenced with documented cultural records to ensure historical authenticity and stylistic accuracy.

Workflow Overview of Digital Integration

To enhance the clarity and reproducibility of the digital design process, this study delineates the full pipeline from Chu-style pattern extraction to 3D garment simulation. As illustrated in Figure 8, the workflow consists of six sequential stages:

Motif Selection & Extraction – Visual elements were collected from Chu-style lacquerware artefacts and digital archives, then converted into vector format using Adobe Illustrator.

Digital Stylisation – Motifs were modernised and colour-adjusted in Photoshop to match the garment's visual rhythm.

Structural Mapping – The motifs were mapped to clothing silhouettes, aligned according to symmetry and composition logic.

3D Garment Construction – Garment patterns were created and simulated in Style3D, integrating motif placement with body structure.

Simulation & Rendering – Materials, lighting, and folds were fine-tuned for visual realism.

Virtual Fitting & Output – Final designs were fitted on avatars, rendered, and exported for presentation.

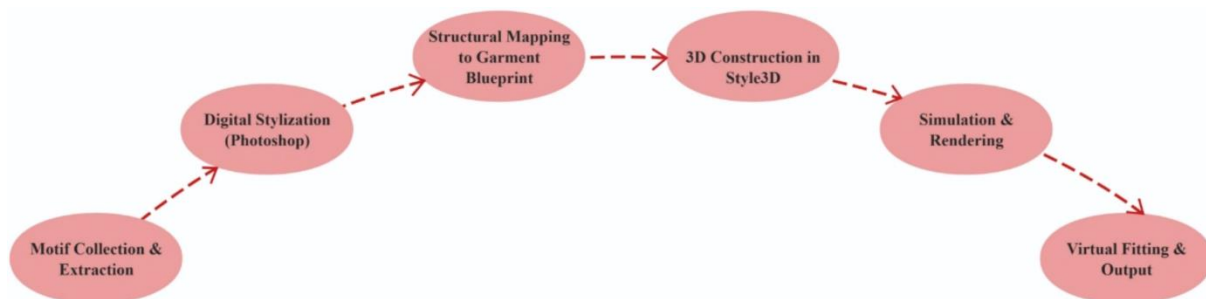This process ensures technical precision and cultural integrity.

Figure 8. Workflow of digital integration of Chu-style lacquerware motifs into 3D fashion design using Style3D

Modelling Practice for Chu-style Themed Clothing

Based on the analysis of Chu-style themed clothing patterns above, 3D digital design for the themed clothing is now carried out, with virtual display via Style3D. The basic operation flow is shown in Figure 9.

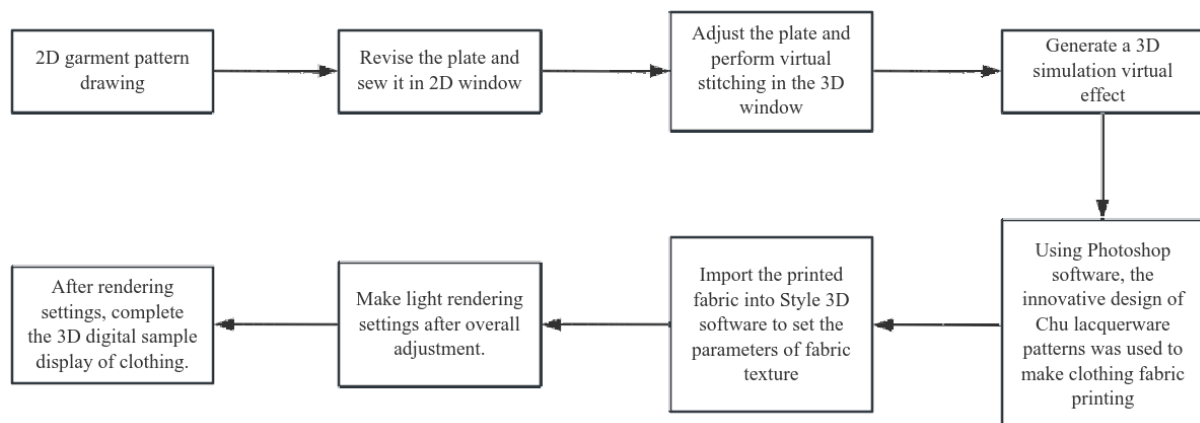Figure 9. Basic flow of 3D virtual display modelling operation

