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Digital Translation of Traditional Textiles: Interactive Design Applications Based on Chinese Fabric Motifs

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ABSTRACT

This study systematically explores the digital translation and interactive redesign of traditional Chinese textile motifs, with a focus on Yunjin, Song brocade, and ethnic weaving patterns. By integrating parametric shape grammar, semantic annotation, and real-time user interaction, the research develops a replicable design framework that enables both cultural preservation and creative reinterpretation. Through a combination of motif extraction, modular modelling, and interactive system construction using Unity and TouchDesigner, the platform allows users to manipulate traditional patterns in real time while receiving embedded cultural feedback. Experimental evaluation involving participants from diverse backgrounds demonstrates the system's effectiveness in enhancing cultural understanding, emotional resonance, and creative autonomy. The findings suggest that computational tools can serve not only as a tool for intangible heritage conservation but also as a catalyst for participatory cultural innovation. This study contributes to the theoretical discourse on digital heritage while offering practical implications for future interactive design practices rooted in cultural authenticity.

KEYWORDS

Chinese textile motifs, parametric design, interactive design platform, digital cultural heritage, shape grammar theory

INTRODUCTION

In recent years, digital technologies have increasingly been employed in the preservation and reinterpretation of cultural heritage, offering innovative methods for safeguarding intangible cultural expressions and facilitating cultural continuity [1,2]. Traditional textiles, characterised by their complex symbolic language and intricate aesthetic forms, represent a critical dimension of intangible cultural heritage. However, traditional approaches to heritage conservation often face limitations, particularly concerning dynamic cultural dissemination and interactive user engagement [3].

Equally important, the essence of interactive design lies in stimulating active user participation and creative agency, which marks a significant shift from static archival reception to dynamic, user-driven reinterpretation. In response to these challenges, the integration of digital interactive design methodologies presents a promising direction for revitalising traditional visual motifs within contemporary contexts [4]. The digitisation of textile motifs has largely focused on static archival

practices, such as 2D scanning, digital photography, and image archiving, which limit their potential for dynamic interpretation and user-centred engagement. These static methods often fail to provide meaningful interactivity, active user participation, or the conveyance of deeper cultural semantics, thereby underscoring the necessity and urgency of developing the proposed interactive platform [5]. Despite these technological advancements, there remains a critical research gap concerning systematic methodologies that combine parametric shape grammar theories with real-time interactive design platforms, specifically targeting the recontextualization of traditional Chinese textile motifs.

Among various textile traditions, Chinese forms such as Yunjin and Song brocade are renowned for their exceptional symbolic richness, intricate modular structures, and significant historical legacy, yet they face critical challenges due to endangered craftsmanship [6]. These qualities make them particularly relevant for digital reinterpretation using parametric modelling and interactive design methods. Addressing this gap, the present study introduces an integrated digital design framework that combines parametric translation and real-time manipulation of traditional Chinese textile motifs, exemplified through Yunjin, Song brocade, and ethnic weaving patterns. By systematically extracting and digitally reconstructing these motifs through a shape grammar-driven parametric approach, this research not only preserves their inherent stylistic and symbolic characteristics but also enables extensive user interaction within culturally defined boundaries.

The core innovation of this research lies in its development of a holistic and replicable interactive design framework. This framework uniquely integrates parametric shape grammars, semantic annotation (also referred to as symbolic meaning annotation in this study), and user-centred interaction feedback loops, facilitating both cultural authenticity and creative reinterpretation. Through empirical evaluation involving users from diverse disciplinary backgrounds, the research demonstrates that the proposed system significantly enhances user engagement, cultural understanding, and perceived creative agency. Moreover, the inclusion of community-driven feedback mechanisms highlights the system's potential as a dynamic platform for participatory cultural heritage practice.

In summary, the primary contributions of this study are threefold: firstly, it introduces an innovative parametric methodology for the digital translation of traditional textile motifs, reinforcing cultural authenticity through shape grammar theory; secondly, it develops and validates an interactive digital platform that promotes active user engagement and personalized cultural interpretation; thirdly, it provides empirical insights into user experience dynamics, emphasizing emotional resonance and cultural learning facilitated through digital heritage interactions. Additionally, similar challenges and opportunities in the digitisation and interactive reinterpretation of traditional motifs can be observed in other cultural contexts, such as South American weaving traditions and Islamic geometric patterns. These examples highlight the broader applicability of the proposed framework and its potential for

future cross-cultural adaptation. Collectively, these contributions establish a novel pathway for leveraging computational design and interactive media in the sustainable revitalisation and dissemination of intangible textile heritage.

LITERATURE REVIEW

The integration of digital technologies into the preservation and reinterpretation of traditional textiles has evolved significantly in recent years. Early initiatives primarily focused on artefact-level digital restoration. For example, Li et al. [7] reconstructed the Yunjin Dahualou loom using 3D modelling and immersive visualisation. This project demonstrated how tangible textile structures can be preserved and accessed virtually, establishing a technical foundation for subsequent digital heritage research.

Building upon these efforts, subsequent studies have shifted attention from machinery to the symbolic grammar embedded in textile motifs. Zahri et al. [8] introduced the Harmonised Shape Grammar (HSG) framework, which formalises traditional motif structures into rule-based modules. This approach ensures cultural coherence while allowing for generative design variations. In a complementary development, Devendorf et al. [9] presented AdaCAD, a parametric design tool that supports the creation and manipulation of woven structures through a user-friendly interface. Together, these studies highlight how computational tools can support both the preservation and creative transformation of cultural design elements.

In addition to modelling techniques, researchers have increasingly focused on user experience and interactive engagement. Wu and Li [10] demonstrated that personalised, data-driven content delivery significantly enhances user interaction on digital heritage platforms. Chen and Zhao [11] further emphasised the role of adaptive user interfaces in maintaining engagement by aligning system behaviours with user preferences, particularly in mobile and touch-based environments.

Interactive storytelling has also been recognised as a means to foster cultural understanding and emotional connection. Li [12], for instance, explored how digital puppetry and traditional painting can be embedded in interactive design platforms to promote cross-cultural appreciation. This narrative approach enhances both user immersion and interpretive depth, which is especially pertinent when designing interfaces for culturally symbolic materials such as textile motifs.

Effective interpretation of traditional designs also depends on structured digital archiving. Garcia and Thompson [13] advocated for standardised metadata practices in textile documentation to improve the accessibility and semantic richness of digital collections. These recommendations align with the user-centred development strategies proposed by Nguyen and Bui [14], who emphasised iterative design processes and real-time feedback as essential for creating meaningful heritage platforms.

