Article

Research on the Integrated Design of Art and Craftsmanship of Song Brocade Patterns in the Digital Intelligence Era: Smart Children's Sports Shoes as an Example

Xueyi Yao[1], **Wei Pan**[2*]

1 Suzhou University of Technology, Suzhou, 215500, China
2 Kangwon National University, Chuncheon, 24341, Republic of Korea
*Correspondence: pw123815@163.com

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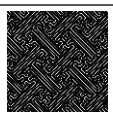
Abstract: ***Background:*** Digital intelligence has expanded Song brocade research from digital preservation to innovative design, yet existing studies largely focus on pattern replication, AI-based generation, and conventional cultural and creative applications. Challenges remain in technical definition, cultural authenticity, smart-product transformation, and art–craftsmanship integration. ***Purpose:*** This study clarifies the boundaries among digitization, digital intelligence, and intelligentization, defines art–craftsmanship integration in the context of intangible cultural heritage (ICH), and explores the contemporary transformation of Song brocade patterns in smart product design. ***Methods:*** Focusing on Suzhou Song brocade, this study digitally extracts and reconstructs Ruyi cloud, Baoxiang flower, and water-wave patterns. These motifs were translated through high-precision embroidery and integrated with lightweight composite materials, positioning sensors, and flexible LED modules to develop the "With Brocade, Grow with Kids" smart children's sports shoes. ***Results:*** The study demonstrates that digital intelligence can transform Song brocade patterns from static decorative motifs into controllable design resources, while high-precision embroidery provides a feasible craft translation path from brocade texture to footwear structure. The narrative association between pattern meaning and smart functions further strengthens the coherence among cultural symbolism, product function, and the interactive experience for children. ***Conclusion:*** A digital-intelligence-enabled art–craftsmanship integration model based on deep artistic and engineering collaboration can enhance the contemporary vitality of ICH and provide a reference paradigm for the modern product transformation of traditional brocades.

Keywords: Song brocade; digital intelligence; art–craftsmanship integration; smart children's sports shoes; intangible cultural heritage

1. Introduction

ICH is an important vehicle for rich traditional Chinese culture, while traditional arts and crafts embody national aesthetic taste, craft wisdom, and life philosophy. Song brocade originated in the Song Dynasty and is mainly produced in Suzhou, China. Because of its flat and firm texture, regular patterns, elegant colors, and strong literati aesthetic, it is known as the "crown of brocades" and, together with Shu brocade and Yun brocade, is regarded as one of China's three major brocades (Liu, 2024). Song brocade integrates silk-weaving techniques, pattern art, color aesthetics, and auspicious symbolism. Its core characteristics are reflected in its meticulous craftsmanship, structured patterns, refined color palettes, and rich symbolic meanings. As summarized in Table 1, representative Song brocade patterns differ systematically in motif category, structural form, visual characteristics, and symbolic meaning.

Table 1. Characteristics of representative Song brocade patterns

Subject	Pattern name	Pattern sample	Pattern outline	Pattern features	Symbolic meaning
Floral and plant motifs	Broken-branch pattern			An independent motif that depicts part of a flower or plant without connected stems; each element remains complete and self-contained.	Its meaning is generally related to the specific flower or plant depicted.
Floral and plant motifs	Continuous-scroll pattern			Uses plant branches as a structural framework extending outward to form two-way or four-way continuous patterns of repetition and continuity.	Symbolizes endless vitality and continuity through generations, suggesting the prosperity and eternity of life.
Animal motifs	Dragon pattern			The dragon body winds in a smooth S-shaped movement; the composition is slender and refined, with archaic and elegant colors and a graceful character.	Symbolizes imperial dignity, auspicious longevity, authority, and wisdom.
Animal motifs	Phoenix pattern			Often composed as paired phoenixes, pearl-linked paired phoenixes, or circular phoenix motifs in symmetrical arrangements. The overall form is gentle, graceful, light, and delicate, with fine and flowing lines.	Symbolizes auspiciousness, beauty, wealth, fidelity, and marital harmony.
Geometric motifs	*Wan*-character pattern			Formed by multiple *Wan* (卍) characters in a four-way continuous pattern; its four ends can extend indefinitely and evolve into various brocade patterns.	Connotes unending continuity, boundless blessings, and longevity.
Composite motifs	Badayun pattern			Takes the main flower as the center and radiates in eight directions in a rice-shaped structure, filled with flowers, birds, and animals to create an intricate, delicate, magnificent, and dignified effect.	Connotes access in all directions and abundant fortune.
Composite motifs	Turtle-back pattern			Derived from the shape of a tortoise shell, using a regular hexagon as the framework and often filled with flowers in four-way continuous repetition.	Symbolizes longevity and auspiciousness.