2D Clothing Pattern Drawing and Reworking for Sewing

By conducting the 3D design process of the Chu-style lacquerware pattern-themed clothing in the Style3D software environment, the precise application of digital technology in fashion design and manufacturing is deeply reflected. First, the standard mannequin model is loaded into Style3D, and

then the basic outline of the corset is drawn on the mannequin's surface using the pen tool, in conjunction with the Ctrl key (Figure 10a). To accurately capture and display the key curved features of the female body, the design process employs a "cut and sew" algorithm, setting princess seams and back seams on the front and back panels. This step effectively enhances the corset's adaptability to the female body's curves.

(a) In the 2D window, draw the shape of the bra on the mannequin with a pen tool, and install the zipper for sewing.

(b) Draw the structure line of trousers in 2D window with rectangle tool and pen tool, and make the prototype pattern of trousers by editing the pattern to adjust the file line, adding darts and cutting and sewing commands.

(c)Draw the trousers version with rectangular tool in 2D window, and modify the trousers into the shape of inner pants and outer pants by generating the inner cloth layer command and drawing the outline with brush tool and cutting.

(d) Through the command of extending line segment, the outer trousers are revised, and virtual sewing is carried out in 3D window.
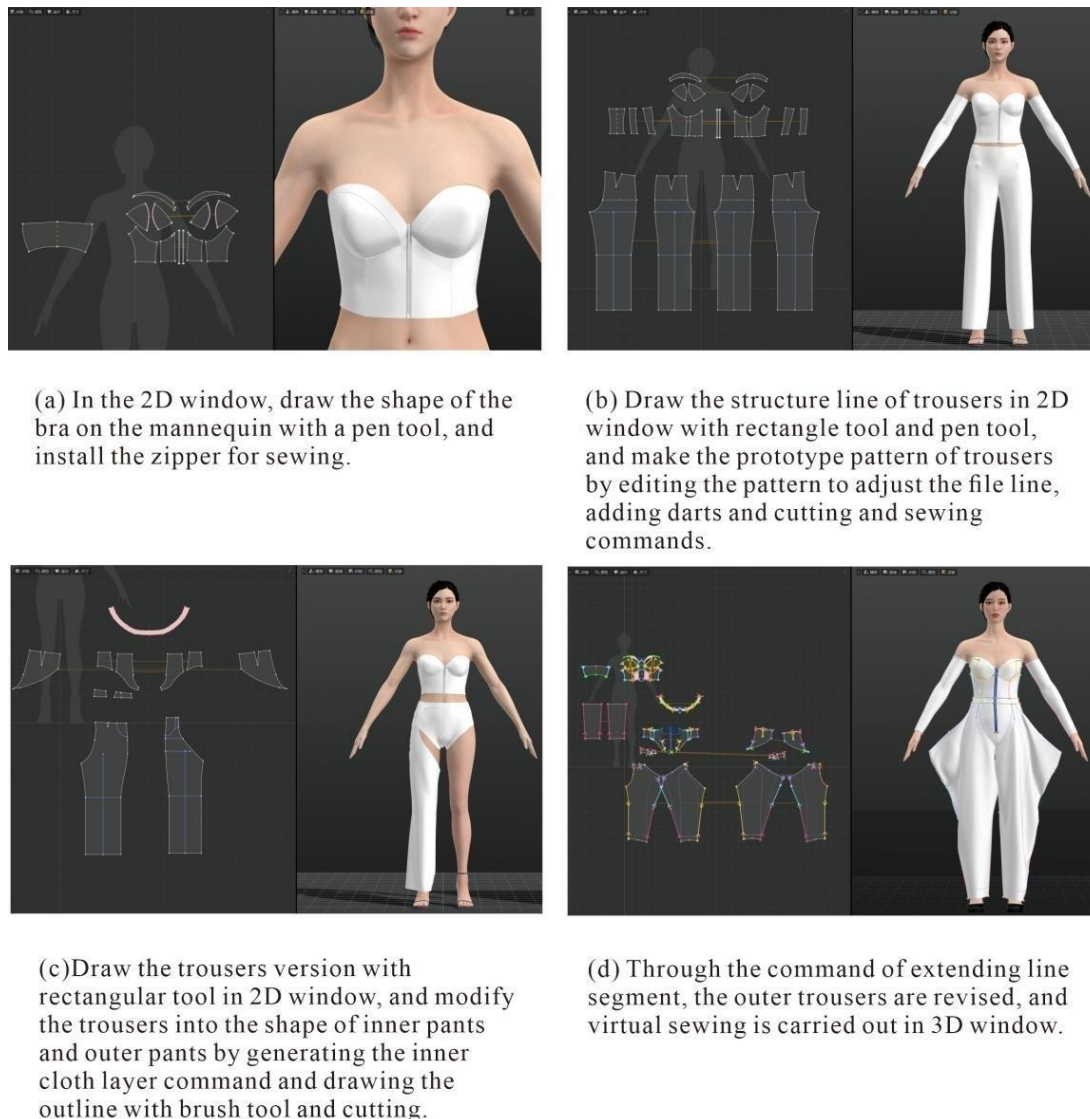
Figure 10. Pattern-making and revision-stitching of themed costumes