The potential of immersive technology in education and engagement has been further validated. Martinez and Chen [15] demonstrated that virtual reality environments can enhance learning by replicating the sensory qualities of cultural artefacts. Rahman and Sari [16] applied similar principles to Indonesian batik, showcasing how localised motifs can be reimaged through digital techniques in ways that remain culturally sensitive yet creatively open.

According to Zhao and Wang [17], the field of digital cultural heritage is increasingly defined by interaction, customisation, and creative agency. Smith and Lee [18] echoed this trend by examining how traditional fashion patterns can evolve through parametric design methodologies. These insights reinforce the relevance of computational frameworks for sustaining both cultural authenticity and contemporary design expression.

Finally, the importance of integrating cultural meaning with interactive design has been emphasised by Garcia and Thompson [19] and further supported by Chen and Li [20]. Their findings suggest that heritage systems should empower users to engage with cultural materials in ways that are both personally meaningful and historically respectful. In response to this evolving context, the current study builds on motif-level semantic and structural analyses, such as those presented by Li et al. [21], and proposes a unified platform that combines parametric modelling, real-time user interaction, and semantic annotation. This system aims to preserve the stylistic and symbolic integrity of traditional Chinese textiles while enabling users to actively participate in their reinterpretation through a digitally immersive framework.

METHODOLOGY AND SYSTEM IMPLEMENTATION FOR DIGITAL MOTIF TRANSLATION

Motif Collection and Digital Extraction

The application of interactive digital design in traditional textile pattern products serves as a new avenue for cultural innovation and digital heritage transformation. This section explores how Chinese fabric motifs are extracted, digitally translated, and recontextualised through interactive design methodologies. Focusing on the core stages of motif digitisation, parametric modelling, system integration, and user validation, the study aims to establish a replicable framework for the revitalisation of intangible cultural assets in a modern design context.

The study begins by identifying and collecting representative fabric motifs from Chinese traditional textile forms, including Yunjin, Song brocade, and ethnic weaving patterns. These motifs were extracted from high-resolution digital images obtained from museum collections, heritage documentation, and classical pattern books. Using vectorisation techniques and image preprocessing tools, the motifs were systematically converted into editable digital elements while preserving the

stylistic essence of their historical forms. Figure 1 illustrates the four-step workflow of collecting, preprocessing, extracting contours, and vectorising traditional Chinese fabric patterns for digital use.

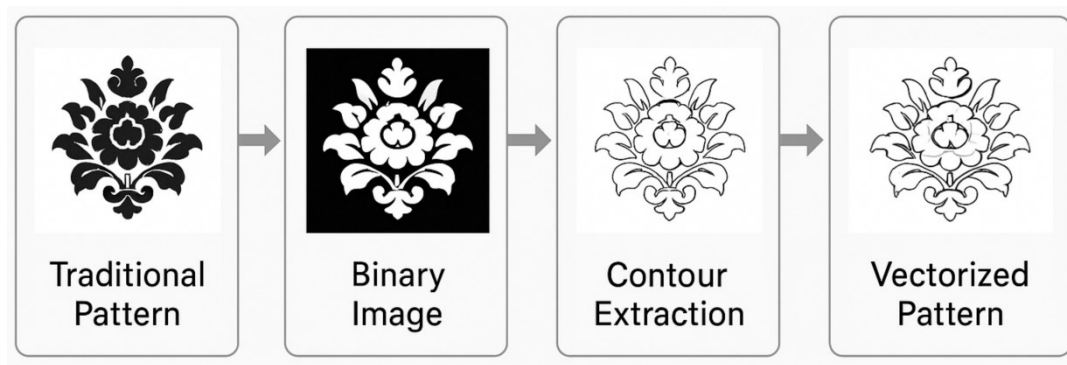


Figure 1. The Digitalisation Process of Traditional Textile Motifs: From Raw Image to Vector Structure

Each motif underwent structural analysis to deconstruct its compositional grammar, enabling subsequent integration into a rule-based interactive design system.

To improve the clarity of the overall system workflow, an overarching system architecture diagram (see Figure 2) has been added. This diagram provides a concise visual representation of the logical and data flow among the key modules, illustrating the progression from motif collection and vector conversion to parametric modelling, the user interface, and the feedback mechanism. The diagram adopts a layered structure comprising input, processing, and output stages, clarifying how the components are functionally connected within the integrated framework. This addition complements the existing figures and helps convey a more comprehensive understanding of how the system operates as a cohesive whole.

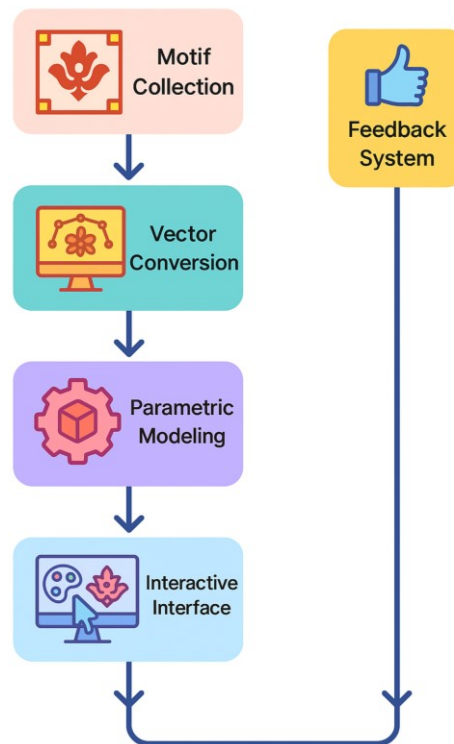


Figure 2. System architecture diagram showing the workflow and data flow among the motif collection, vector conversion, parametric modelling, interactive interface, and user feedback modules

Parametric Modelling and Shape Grammar

To realise the digital translation of these motifs, a parametric design method was implemented (parametric modelling refers to a computational approach that uses adjustable parameters to generate design variations within defined rule sets). Through Grasshopper visual scripting and Rhino modelling environments, the basic geometries of the traditional patterns were programmed into modular structures that allowed variation within fixed cultural rules.

Shape grammar is a formal design system that defines how motifs can be generated and transformed through rule-based geometric operations. This transformation process, rooted in shape grammar theory, facilitated the generation of multiple design outcomes from a single motif base, ensuring that every visual recombination retained semantic coherence and cultural authenticity (see Figure 3).