Today, Song brocade faces challenges such as difficulties in resource preservation and a disconnection between pattern innovation and modern life. In the past five years, as big data, AI, computer vision, digital twins, and related technologies have increasingly been integrated into traditional arts and crafts, research on Song brocade patterns has gradually shifted from digital preservation to digital-intelligence design innovation, forming a more complete system ranging from data acquisition to industrial application. At present, Chinese research on the digital preservation, pattern extraction, intelligent design, and industrial transformation of Song brocade has produced significant outcomes. Major research institutions are concentrated in universities, silk museums, ICH protection centers, and related enterprises in the Yangtze River Delta region. Research perspectives have gradually moved from early explorations of technical applications toward deeper concerns regarding cultural authenticity, craft integration, and industry–university–research collaboration (Song & Chen, 2025).

Focusing on the digital-intelligence design of Song brocade patterns, this paper explores the implementation mechanisms underlying the digital transformation of traditional arts and crafts. Traditional design models, which are based mainly on hand drawing and experiential inheritance, can no longer meet the demands of modern design efficiency and industrial development. By reviewing research progress, summarizing practical experience, reflecting on existing challenges, and proposing optimization paths, this study provides systematic insights into the digital-intelligence design of Song brocade patterns (Su et al., 2025). Digital-intelligence design not only improves the design efficiency and innovation capacity of Song brocade patterns, but it also promotes the

modernization of traditional arts and crafts while preserving cultural genes, thereby becoming an important direction for the living inheritance of ICH (Wei et al., 2024). This study is intended to provide a foundation for theoretical research and design practice in related fields.

2. Literature Review and Theoretical Basis

2.1 Literature Review

As AI technology has rapidly entered the fields of traditional arts and crafts and ICH design, relevant research has shifted from isolated forms of digital presentation to comprehensive explorations of generative design, cultural-semantic translation, and product application. In Song brocade studies, Hu and Shu (2024) examined the innovative digital applications of traditional patterns in fashion design using Tianhua brocade patterns as an example, emphasizing the relationship among pattern extraction, formal recombination, and garment application. Mao and Su (2025) further explored an artificial intelligence-generated content (AICG)-driven design path for generating two-dimensional (2D) images and three-dimensional (3D) models of Badayun patterns, extending Song brocade pattern research from the reproduction of flat images to visual modeling and spatial transformation. Regarding the digital transformation of ICH and creative goods, Liu et al. (2024) examined the transformation paths of cultural heritage resources in product development, communication mechanisms, and industrial upgrading from an AIGC perspective. Yun (2026), focusing on the Pan embroidery of the Tu ethnic group, discussed the AIGC-enabled transformation of visual genes of ICH and its translation path for the textile and apparel industry. These studies collectively indicate that AI is not merely an image-generation tool; rather, it is increasingly participating in the extraction of visual genes, reorganization of structural rules, recoding of cultural symbols, and adaptation of traditional patterns to product scenarios.