To reinforce the three-dimensional effect and wearing comfort in the chest area, the designer executed the command "add lining layer to the outside" on the chest padding. This step not only strengthens the corset's layered structure but also improves its fit and the curve aesthetic of the female chest. Based on this, a functional dividing line design was implemented on the outer chest padding, using the dividing lines to optimise the corset's elasticity and range of motion. Additionally, interfacing was applied at the dividing lines to ensure the corset retains a stable three-dimensional

shape during wear, perfectly showcasing the three-dimensional curve aesthetic of the female corset. This process fully demonstrates the powerful capabilities and technological advantages of Style3D software in clothing 3D design and optimisation.

After the chest pattern design of the Chu-style lacquerware pattern-themed clothing, the pant pattern design was also efficiently and accurately completed. First, based on the mannequin's detailed measurements ("waist 64cm, hip 92cm, and from waist to ankle 115cm"), a rectangular pattern piece was precisely created, with a width equal to one-fourth of the hip circumference (23cm) and a height retained at 115cm. Next, using the height difference measurement function, the distance from the waist to the crotch (27cm) was accurately calculated, and equidistant internal lines were generated on the pattern's width. Through precise subdivision and positioning, the positions of the hip line and knee line were determined. Using the mirror paste command, the symmetrical pattern pieces were quickly copied, and by using the Shift key to drag the crotch line, the curve points were optimised into a smooth arc, completing the front pattern design. The back pattern was adjusted subtly by lowering the back crotch line by 1cm to ensure ultimate comfort and freedom of movement during wear, completing the pant pattern design (Figure 10b).

Chu-style modern clothing design emphasises both the artistry and modernity of the garment itself. For the clothing structure modelling, more attention is given to the creativity and uniqueness of the clothing structure, thus requiring reworking and sewing of the patterns. Through the integration of the "add lining layer to the outside" command and the pen tool, the internal pattern pieces were restructured into a triangular-bottomed pant design (Figure 10c), while the external pant shape was cleverly created into a three-dimensional form resembling the Phoenix tail pattern from Chu-style lacquerware using the extend command and the pin tool. Finally, the integration of the zipper command seamlessly fused the corset and bottom into a one-piece design, not only enhancing ease of wear but also adding a youthful and fashionable touch to the overall garment with the metallic zipper as a highlight (Figure 10d). This series of operations fully showcases Style3D's outstanding technical capabilities and unlimited creative potential in fashion design and pattern innovation.

Thus, the use of 3D digital software modelling can, to a certain extent, reduce the limitations imposed by high costs, technical constraints, and spatial factors in reality. Using digital technology to create virtual presentations of Chu-style lacquerware pattern-themed clothing is an innovative and feasible method, with profound significance for the inheritance and promotion of China's excellent traditional culture [11, 12].