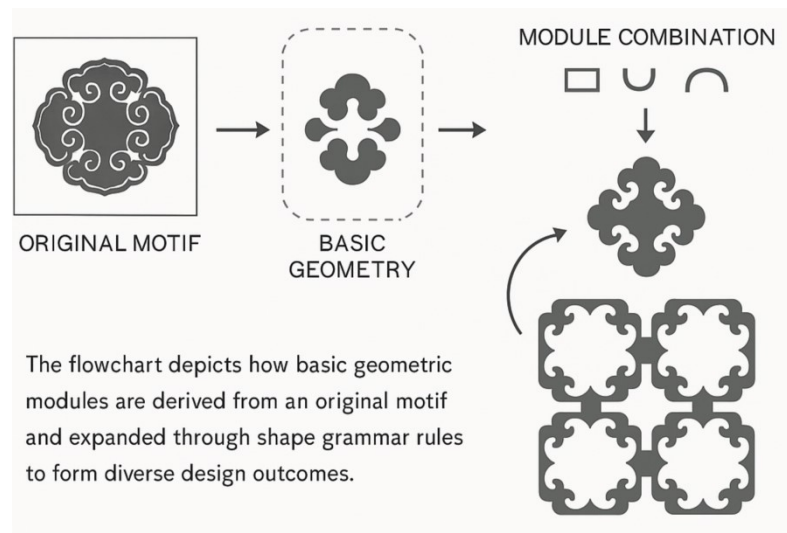


Figure 3. Shape Grammar Modelling of Traditional Textile Motifs

Interactive Design Platform Construction

Following motif modelling, the study developed a digital interactive design platform (an integrated system that enables users to manipulate, visualise, and recompose design elements in real time). Within this platform, users were empowered to select, adjust, and reconfigure traditional patterns using real-time visual feedback.

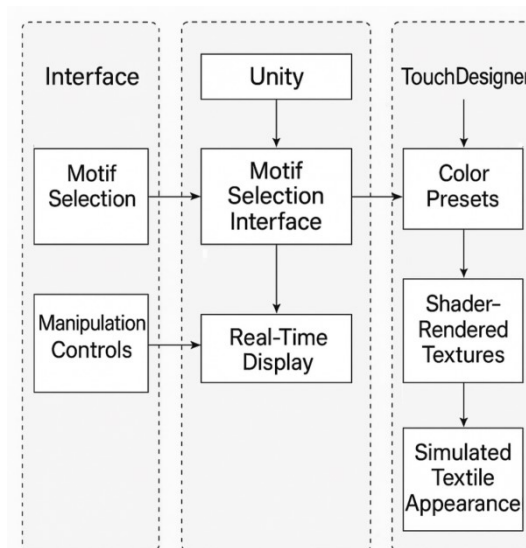


Figure 4. Digital Interaction Platform Architecture

Figure 4 details the integration of motif selection and manipulation interfaces, visual display, shader-rendered textures, and cultural colour presets using Unity and TouchDesigner environments.

The system enabled motif transformation in terms of scale, rotation, and layering, and incorporated a historically informed colour palette derived from traditional dye sources, including cinnabar red, indigo

blue, and celadon green. Additionally, simulated textile textures such as silk, gauze, and brocade were rendered via shaders to enhance user immersion and material realism. The system also supports a built-in feedback module, which captures user interactions and feeds them into the community archive and evaluation logic detailed in Section 4.4.

To clarify the division of tasks, Unity is primarily responsible for user interface management, event logic processing, and interaction data logging, ensuring seamless handling of user selections, transformations, and feedback capture. In contrast, TouchDesigner is employed for high-performance real-time graphics rendering, including shader-based visual effects, motif dynamics, and texture simulation. Interoperability between Unity and TouchDesigner is achieved via the Open Sound Control (OSC) protocol, which facilitates real-time, low-latency data exchange between the two environments. This integration ensures that user inputs processed in Unity are visually manifested in TouchDesigner, maintaining synchronisation across the interactive system.

Experimental Design and Evaluation

To evaluate the effectiveness of the interactive design system based on traditional Chinese fabric motifs, a structured experimental study was conducted. This study aimed to measure the system's performance in facilitating cultural understanding, user engagement, and perceived creative autonomy. All paired-sample t-tests were conducted as two-tailed tests using SPSS 26.0. Effect sizes (Cohen's *d*) were also calculated to assess the practical significance of the results.

Twenty participants ($n=20$) were recruited from interdisciplinary backgrounds including design, cultural heritage, and interactive media. All participants had basic digital literacy but varied levels of familiarity with Chinese textile traditions, ensuring a representative range of responses. Before the experiment, participants were briefed on the goal of the system and provided with a short tutorial on its functions.

Each participant completed three design tasks using the interactive platform:

1. Selecting a traditional motif from the digital library;
2. Modifying the motif using transformation tools (e.g., scaling, rotation, layering);
3. Applying the final design to a simulated textile surface (e.g., garment or tapestry model).

In addition to the basic comparison between users with and without design backgrounds, a deeper analysis of behavioural differences across user groups was conducted to identify patterns that could inform future system development. Specifically, a behavioural clustering analysis was performed to identify distinct user interaction patterns. This analysis revealed that users with a design background were more likely to engage with complex transformations of motifs, spending significantly more time on tasks involving geometric adjustments. In contrast, non-design users tended to focus on simpler

tasks, such as colour adjustments and scaling and demonstrated higher rates of retries on more complex interactions.

To gain further insights into user behaviour, path tracing analysis was also applied to track the steps users took during motif transformation tasks, identifying recurring difficulties such as repeated attempts to modify motif orientation or layering. These findings suggest that future iterations of the system could incorporate more explicit guidance for non-design users, particularly in tasks involving advanced transformations.

The experiment was structured into three phases:

- Pre-test, in which participants completed a questionnaire measuring baseline cultural familiarity and expectations;
- Task interaction, during which screen recordings and behavioural observations were collected;
- Post-test, including a Likert-scale questionnaire and semi-structured interviews assessing usability, cultural resonance, and emotional connection to the motifs.

Data collection included both quantitative metrics (task completion time, system usage frequency, Likert scores) and qualitative feedback (user reflection, cultural associations, design satisfaction).

The evaluation results showed that users with initially low familiarity with traditional textile aesthetics reported an increased appreciation and emotional connection after engaging with the platform. Most participants agreed that the interactive manipulation of motifs enhanced their understanding of symbolic meanings and empowered them to create personalised yet culturally grounded outcomes. The clustering and path tracing analyses provided a deeper understanding of user engagement with the system. Non-design users exhibited a higher incidence of retries in tasks requiring precise geometric adjustments, suggesting that these users may benefit from more intuitive design aids or step-by-step guidance. Conversely, design-background users demonstrated faster completion times in transformation tasks, likely due to their familiarity with visual design principles. To visually illustrate these behavioural differences, Figure 5 presents a comparative overview of task completion time and retry frequency across the three core phases. The results highlight the necessity for an adaptive system that can tailor user experiences based on individual cognitive profiles and professional backgrounds.