At the methodological level, Pang and Jiang (2025) conducted a form–meaning deconstruction study of Song brocade patterns based on AIGC technology. They used shape grammar to generate innovative patterns and applied them to home textiles and cultural and creative design, reflecting a research orientation that moves from the structural recombination of "form" to the cultural reinterpretation of "meaning." Li and Chen (2026) explored the graphic reconstruction of Yantai paper-cutting art through AIGC and its integration with interior decoration, providing a reference for the spatial expression of graphic language in ICH. In broader technological and artistic research, Kocsis et al. (2003) discussed the relationship between image quality and computer-generated test images in medical imaging systems, offering cross-disciplinary implications for precision control and quality evaluation in digital image processing. Ho (2025) emphasized in a study of cross-cultural affective design that creative AI must consider both local cultural semantics and cross-cultural reception mechanisms to reduce the risk of cultural distortion in the digital reconstruction of traditional patterns. Darda et al. (2025) demonstrated, through a comparative study of art engagement across physical museums and digital media, that digital media can expand public access to art and ICH resources, thereby providing methodological references for the modern communication of Song brocade culture. Overall, existing research has laid a technical and methodological foundation for the digital-intelligence design of Song brocade patterns, but three limitations remain. First, most studies focus on pattern generation or visual style transfer, with insufficient discussion of the coordination among weaving logic, cultural-semantic authenticity, and product function. Second, the transformation chain from cultural and creative patterns to smart products remains incomplete and lacks design validation for specific user scenarios. Third, the relationship between "art" and "craftsmanship" is still often presented in parallel, without forming an operational integration framework. Therefore, this paper takes the transformation practice of Song brocade patterns in smart

children's sports shoes as its focal point and further examines the systematic relationship among digital-intelligence technology, craft translation, and cultural expression.

2.2 Theoretical Basis

1) Defining technical levels and clarifying concepts

To clarify the technical boundaries of modern innovation in traditional patterns and to avoid conceptual confusion, category expansion, or the equation of general digital processing with intelligent design, this paper defines the differences and progressive relationships among digitization, digital intelligence, and intelligentization according to the degree of technological intervention, the relationship between design agents, and modes of innovative output (Yang, 2009). These three concepts are not interchangeable; rather, they represent a progressive process from resource preservation and knowledge organization to design generation. Their boundaries directly determine the research objects, methodological choices, and evaluation criteria for Song brocade patterns in modern product design.

Digitization is the foundational layer for the modern application of traditional patterns. It mainly refers to the transformation of physical visual resources, such as Song brocade patterns, weaving textures, and traditional motifs, into standardized digital information through image scanning, line-drawing extraction, vector reproduction, and information archiving. This process completes the translation from physical to digital forms. Its core functions are information preservation, morphological reproduction, material storage, and subsequent retrieval, which can address issues such as the vulnerability, low retrievability, and limited shareability of traditional patterns. However, its output remains primarily at the level of digital visualization and does not directly possess the capacity of rule analysis, structural inference, or design decision-making.

Digital intelligence introduces data analysis, knowledge organization, parametric modeling, and human–machine collaboration mechanisms built upon digitized resources, transforming the compositional rules, color relationships, craft constraints, and cultural meanings of patterns into design knowledge that can be calculated, retrieved, and regulated. Its purpose is not to allow machines to completely replace designers, but to use algorithmic assistance to conduct pattern analysis, rule visualization, variant generation, and scheme optimization, so that traditional patterns can be adapted to modern product requirements while maintaining cultural semantics. Intelligentization represents a higher-order technological form. Relying on artificial intelligence, deep learning, generative design models, and related technologies, it enables autonomous pattern generation, adaptive style matching, and scenario-based intelligent adaptation, focusing on machine-led decision-making and creative output (Yang & Pan, 2026). As shown in Figure 1, digitization, digital intelligence, and intelligentization form a three-stage progression from resource preservation to rule-based human–machine collaboration and, ultimately, higher-order autonomous intelligent design.

In summary, this study takes digitization as the foundation, digital intelligence as the core, and intelligentization as a future extension. It emphasizes that, at the present stage of Song brocade pattern transformation into products, the progressive path of "resource digitization–rule-based digital intelligence–application intelligentization" should be prioritized. This approach both avoids conceptual confusion while precisely limiting the technical scope of this study to human–machine collaboration, controllable reconstruction, and product adaptation.