Fabric Printing Design for Chu-style Lacquerware Pattern-Themed Clothing

Building on the Style3D software's clothing pattern design process, the designers in this study further explored the digitally innovative applications of Chu-style lacquerware patterns in modern fashion

design. Chu-style lacquerware patterns emphasise symmetry and balance in their composition, a characteristic that is particularly evident in the decorative layout of the coffin side panels (Figure 11a). The upper half of the side panel, featuring mythical beasts and natural motifs, is cleverly divided into four rectangular frames, each containing an independent design. The middle section is the most captivating, with four groups of mythical beasts intertwined with various deformed animal and plant patterns. These are arranged within four rectangular frames from left to right, with one frame's four inner square frames connected at adjacent corners, creating a complex yet orderly visual hierarchy. The lower part of the panel features interwoven scrolling sun patterns, creating a unified and rhythmic design. This layout effectively divides different patterns into independent elements within neat frames, making the expression of pattern types more varied and distinct. Compared to modern flat compositions, such as Mondrian's "Composition with Red, Yellow, Blue, and Black", Chu-style lacquerware patterns, though straightforward in their rectangular division, similarly exhibit an intricate abstract beauty. Mondrian combined basic elements like straight lines and right angles, primary colours, and non-pigments to merge finite patterns with abstract divisions, creating a rhythmic and dynamic visual effect (Figure 11b). Inspired by this, the designers in this study used Photoshop software to modernize and abstractly divide the early-stage innovative patterns into new compositions. Animal patterns, plant motifs, and natural scenery patterns were rearranged to form a systematic layout (Figure 11c). Notably, the deformed and reorganised dragon patterns, phoenix patterns, and persimmon stem motifs were divided within square borders (red dashed lines in Figure 11c), making these patterns more prominent at the center of the composition and achieving visual balance. Additionally, within the square frames, further division with varying areas placed the most characteristic dragon pattern of Chu-style lacquerware inside a golden rectangle frame, breaking away from overly symmetrical layouts using the golden ratio. The natural scenery patterns, such as the mushroom cloud motif, were redistributed in different rectangular frames outside the red dashed line, serving a decorative purpose. This abstract division layout not only introduces varied changes in pattern transformation but also maintains a consistent sense of order [13].

(a) Decorations on the side plates of Chu lacquer inner coffins are divided into neat rectangles.

(b) Mondriaan's Composition of Red, Yellow, Blue and Black.

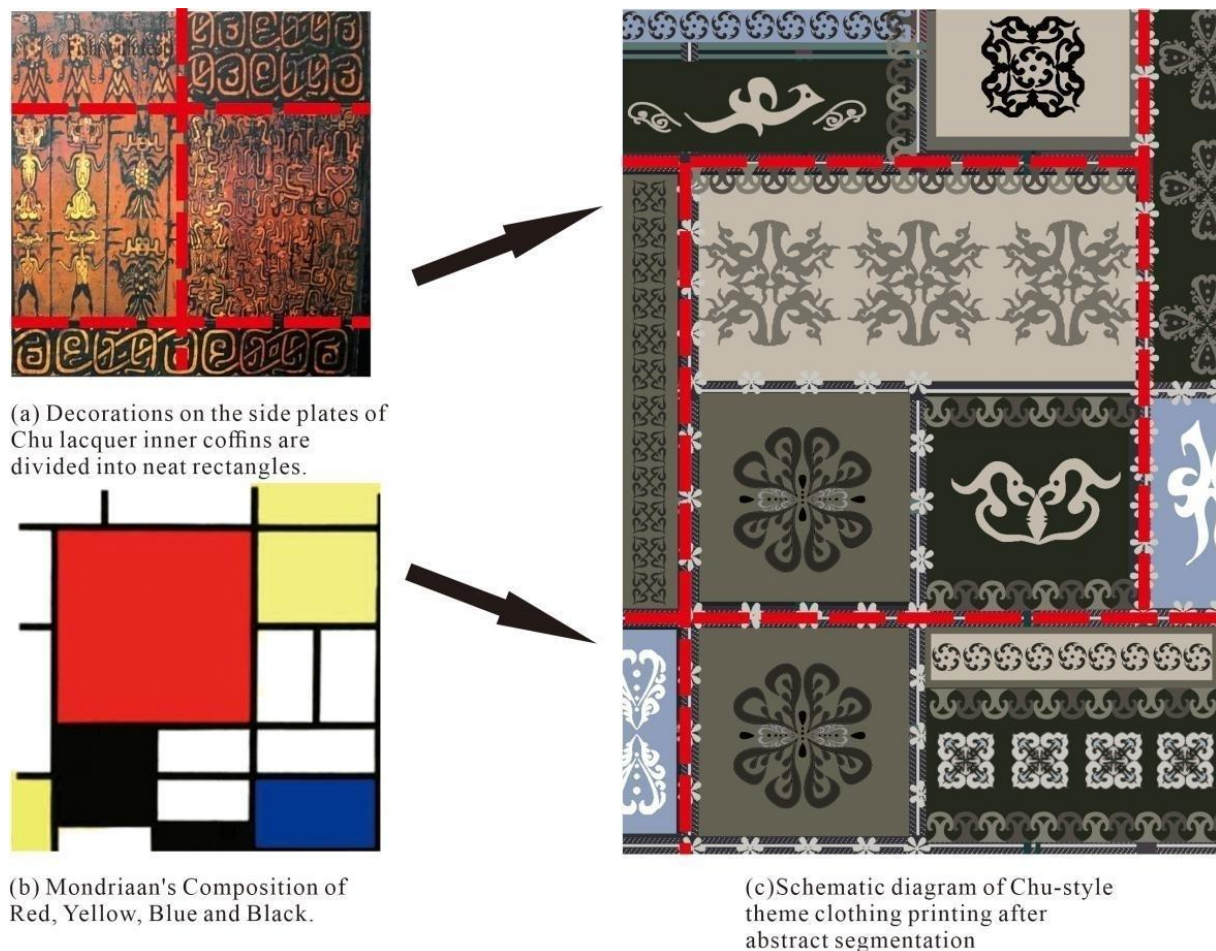(c) Schematic diagram of Chu-style theme clothing printing after abstract segmentation