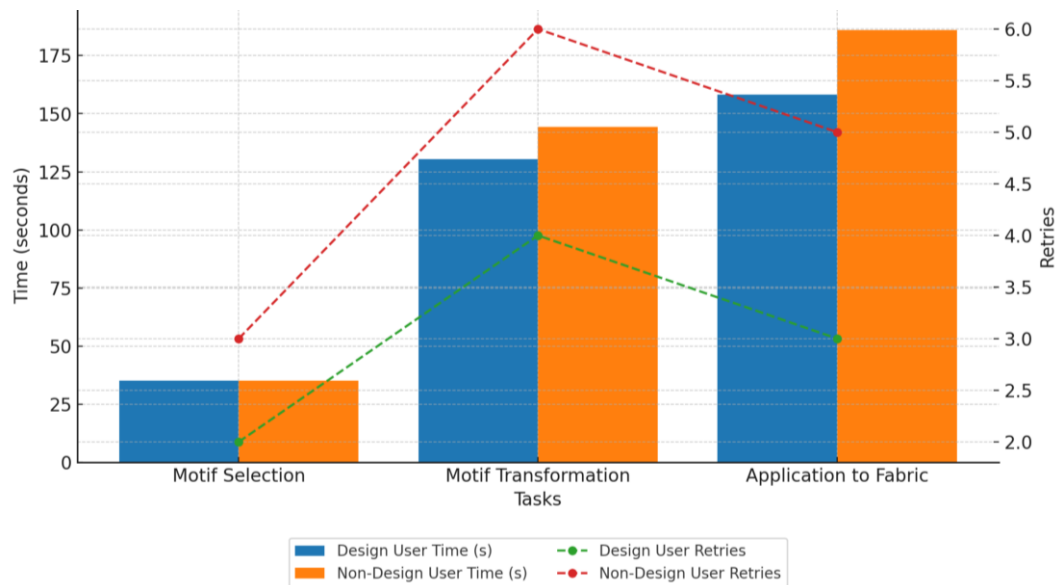


Figure 5. Comparison of task completion time and retry frequency for users with and without design backgrounds across three interaction phases (motif selection, transformation, and application)

CASE STUDY: CHINESE TEXTILE MOTIF DIGITIZATION

Motif Selection and Semantic Deconstruction

To demonstrate the system's applicability across diverse textile traditions, including Song brocade and ethnic weaving, this section presents a focused case study on Yunjin (Nanjing brocade), chosen for its symbolic richness and cultural prestige. As one of the most culturally significant forms of Chinese textile art, Yunjin provides an ideal context to demonstrate how traditional motifs can be computationally reinterpreted using the proposed framework.

A structural analysis was first performed to identify the motif's base unit and repetition logic. The design exhibits radial symmetry with modular floral and cloud elements forming a continuous repeat pattern. Semantic segmentation of the pattern was conducted to classify components based on cultural meaning and structural function.

To visualise the complete process from heritage reference to digital reassembly, a full translation pipeline was developed. This pipeline consists of four key stages: (1) sourcing high-resolution archival imagery, (2) conducting vector-based extraction of key motifs, (3) applying parametric modularisation through Grasshopper scripts, and (4) enabling interactive manipulation via a dynamic visual interface.

Interactive Application Scenario

To demonstrate the real-world design application of the digitised Yunjin motif, an interactive visual interface was developed. This interface allows users to explore, manipulate, and recompose textile patterns in real time, emphasising cultural learning through experiential engagement.

The interaction system was constructed using Unity and TouchDesigner, enabling both desktop and installation-scale deployment. Within this system, users can freely adjust pattern scale, orientation, layering, and colour palette through touch or mouse gestures. The interface also supports material simulation, rendering textile surfaces with visual effects that mimic silk, brocade, and gauze textures. Three application scenarios were designed to represent different cultural and commercial use cases:

Touchscreen Pattern Wall

A large-format digital wall allows museum or exhibition visitors to touch-select and reassemble traditional motifs. The interface responds to gestures by transforming the motif's geometry and colour in real time, creating a personalised design output rooted in historical elements.

Clothing Customisation Interface

An e-commerce prototype enables users to apply their customised motifs to virtual garments such as jackets, scarves, and robes. The garments are rendered with draping simulation to preview textile flow and pattern placement, bridging heritage with fashion technology. As shown in Figure 6, a digitally simulated traditional Chinese jacket was generated using a user-customised motif featuring a lotus and auspicious cloud pattern. The garment visualisation showcases how traditional symbolic forms can be seamlessly embedded within modern clothing silhouettes, enabling culturally expressive fashion outcomes that reflect both heritage and personalisation.



Figure 6. Digitally simulated garment integrating user-designed lotus and cloud motif within a traditional Chinese jacket

Digital Exhibition Hall: A 3D digital gallery showcases multiple variants of the translated Yunjin motif in architectural, textile, and accessory forms. Visitors navigate the space through an avatar or touchscreen, accessing additional layers of information on the pattern's history, meaning, and stylistic evolution. Figure 7 presents interface snapshots from the three application scenarios, capturing the

dynamic interaction between user input and motif behaviour. These visualisations emphasise the flexibility of the system in supporting education, cultural transmission, and creative design applications.

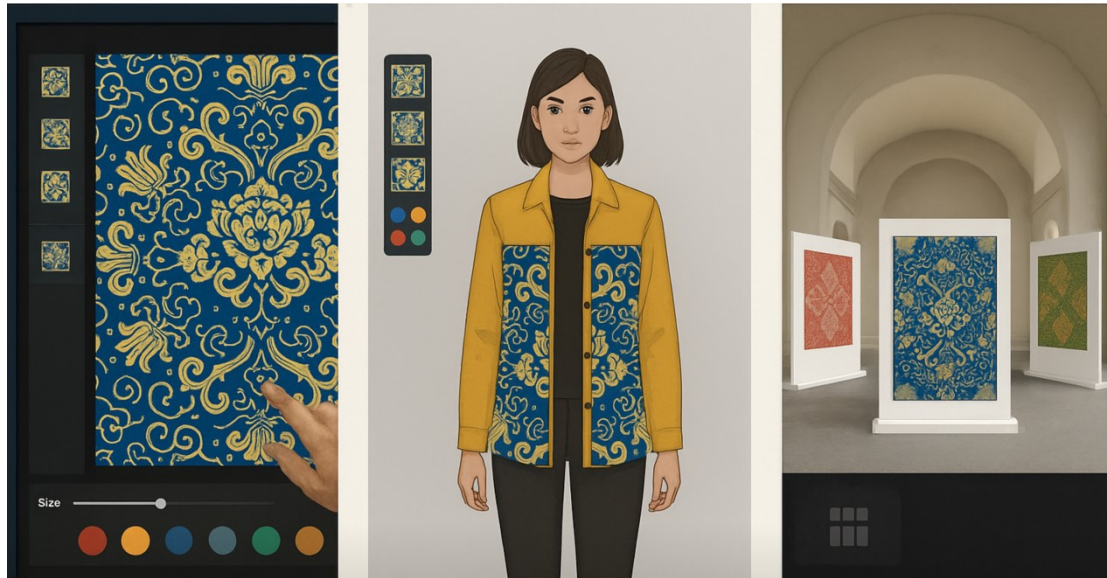


Figure 7. Interactive application scenarios including touchscreen pattern wall, virtual clothing customisation interface, and digital textile exhibition hall (Each scenario interface includes gesture-based or parameter-driven modules, real-time preview areas, and embedded semantic annotations)

User Experience and Interaction Flow

To ensure that the digitised motif system supports the intuitive operation and fosters cultural engagement, this section presents a structured user interaction framework. The experience design follows a sequential model from motif selection to customised output.