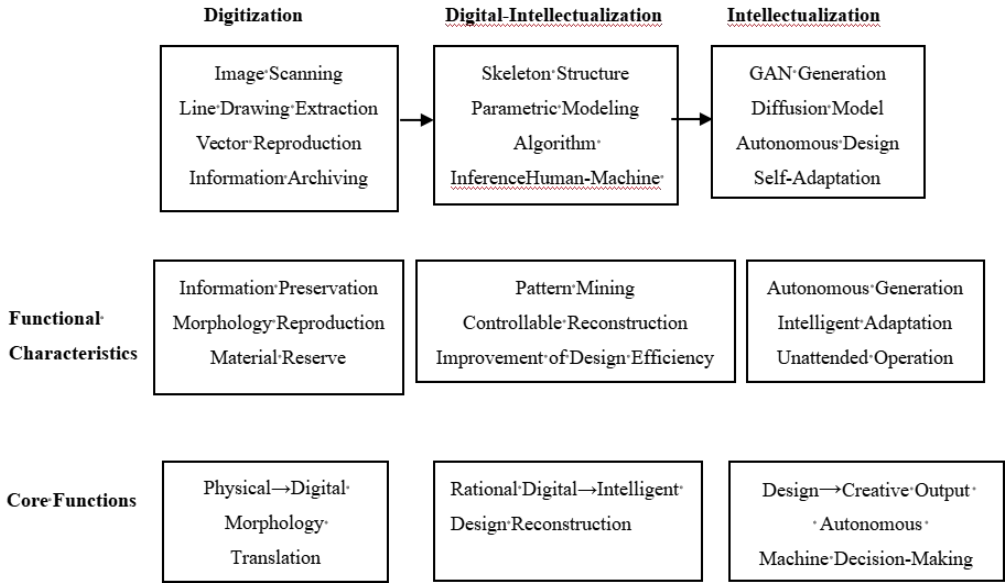


Figure 1. Three-stage progression model from digitization to digital intelligence and intelligentization
Note. Created by the author(s).

2) Connotation and research framework of art–craftsmanship integration

The art–craftsmanship integration defined in this paper (Huang, 2021) does not refer to the decorative attachment of traditional patterns to modern products, nor does it refer to the simple embedding of technical functions into cultural symbols. Rather, it proposes a bidirectional and in-depth integration paradigm for enabling modern product design through traditional Song brocade patterns. The key is to leverage traditional artistic value to guide technological choices and to use modern engineering logic to support cultural translation, so that pattern aesthetics, craft feasibility, and product function can form a mutually validating relationship within the same design system.

In this framework, "art" represents the traditional artistic core, including the visual aesthetic features, auspicious cultural meanings, traditional symbolic semantics, weaving textures, and the Chinese aesthetic system of Song brocade patterns. It serves as the cultural core and spiritual foundation of the design and determines the value orientation and aesthetic boundaries of pattern innovation. "Craftsmanship" represents modern engineering technology, specifically digital-intelligence deconstruction techniques, parametric configuration methods, structural optimization logic, product-function adaptation, and modern production pathways. It provides technical support for pattern decomposition, innovative reconstruction, material adaptation, and functional realization.

The relationship between the two is neither unilateral technological empowerment nor a superficial juxtaposition of art and engineering. Instead, it follows the cyclical logic of "art raises cultural questions–technology provides solution paths–craft verifies implementation feasibility–products respond to modern life." For Song brocade, pattern meanings, weaving textures, and color order provide the cultural starting point for design, while digital-intelligence modeling, embroidery translation, material compounding, and smart-module integration constitute the technical path for modern product realization.

Accordingly, the research framework of this paper is guided by the intangible cultural connotations of Song brocade, uses digital-intelligence design technology as its primary method, and adopts children's smart sports shoes as its application scenario. It seeks to unify the aesthetic, cultural, and practical values of traditional patterns in modern products, complete the precise translation of traditional ICH symbols into contemporary design language, and provide a verifiable innovative path for empowering contemporary design through traditional culture.

3. Digital-Intelligence Design Methods for Song Brocade Patterns

3.1 Digital Acquisition and Resource Database Construction

Digital acquisition technologies and resource database construction provide foundational support for the digital-intelligence design of Song brocade. Their task is not simply to preserve pattern images, but to transform dispersed physical samples, pattern documents, weaving textures, and cultural information into foundational data that can be identified, retrieved, analyzed, and redesigned. To address challenges such as the deterioration of traditional pattern materials, low retrieval efficiency, and sharing difficulties, high-precision scanning, multi-view photogrammetry, and hyperspectral imaging have become the primary acquisition methods. These techniques can capture detailed features, color-gradient changes, and microscopic fabric textures of museum Song brocade relics and heritage pattern samples under non-destructive conditions (Chen & Wang, 2025).