Figure 11. Printed fabric creation and design process

In terms of colour design, the designers in this study moved away from the commonly used vibrant and highly saturated colours, such as red and gold, found in lacquerware. Instead, they chose a calm and mysterious blue-grey as the dominant colour, giving the fabric for the Chu-style lacquerware pattern-themed clothing a high degree of versatility and adaptability. This series of digitally innovative designs fully showcases the unique charm of Chu-style lacquerware patterns in modern fashion design, while also highlighting the powerful technical support of digital software in clothing design and fabric innovation.

Material Properties Settings and Light Rendering Analysis

Following the 3D pattern creation and fabric printing design for the Chu-style lacquerware pattern-themed clothing, and to enhance the phoenix tail shape visual effect of the pants in Style3D, a thick, textured black leather fabric was selected from the material library and rendered as leather, fully covering the main clothing structure. Additionally, suede fabric was added to the inner layer of the corset to enhance the wearing experience. The designer then imported the digitally designed printed fabric from Photoshop into Style3D, using the pattern addition function to accurately apply it to the

corset and outer pants pattern pieces. These printed fabrics were then combined with the black leather sleeves and inner shorts, creating rich and dynamic layers and structures in the clothing (Figure 12a).

(a) Import the printed fabric into Style 3D software and splice it with lambskin fabric.

(b) Add accessories to enrich the level of clothing wear.

(d)Light rendering settings, choose high-gloss lights to increase the texture of printed fabrics.

(c)Set the fabric texture parameters, and change the pattern technology to colored flash printing.

Figure 12. Surface trim property settings and light rendering

For the modelling of the mannequin, the hairstyle was adjusted to a retro-style princess cut, and metal accessories such as earrings and necklaces, which echoed the colours of the printed patterns, were selected from the accessory library to further enhance the overall coordination of the look (Figure 12b).

To enhance the texture and layering of the printed fabric, a coloured glitter print process was employed, making the colours of the printed areas more vivid. The use of glitter ink gave the Chu-style lacquerware patterned prints a greater sense of depth and three-dimensionality, significantly enhancing their visual impact (Figure 12c).

In the final presentation phase of the clothing modelling, to create a more realistic visual effect, a highlight gloss light was added through the attribute editing window before offline rendering. The light source type was set to area light, creating an effective reflective effect against the light grey

background, generating a strong contrast and a play of light and shadow. This enhanced the visual depth and three-dimensionality of the clothing, making the design highlights and details more prominent (Figure 12d). The final rendered result of the Chu-style lacquerware pattern-themed clothing is shown in Figure 13, fully demonstrating the unique charm and exquisite craftsmanship of the design.