The process begins with the motif library interface. Users are presented with a categorised collection of traditional patterns, which are organised based on cultural origin, visual attributes, and encoded meanings. After selecting a motif, users proceed to the editing interface. Within this environment, they can adjust parameters such as size, rotation, colour configuration, and layering position. These adjustments are displayed in real time, allowing for continuous visual feedback and iterative refinement. As shown in Figure 8, the system interface is composed of three clearly defined sections: a motif library panel, a parameter adjustment panel, and a real-time preview display. Users can intuitively browse design elements, control geometric and chromatic parameters via slider-based input, and observe immediate visual feedback as motifs are recomposed. This modular interface structure ensures transparency of transformation logic while enhancing creative fluency.

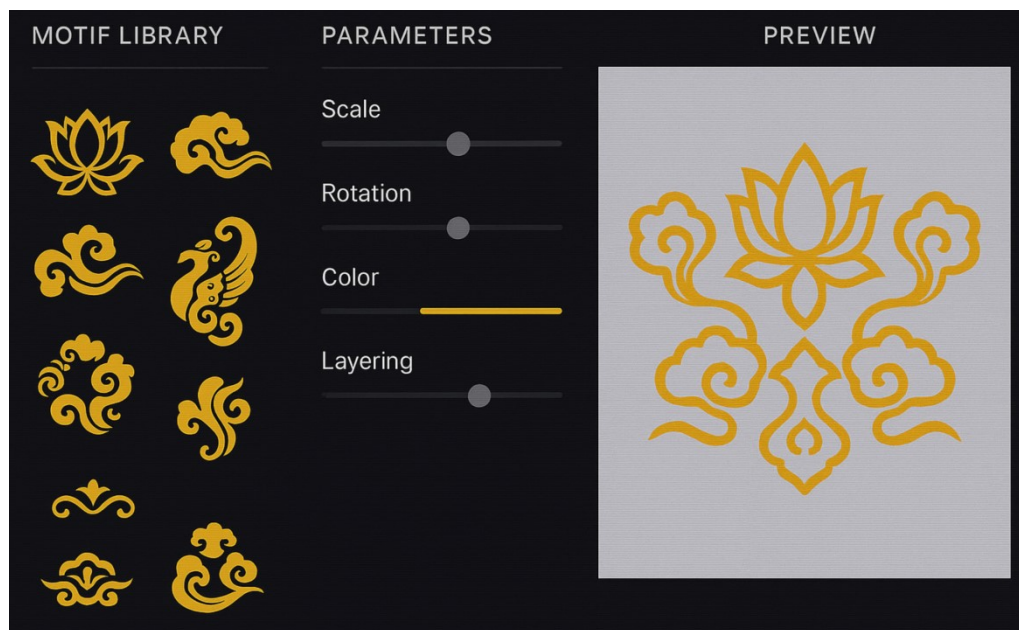


Figure 8. Interface of the Interactive Design Platform Featuring Motif Library, Adjustable Parameters, and Real-Time Preview

The next stage introduces a contextual preview interface. In this space, users can view the application of their customised motifs onto simulated textile products. The platform includes visual rendering functions that replicate the surface texture, reflective properties, and drape behaviour of fabrics such as silk, gauze, and brocade. This feature assists users in evaluating both the visual impact and material realism of their designs.

To enhance cultural understanding, the system also includes an embedded information overlay. As users interact with design elements, relevant semantic annotations are displayed. These include historical references, traditional usage contexts, and interpretations of symbolic motifs. The combination of visual design and embedded knowledge enables users to form a more comprehensive understanding of the textile's cultural significance.

At the final stage, users may export their outcomes in a variety of formats. These include scalable vector files for digital printing, texture maps for 3D visualisation, and video animations for virtual display. This flexibility enables the platform to support applications in education, cultural communication, product customisation, and virtual exhibition.

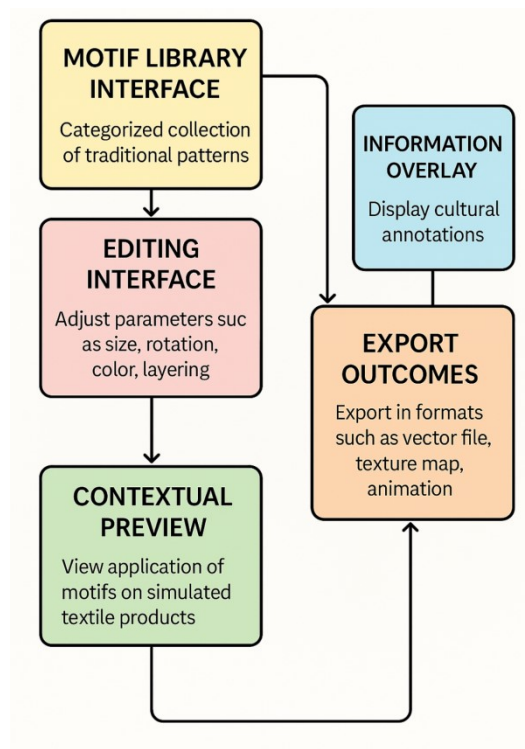


Figure 9. User Interaction Flow within the interactive design platform for Traditional Textile Motif Recombination, showing the sequential steps from motif selection to parameter editing, preview, and export, with interface panels clearly labeled for intuitive user guidance

This framework in Figure 9 illustrates how computational tools can support individualised creativity while maintaining respect for cultural authenticity. It demonstrates the potential of interactive design platforms to serve as both creative engines and educational platforms for traditional visual heritage.

User-Centred Cultural Feedback Loop

To ensure sustainable interaction between digital innovation and cultural preservation, a user-centred cultural feedback loop was designed and integrated into the interactive textile motif system. This feedback mechanism functions as an iterative, reflective interface that continuously captures user interactions, cultural interpretations, and personal preferences, subsequently informing the ongoing refinement and cultural accuracy of the interactive platform.