Following data acquisition, resource database construction must further achieve the structured organization and knowledge-based annotation of patterns. The core of constructing a pattern gene database is to extract multidimensional features and standardize Song brocade patterns according to subject categories, structural characteristics, color systems, craft parameters, and cultural meanings, thereby forming a Song brocade pattern gene database with retrieval, querying, and extension functions (Li & Yu, 2026). Such a database not only serves pattern retrieval but also provides rule-based support for subsequent parametric modeling, AI reconstruction, and product design, transforming patterns from static materials into knowledge units that can participate in design decision-making.

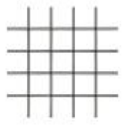
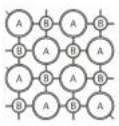
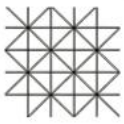
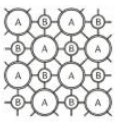
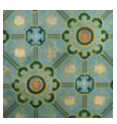
Building upon the gene database, it is also necessary to integrate associated information such as Song brocade weaving parameters, historical evolution, and cultural connotations to achieve visualized connections among pattern features, weaving techniques, and cultural semantics. Drawing upon the construction logic of intelligent art design systems based on multimodal perception and generative AI, this study connects digital acquisition, feature annotation, AI reconstruction, and intelligent design into a continuous process to ensure both the reliability of data sources and the controllability of cultural translation and product transformation in subsequent design (Hang & Li, 2025).

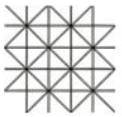
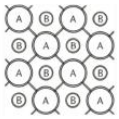
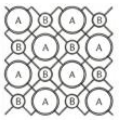
3.2 Multidimensional Digital-Intelligence Modeling and Resource Construction

Digital-intelligence modeling is the key bridge connecting traditional patterns with modern design. Its core objective is to transform the form, structure, color, craft, and cultural semantics of Song brocade into design models that are computable, generative, and controllable.

Morphological and structural analysis is a core technical step in the digital-intelligence design of Song brocade. Researchers use image-segmentation algorithms, contour-feature extraction, and parametric quantitative analysis to systematically decompose and digitally model the compositional elements, skeletal structures, and combination logic of Song brocade unit patterns (see Table 2).

Table 2. Morphological and structural analysis of representative Song brocade patterns

Name	Pattern composition	Roundel arrangement structure	Strip-like skeleton structure	Combined configuration	Physical example
Sidayun	1. Ground/small motifs: small geometric flowers and scrollwork; 2. Skeleton: orthogonal horizontal–vertical linear skeleton; 3. Roundel: square and circular main roundels.	Roundels are arranged in a regular matrix, aligned horizontally and vertically, evenly spaced, and strongly ordered.			
Badayun	1. Ground/small motifs: flowers, scrollwork, and small geometric flowers; 2. Skeleton: eight-directional radial skeleton in a rice-shaped structure;	Roundels are arranged at the intersections of the rice-shaped skeleton in a radiating symmetrical pattern, with clear hierarchy between			

Name	Pattern composition	Roundel arrangement structure	Strip-like skeleton structure	Combined configuration	Physical example
	3. Roundel: octagonal and circular main roundels.	main roundels and auxiliary small flowers.			
Tianhua brocade (1)	1. Ground/small motifs: fine flowers, coin patterns, and geometric motifs; 2. Skeleton: oblique diamond-cross skeleton; 3. Roundel: circular and polygonal main roundels.	Roundels are distributed at the nodes of the diamond grid in an oblique and staggered arrangement, orderly and rhythmic.			
Tianhua brocade (2)	1. Ground/small motifs: Baoxiang flowers, eight-petal flowers, and auspicious small flowers; 2. Skeleton: oblique diamond-cross skeleton; 3. Roundel: large circular main roundels.	The enlarged main roundels are arranged prominently, with auxiliary small flowers filling the gaps. The composition is diagonally aligned and has a strong contrast between primary and secondary elements.			