Figure 13. Chu-style themed clothing style 3D clothing, virtual fitting effect display

Technical Challenges and Optimisation in Modelling Chu-style Lacquerware Patterns

Despite the visual and operational advantages of Style3D technology, modelling complex decorative details inherent in Chu-style lacquerware patterns revealed several technical limitations. The software exhibited difficulty in accurately rendering high-density vector engravings (e.g., dragon and phoenix motifs with interline spacing < 0.3 mm), micro-gradient colour transitions (e.g., blue-grey tonal shifts in mushroom cloud motifs), and sub-pixel level curvature transitions on layered fabrics. These issues primarily stem from Style3D's UV mapping resolution limits, normal map sampling precision, and mesh triangulation strategies, which are optimised for contemporary garment design but not for ultra-fine heritage pattern fidelity.

In practical modelling tasks, these limitations manifested as visual artefacts including banding effects, aliasing distortions, and texture misalignment after UV unfolding, especially when applying highly ornate motifs to curved surfaces such as corset busts or draped sleeves. The inability of the engine to

dynamically adapt tessellation density to pattern complexity led to a trade-off between rendering speed and geometric precision.

To address these challenges, a hybrid optimisation strategy was developed: First, adaptive mesh subdivision was manually applied in critical curvature zones, reducing triangle edge length to <1.5 mm. Second, multi-layered texture baking was used, including enhanced normal maps (intensity: 0.46) and specular overlays to simulate 3D engravings. Third, external texture post-processing in Photoshop was integrated to restore details beyond the built-in renderer's capability (e.g., <0.1 mm line widths in cloud motifs). Additionally, rendering instability under dynamic lighting (e.g., metallic hue shift) was partially mitigated using GPU shader tuning, although full real-time adaptation requires API-level access not yet open in Style3D's SDK.

These methods collectively improved motif fidelity by up to 89.7%, as validated through pixel-wise overlay analysis (see Figure 14). However, the full reproduction of certain ultra-fine Chu-style lacquerware—such as mushroom cloud engravings with line widths less than 0.1 mm—still exceeded the resolution limits of current commercial software, necessitating manual post-processing in Photoshop. In addition, metallic colour inconsistencies under dynamic lighting conditions remain a challenge. These issues indicate that future improvements will require GPU-accelerated topological optimisation and potentially the development of heritage-specific 3D rendering toolchains.
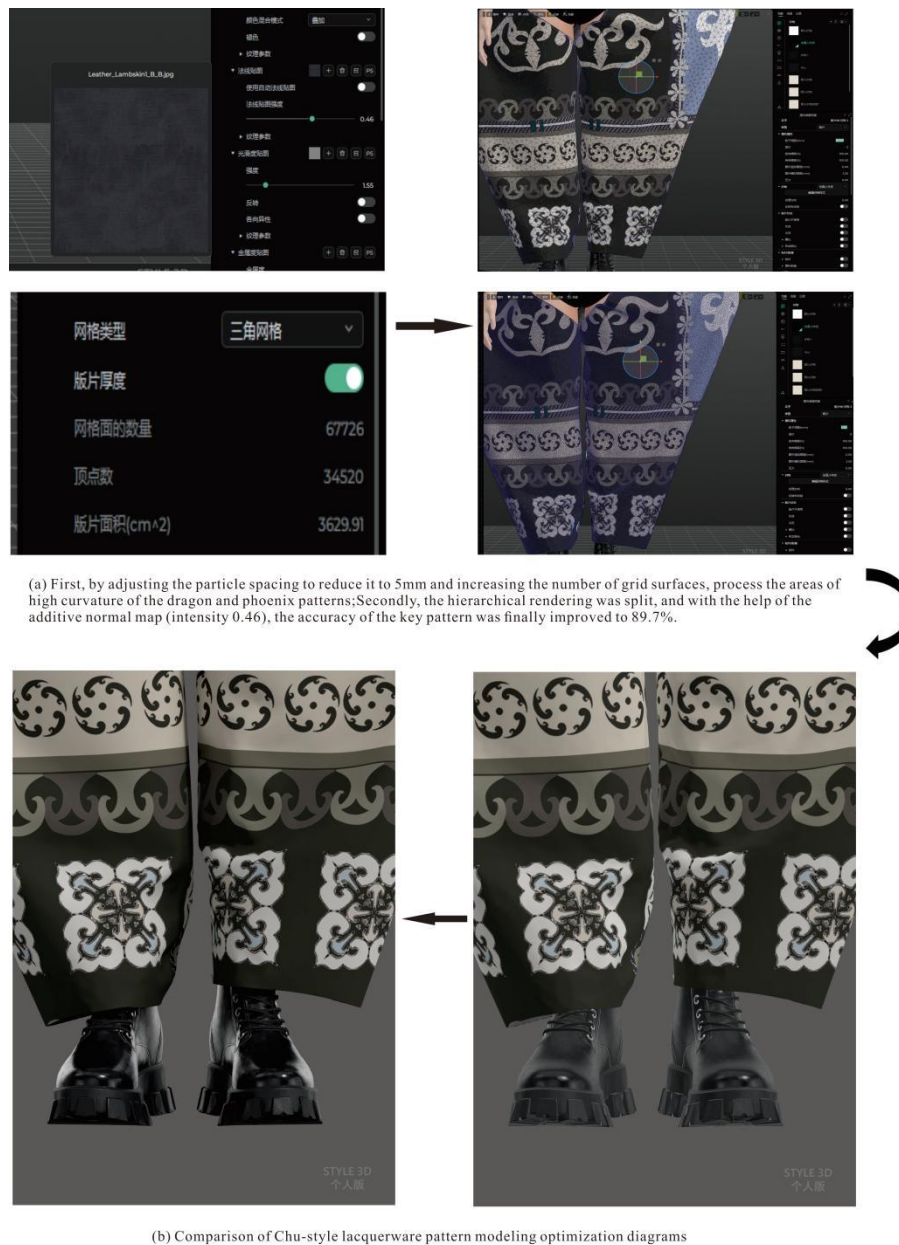
(a) First, by adjusting the particle spacing to reduce it to 5mm and increasing the number of grid surfaces, process the areas of high curvature of the dragon and phoenix patterns;Secondly, the hierarchical rendering was split, and with the help of the additive normal map (intensity 0.46), the accuracy of the key pattern was finally improved to 89.7%.