During the user interaction sessions described in Section 3.4, the platform systematically recorded detailed behavioural analytics, including patterns of motif selection, frequency and style of motif transformations, time spent on each design task, and overall interaction sequences. These data streams provided valuable quantitative insights into user preferences, highlighting favoured motifs, common modification techniques, and interaction challenges encountered by different user groups. Complementing this quantitative data collection, the platform actively elicited qualitative reflections from users through context-aware prompts embedded within the interface. As users engaged in motif

transformation, the system dynamically presented annotations and reflective questions about the historical, cultural, and symbolic significance of the motifs being manipulated. Users were invited to reflect upon and articulate their personal perceptions or emotional responses to these motifs, facilitating deeper cultural engagement and personalisation of the heritage content.

Furthermore, to foster a participatory cultural exchange, the platform established a digital archive feature, allowing users to share their customised design outcomes with the broader community. Within this online repository, users could view, comment on, and collaboratively evaluate designs based on criteria such as cultural authenticity, aesthetic innovation, and symbolic resonance. This community-driven evaluation promoted active user participation in heritage reinterpretation, effectively transitioning users from passive recipients of traditional content to active co-creators and curators of digital cultural heritage.

The implementation of this user-centred cultural feedback loop created a meaningful dialogue between contemporary digital experiences and traditional cultural narratives, generating continuous opportunities for enhancing both the interactive design framework and the authenticity of cultural representations. As shown in Figure 10, this feedback loop encompasses user input collection, reflective dialogue, and community-based curation, ultimately contributing to a self-evolving digital heritage ecosystem capable of adapting to diverse user expectations and interpretations.

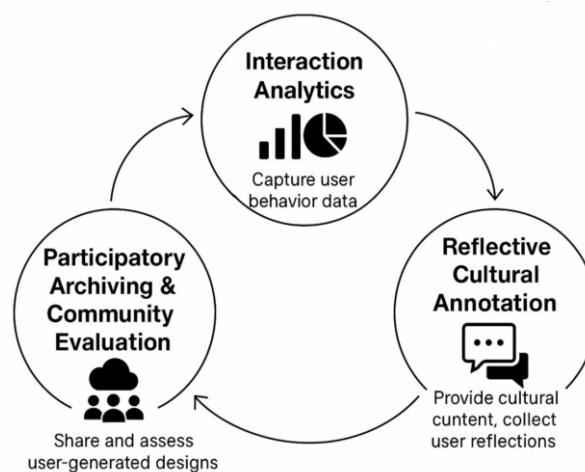


Figure 10. User-Centred Cultural Feedback Loop in the Interactive Textile Motif System

As illustrated in Figure 11, the platform's community archive interface enables users to submit and share customised motif designs. Each motif tile displays interaction metadata such as likes, comments, and semantic annotations. A filtering system on the right side of the interface allows viewers to sort motif contributions by historical origin, symbolic theme, or traditional function. This participatory repository enhances both cultural exchange and collective interpretation, making the system a dynamic space for living heritage documentation.

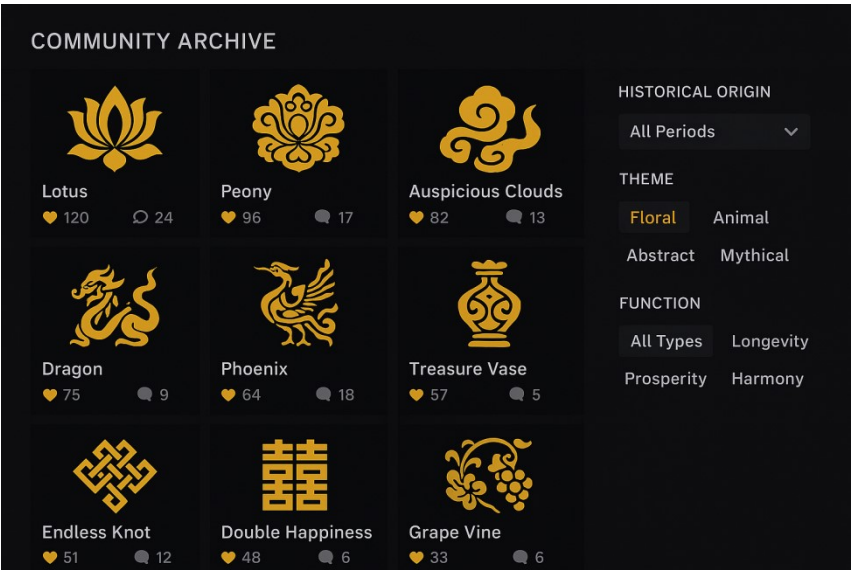


Figure 11. Community archive interface displaying user-submitted motifs with interaction metrics and semantic filters

RESULT AND DISCUSSION

Quantitative Results and System Performance Evaluation

To quantitatively evaluate the performance of the interactive design system and its capacity to promote cultural understanding, a series of behavioural and attitudinal metrics were collected during the user study. These metrics included task completion time, pre- and post-test scores on cultural familiarity, system usability ratings, and interaction frequency logs. The results provide evidence of both operational efficiency and measurable cognitive impact among participants.

Participants were asked to complete three tasks using the interactive motif system: (1) selecting a traditional pattern, (2) modifying its form through transformation tools, and (3) applying the final result to a virtual textile surface. As shown in Table 1, participants completed all tasks within reasonable time frames, suggesting a high degree of usability and intuitive design.

Table 1. Average Task Completion Time and Standard Deviation across Design Phases

Task Phase	Mean Time (seconds)	Standard Deviation
Motif Selection	35.2	6.8
Motif Transformation	144.3	22.5
Application to Virtual Fabric	186.0	27.4

To assess the platform’s cultural impact, participants completed a pre-test and post-test cultural familiarity scale ranging from 1 (no familiarity) to 5 (strong familiarity) with Chinese textile motifs. Participants were divided into two groups based on their initial cultural knowledge: Group A (Low

familiarity, $n=10$) and Group B (Moderate familiarity, $n=10$). As illustrated in Figure 12, both groups showed increases in cultural understanding following the interaction, with the improvement more pronounced in Group A.