For classic Song brocade patterns with prominent geometric features and strong structural regularity, such as Badayun and Tianhua brocade, research focuses on accurately restoring their internal generative logic through a combination of shape grammar theory and procedural rule modeling, thereby providing AI design with constraints that conform to the characteristics of Song brocade weaving techniques.

The digital study of color aims to accurately extract traditional color palettes, conduct quantitative analysis, and identify aesthetic laws. Through color-feature extraction, researchers construct standardized Song brocade color databases and systematically analyze the proportional relationships and visual aesthetic features of primary, secondary, and accent colors. Trending colors can reflect the styles and trend elements pursued by consumers, representing an important path for innovation in the redesign of traditional patterns. On the basis of traditional color research, some scholars have integrated analyses of contemporary color trends to explore the fusion of traditional color palettes with contemporary aesthetic needs, thereby improving the market adaptability of digital-intelligence design works (Li & Wu, 2022).

Cultural-semantic modeling focuses on the digital transformation and standardized presentation of the cultural connotations of Song brocade patterns. Researchers systematically organize and digitally annotate the meanings, symbolic signs, and historical contexts carried by Song brocade patterns, transforming auspicious motifs such as peonies and lotuses, as well as cultural symbols such as Ruyi forms and auspicious characters, into semantic tags that can be recognized and invoked by AI. This digital processing enables AI-generated Song brocade patterns not only to achieve visual resemblance in form but also to accurately convey the cultural connotations of traditional arts and crafts, thereby achieving the design goal of "spiritual resemblance" (Li et al., 2025).

3.3 AI-Driven Innovative Design Practice for Song Brocade Patterns

The value of generative AI in ICH protection lies not only in improving image-generation efficiency, but also in breaking through the traditional preservation mode of "passive recording," enabling ICH resources to achieve active generation, dynamic restoration, rule organization, and redesign in digital environments. ICH protection must address both the issue of "preservation" and the issue of "inheritance," and generative artificial intelligence provides new methodologies and technical paths spanning resource preservation, knowledge organization, and communication transformation (Liang, 2026). For Song brocade patterns, the significance of AI is not limited to generating new pattern styles; more importantly, by learning the structures, colors, and symbolic rules of classic patterns, AI can provide a controllable design foundation for traditional patterns entering modern product scenarios.

Currently, AI applications in Song brocade pattern design manifest primarily through three pathways: generative design, parametric design, and human–machine

collaborative design. Generative design is based on technologies such as generative adversarial networks (GANs) and diffusion models, which can automatically generate new design schemes by learning from large numbers of classic Song brocade patterns. Fine-tuned domain-specific models can produce relatively stable outputs in terms of style, theme, composition, and color, with advantages such as rapid generation, abundant variants, and design inspiration. However, purely AI-generated results are prone to problems such as cultural-symbol displacement, confused pattern hierarchies, and structures that do not conform to weaving or embroidery techniques; therefore, they cannot directly replace the judgment of arts-and-crafts designers. Parametric design is more suitable for Song brocade patterns with clear geometric structures and explicit cyclic rules, such as Badayun and Tianhua brocade. By defining nodes, proportions, symmetry relationships, and repetition modes, it realizes standardized and modular pattern generation, making outputs better suited to jacquard weaving, embroidery translation, and industrial drawing.

Based on these characteristics, human–machine collaborative design should become the dominant mode of current digital intelligence innovation in Song brocade. AI is responsible for rapid drafting, variable combination, and multi-scheme iteration; designers are responsible for aesthetic selection, product-context adaptation, and visual-order control; and inheritors or craft experts verify pattern meanings, weaving logic, and craft feasibility. This collaborative mechanism not only makes full use of technology's advantages in efficiency and scheme quantity, but also preserves the core role of traditional arts and crafts in cultural authenticity, manual experience, and aesthetic judgment. As a result, innovation in Song brocade patterns can move beyond the visual surface and enter a modern design system that is producible, communicable, and experiential.

3.4 Song Brocade Patterns and Arts-and-Crafts Innovation

1) Digital intelligence promoting craft adaptation and arts-and-crafts innovation in Song brocade

In Folk Culture in a Technological World, Bausinger (2014) argues that tradition itself is something that continually evolves: when human environments change, tradition also changes in form, but it never disappears. This theory reveals the internal law of traditional craft evolution and provides an important perspective for understanding the modern transformation of Song brocade patterns in the digital-intelligence era.