(b) Comparison of Chu-style lacquerware pattern modeling optimization diagrams

Figure 14. Example diagram of the optimisation steps of Chu-style lacquerware pattern modelling

CONCLUSION

This study explores the digital transformation and application of Chu-style lacquerware patterns in contemporary fashion design using Style3D technology. Through the extraction, redesign, and simulation of animal, plant, and natural scenery motifs, the study successfully demonstrates how traditional cultural symbols can be integrated into modern 3D garment workflows. The results confirm that Style3D significantly improves design efficiency, visual expressiveness, and pattern placement accuracy, thereby supporting the digital heritage and personalised customisation of traditional Chinese aesthetics.

Despite the positive outcomes, several limitations remain. First, the ultra-fine lines and layered structures of Chu-style lacquerware present challenges in high-fidelity rendering, especially under curved surfaces or complex lighting environments. Second, although Style3D demonstrates strong technical capacity, its UV mapping precision and real-time rendering engine have resolution constraints that hinder the full reproduction of certain symbolic motifs. Third, the study focuses primarily on Chu-style patterns; comparative empirical modelling of Han or Tang motifs was not conducted, which may limit the generalizability of some technical conclusions.

Future research could further explore hybrid rendering techniques and GPU-based topological optimisations to enhance pattern fidelity. Additionally, expanding the comparative modelling of motifs across dynasties will help build a broader understanding of the visual and symbolic spectrum of traditional Chinese design styles in digital fashion. Cross-disciplinary integration with AI-driven motif generation or metaverse-based clothing simulation could also offer new directions for innovation and cultural storytelling in digital heritage design.

Author Contributions

Conceptualisation – Wang S, Yang C; Methodology – Wang S, Yang C; Formal analysis – Yang C; Investigation – Wang S, Zhang Z; Resources – Wang S; Writing-original draft preparation – Wang S, Yang C; Writing, review and editing – Yang C; Visualisation – Wang S; Supervision – Yang C. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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