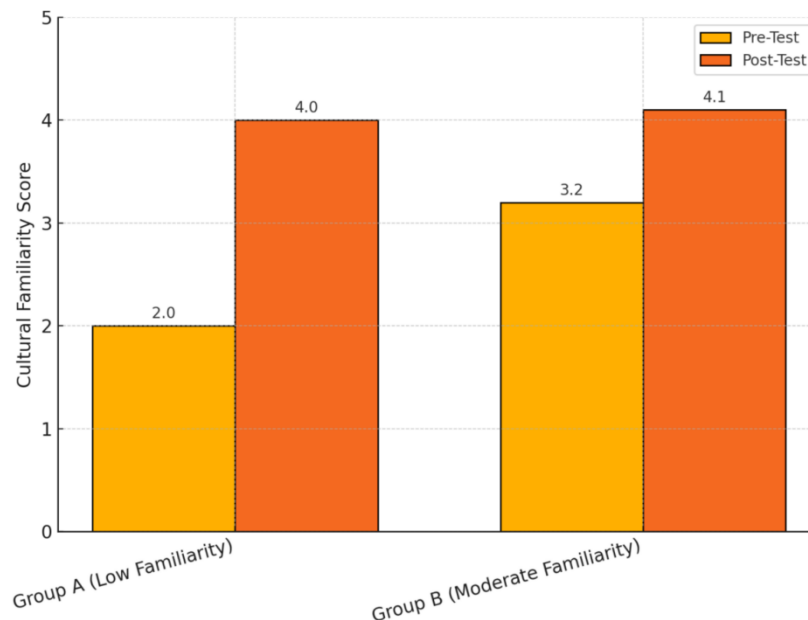


Figure 12. Cultural Familiarity Score Changes: Pre-Test vs Post-Test

A paired-sample t-test conducted for each group revealed statistically significant gains in cultural familiarity for Group A ($t(9) = 8.34$, $p < 0.001$, Cohen's $d = 2.6$) and a moderate yet significant increase for Group B ($t(9) = 3.12$, $p = 0.012$, Cohen's $d = 0.9$). These results demonstrate the platform's strong capacity to bridge cultural knowledge gaps, particularly for users without prior exposure to traditional Chinese textile heritage. The large effect sizes further confirm the practical significance of these knowledge gains.

In addition to knowledge gains, participants rated the system's usability using the System Usability Scale (SUS). The average SUS score across all participants was 85.2 out of 100 ($SD = 5.6$), placing the system in the "excellent" usability tier. This result suggests that the system's interaction mechanisms are not only functionally accessible but also positively received by users from diverse disciplinary backgrounds.

Collectively, these quantitative findings validate the platform's design objectives: enabling efficient task execution, fostering culturally meaningful engagement, and lowering the barrier to traditional knowledge acquisition through digital interactivity.

User Feedback and Interpretation

In addition to the quantitative performance metrics discussed in the previous section, qualitative data were obtained through post-task semi-structured interviews. These interviews were designed to elicit participants' subjective impressions, emotional responses, and interpretive reflections on their interaction with the motif interactive design platform. The thematic analysis of the interview content revealed several recurring dimensions of user experience, including emotional immersion, cultural engagement, and intuitive creative flow.

A significant number of participants reported that the ability to directly manipulate traditional Chinese motifs within an interactive digital environment fostered a stronger emotional connection with the underlying cultural content. Users described their experience as “immersive”, “meaningful”, and “spiritually engaging”, particularly when motifs were accompanied by dynamic annotations that explained their symbolic origins. One participant reflected that “once I understood the symbolic function of the cloud pattern, I began designing with greater intention rather than just visual balance.” This shift from aesthetic experimentation to culturally informed design suggests the platform's effectiveness in deepening interpretive engagement.

To better understand the qualitative dimensions of user experience, a frequency analysis was conducted on the interview transcripts. As illustrated in Figure 13, the most frequently used descriptors included terms such as immersive, authentic, creative, and intuitive. The prominence of such terms indicates that users not only appreciated the cultural content embedded in the platform but also found the interaction flow to be cognitively accessible and emotionally resonant.

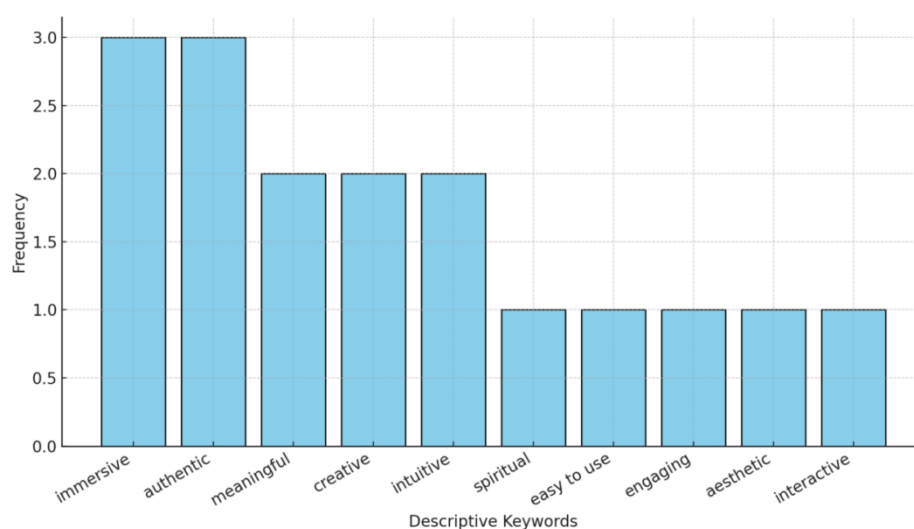


Figure 13. Frequency of Key Emotional and Descriptive Terms

The interface design was widely praised for its clarity and responsiveness. Users noted that the real-time visual feedback during motif manipulation (e.g., scaling, rotation, layering) enabled a sense of design agency. Even those with no formal background in visual design expressed confidence in their ability to generate aesthetically and culturally coherent outputs. The system's low learning threshold and high visual responsiveness were repeatedly cited as contributing factors to a positive user experience.

Beyond usability and creative empowerment, several participants emphasised the emotional and mnemonic value of the motifs themselves. Motifs such as peonies, lotuses, and auspicious clouds were described as evoking personal memories, intergenerational narratives, and spiritual reflections. For instance, one participant associated the peony design with childhood memories of their grandmother's traditional garments, while another noted that the lotus motif "felt quietly sacred, like something to be respected, not just redesigned." These reflections highlight the potential of interactive design systems to serve not only as tools for visual creativity but also as interfaces for affective cultural memory.

Nevertheless, some participants expressed a desire for deeper historical contextualization and comparative cultural insight. While the embedded annotations were considered informative, users suggested the addition of layered narratives that might include temporal evolution, regional stylistic differences, or connections to other craft traditions. These suggestions point toward future opportunities for enriching the system's educational dimensions through integrated multimedia storytelling and comparative motif analysis.

Taken together, these qualitative findings demonstrate that the platform successfully facilitated an integrated user experience that combines intuitive creative interaction with culturally anchored meaning-making. The consistency between emotional keywords and design reflections provides further evidence that interactive design platforms can promote not only engagement and usability but also cultural empathy and reflective learning.