From the perspective of the evolution of traditional crafts, the digital-intelligence reconstruction of Song brocade patterns embodies the dynamic characteristic of the "continuous evolution of tradition." The intervention of contemporary digital technology is essentially a modern extension of craft tools and aesthetic demands within the traditional weaving environment. From hand-drawn design drafts to parametric modeling, and from experiential inheritance to knowledge-graph encoding, technological iteration has not severed the cultural genes of traditional patterns; instead, it has provided new carriers for the living continuation of traditional symbols.

The threefold role of digital-intelligence technology in Song brocade pattern design can be understood in dialogue with Bausinger's theory. First is media conversion: patterns are transformed from the physical form of woven silk threads into digitally computable symbols, extending the visibility of tradition from museum collections to digital platforms. Second is rule visualization: implicit craft rules, such as skeletal proportions, cyclic logic, and color ratios, are transformed into explicit algorithms that can be parametrically controlled, allowing traditional making wisdom to be systematically recorded and disseminated. Third is contextual reconstruction: digital patterns can flexibly adapt to modern product carriers such as clothing, home textiles, and digital media, enabling traditional patterns to acquire new functional meanings in contemporary life. Therefore, digital intelligence does not negate tradition; rather, it represents the contemporary

manifestation of traditional vitality under technological transformation, echoing Bausinger's theory of the continuous evolution of tradition.

2) Big-data-driven cultural and creative development and industrial transformation of Song brocade

Big data plays an important role in user-preference analysis, market-trend prediction, and product positioning, promoting Song brocade from ICH protection toward everyday use and marketization, and thereby realizing the contemporary value of arts and crafts (Zhang, 2001).

Through the analysis of multi-source data such as e-commerce data, social media sentiment, and user surveys, researchers can accurately grasp modern consumers' preferences regarding Song brocade patterns, colors, styles, and uses, thereby guiding the development of cultural and creative products. Digital-intelligence design enables Song brocade patterns to be applied more flexibly to new Chinese-style clothing, home textiles, gift stationery, digital cultural and creative products, and other fields. It promotes Song brocade's transition from high-end fabric to mass consumption, enhances the fashionability, recognizability, and market competitiveness of Song brocade products, and facilitates the living inheritance of ICH (Pan & Zhao, 2008). At the level of communication, big data and AI-assisted content generation help disseminate Song brocade culture efficiently through short videos, posters, and interactive exhibitions, attracting the attention of younger groups.

4. Design Practice of "With Brocade, Grow with Kids"

4.1 Design Positioning and Core Concept

Based on the digital-intelligence design methods and art–craftsmanship integration framework proposed previously, this section verifies the application of Song brocade patterns to children's sports shoes. The focus of the design practice is not simply to transplant Song brocade patterns onto shoe uppers as decoration, but to test whether traditional ICH symbols can simultaneously achieve cultural expression, craft adaptation, and functional response in children's everyday products through pattern-gene extraction, digital-intelligence reconstruction, modern footwear craft translation, and smart-function integration.

From the perspective of product positioning, the children's sports shoe market has shifted from basic demands for comfort and durability toward comprehensive demands encompassing cultural meaning, intelligent safety, aesthetic experience, and emotional companionship. Children are not only product users, but also important subjects of traditional cultural perception and aesthetic enlightenment. Incorporating Song brocade elements into children's sports products can free ICH from merely display-oriented or commemorative consumption scenarios and bring it into everyday, interactive, and growth-oriented spaces, thereby achieving two-way empowerment between cultural inheritance and industrial upgrading.

The design process in this study includes six stages: research positioning and concept establishment, Song brocade pattern-gene extraction, digital-intelligence reconstruction, scheme design, function integration, and outcome presentation. AI participates throughout the process: in the pattern-gene extraction stage, it assists with skeletal recognition, feature annotation, and color quantification; in the digital-intelligence reconstruction stage, it is used for parametric modeling, pattern-variant generation, and color-scheme recommendation; in the scheme-design stage, it provides rapid iteration of multiple alternatives, which are then aesthetically judged and craft-verified by designers and inheritors; and in the function-integration stage, it assists with structural optimization and ergonomic parameter adjustment. Through this process, Song brocade patterns are transformed from traditional brocade motifs into a visual language, craft scheme, and interactive medium that can be absorbed by modern footwear products.