Theoretical and Design Implications

The empirical findings of this study carry broader implications for both the theoretical discourse surrounding digital cultural heritage and the practical design of interactive design platforms. By integrating parametric modelling, semantic annotation, and user-centred feedback into a unified framework, the platform demonstrates a novel approach to the reinterpretation of traditional visual culture.

From a theoretical standpoint, this research extends the application of shape grammar theory into the domain of intangible heritage, illustrating how rule-based geometric structures can be embedded with symbolic meaning. This combination not only facilitates visual variation within culturally appropriate

boundaries but also reinforces the epistemological alignment between traditional design logics and computational generation. The result is a system that does not merely simulate traditional forms but structurally encodes their cultural semantics, ensuring that even user-customised outputs remain conceptually authentic.

The methodological structure adopted in this study highlights the importance of combining quantitative performance analysis with qualitative cultural reflection. The use of behavioural data (such as task completion times and system usage patterns), when paired with affective and interpretive user feedback, produces a multidimensional understanding of user interaction. This is further enhanced by the integration of a user-centred cultural feedback loop, which captures not only interaction efficiency but also the personal and emotional responses elicited by traditional motifs.

Additional analysis of user performance based on academic background reveals that both design-trained and non-design participants achieved high usability scores, though with different interaction patterns. As shown in Figure 14, participants with a design background completed motif transformation tasks more quickly (mean = 130.5 seconds) than those from non-design fields (mean = 158.2 seconds). However, the difference in system usability scores was modest, with design users reporting a slightly higher average score (88.1) compared to non-design users (82.3). This finding underscores the platform's inclusive usability: while design experience may improve task efficiency, the overall interface remains accessible and positively received across user groups.

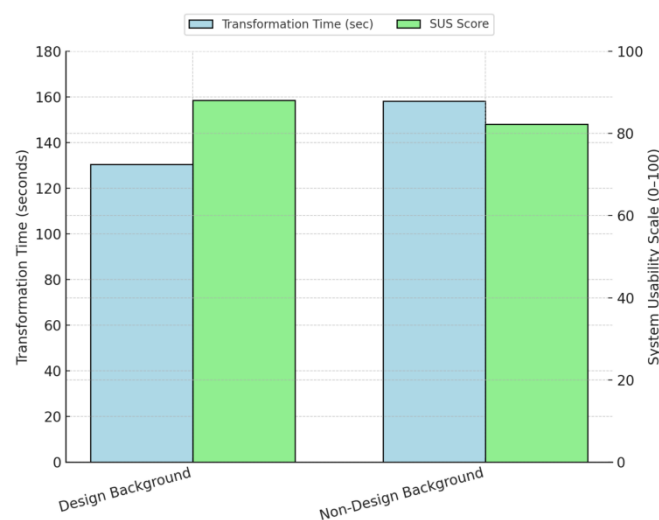


Figure 14. Comparison of Task Performance and Usability by User Background

The platform's generalizable framework suggests strong potential for adaptation to other cultural contexts. Although this study focused on Chinese textile motifs, the technical architecture, consisting of vector-based motif modelling, semantic structuring, and interactive visualisation, is not culturally exclusive. Future adaptations could incorporate design traditions from other regions, such as South

American weaving, Islamic geometric art, or West African kente cloth. By encoding culturally specific design grammars into flexible interactive design platforms, designers can create platforms that support both heritage conservation and contemporary reinterpretation.

Finally, the study emphasises the significance of affective engagement in digital heritage systems. Users did not merely interact with visual forms; they formed emotional and symbolic connections through personalised design activities. The findings suggest that digital heritage platforms should not only focus on technical accuracy or content richness, but also address the emotional dimensions of user experience. Designing for emotional resonance, cultural memory, and personal creativity constitutes a critical aspect of meaningful digital heritage interaction.

Beyond the current implementation of embedded semantic annotations, the findings suggest that expanding the cultural information layer into a structured, multi-tiered storytelling mechanism holds significant promise for future iterations of the system. Such a layered approach could offer users the flexibility to navigate cultural knowledge at different depths, ranging from basic symbolic identification to more comprehensive contextual histories, stylistic evolutions, and regional variations. By allowing users to choose the level of detail they wish to explore, the interactive platform has the potential to transform from a primarily aesthetic engagement tool into a dynamic learning environment that fosters sustained cultural curiosity and interpretive depth.

In conclusion, this study contributes a comprehensive model for interactive heritage systems that integrates cultural authenticity, creative agency, and educational value. It offers a viable direction for future research and design practices in fields ranging from digital humanities to computational creativity and cultural informatics.

CONCLUSION

This study demonstrates an integrated approach for the digital reinterpretation of traditional Chinese textile motifs through the combination of parametric modelling, interactive manipulation, and semantic annotation. By systematically extracting structural elements from heritage patterns such as Yunjin and Song brocade, the framework translates historical visual languages into programmable modules informed by shape grammar theory, ensuring that user recombination remains stylistically coherent and culturally meaningful.

The interactive platform enables users to work with traditional motifs in ways that encourage both creative exploration and reflective cultural engagement. Empirical evaluation shows that this process supports not only intuitive design experimentation but also deeper cognitive and emotional connections, particularly for individuals with limited prior exposure to these textile traditions. The

positive response to embedded cultural explanations highlights the potential for digital systems to facilitate more intentional reinterpretation of traditional forms.

An important contribution of this work lies in its balance between computational rigour and interpretive openness. Unlike static archival methods, this approach positions motifs as living design elements that can evolve through user interaction while remaining grounded in cultural logic. Nonetheless, the current implementation remains primarily visual and structural. Future refinements could introduce tactile feedback, more advanced material simulation, or immersive environments to communicate the sensory qualities of textiles more effectively. While this study centres on Chinese motifs, the underlying framework is readily adaptable and could be extended to other craft traditions, enabling comparative perspectives in digital heritage practice.

Findings also indicate that the semantic layer could be developed further into a more structured narrative format. A multi-layered approach to cultural information, moving from basic symbolic recognition to contextual history, stylistic development, and regional variation, would expand the system's educational capacity and allow users to access content at a depth appropriate to their interests. This would transform the interaction from aesthetic manipulation alone into a more substantial process of cultural learning.

In sum, this research offers a practical and adaptable model for bridging intangible heritage with contemporary interactive design. By integrating algorithmic techniques with meaningful cultural interpretation, the system demonstrates how digital tools can sustain both conservation and creative renewal, transforming traditional motifs from static references into dynamic, living elements within evolving cultural practice.

Author Contributions

Conceptualization – Ge H and Gao S; Methodology – Ge H and Gao S; Formal analysis – Ge H and Gao S; Investigation – Ge H; Resources – Ge H; Writing – original draft preparation – Ge H and Gao S; Writing – review and editing – Gao S; Visualization – Ge H; Supervision – Gao S. 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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