With the theme "With Brocade, Grow with Kids," the product is positioned as an integrated sports shoe for children aged 3 to 12 that combines ICH inheritance, smart technology, and child-friendly design. The design concept unfolds around three dimensions: culture, function, and technology. The cultural dimension takes Song brocade patterns as the core and translates traditional motifs through modern footwear techniques such as embroidery, thereby promoting the youthful and living communication of ICH. The functional dimension is based on children's sports science and wearing safety, taking into account comfort, wear resistance, and foot protection. The technological dimension relies on intelligent positioning and flexible LED interaction to respond to parents' safety-monitoring needs and children's interest in playful interaction.

4.2 Modern Translation and Visual Design of Song Brocade Elements

This section conducts an in-depth analysis of the most representative Baoxiang flower, Ruyi cloud, and water-wave patterns in Song brocade, extracts their pattern outlines, and reconstructs them in a modernized form (see Table 3).

Table 3. Analysis of three relevant patterns

Pattern type	Pattern image	Pattern outline	Basic pattern form	Pattern meaning
Baoxiang flower pattern			A centrally symmetrical roundel type, with multiple layers of petals arranged circularly around a central pistil dot. Curvilinear motifs are nested inside the petals, creating a full, regular, and balanced structure.	Implies completeness, prosperity, and wealth.
Ruyi cloud pattern			A four-combined Ruyi-style cloud form, composed of multiple swirling cloud heads with extended flowing cloud tails. The lines are graceful and fluid, and the cloud heads take the form of Ruyi spirals.	Symbolizes auspiciousness, wishes fulfilled, and enduring vitality.
Water-wave pattern			Composed of multiple layers of smooth, undulating arc lines forming the wave body, with simplified curling spray at the top. The lines are continuous, relaxed, rhythmic, and concise.	Symbolizes flowing water, continuity, and endless vitality.

The translation strategies include simplifying the complex details of traditional patterns, optimizing line curvature, preserving core cultural symbols, and adapting them to the lightweight visual demands of children's shoes; adjusting pattern proportions by applying cloud and water-wave patterns to visually prominent areas such as the shoe side and tongue, while using Baoxiang flower motifs as details on the heel and upper to create a clear visual hierarchy; and retaining the "elegant and soft" color system of Song brocade by using off-white as the base color and pairing it with low-saturation tones such as light gold and light blue.

4.3 Child-Oriented Translation and Color Design

In response to children's lively and active characteristics, Song brocade elements are translated in a child-oriented manner: wing-shaped decorations are incorporated on the shoe side to echo the growth theme of "With Brocade, Grow with Kids;" the shoelaces are paired with detachable tassels and Song brocade pendants, which both restore the traditional accessory culture of Song brocade and satisfy children's desire for personalized dressing; and the shoe side is equipped with a flexible LED display that can show steps, positioning status, and other information, combining traditional patterns with modern technological visuals and stimulating children's interest in traditional culture (see Figure 2).



Figure 2. Product display
Note. Created by the author(s).

4.4 Product Function Design, Structural Realization, and Theoretical Response

The product follows a dual-track design logic of "cultural core + technological extension," aiming to achieve deep integration between traditional arts and crafts and modern smart wearable technology. At the cultural level, Song brocade, as a brocade-weaving craft, originally presents traditional textures through specific textile structures; children's sports shoes, by contrast, require lightness, wear resistance, breathability, and flexibility. Therefore, this design does not directly replicate the weaving structure of Song brocade, but adopts high-precision embroidery as the craft translation carrier for Song brocade patterns. Embroidery can be flexibly attached to shoe materials, and variations in stitching can simulate the layered texture and luster of Song brocade weaving, preserving cultural recognizability while adapting to the practical requirements of footwear materials, curved structures, and mass production.

At the functional level, the design of smart children's sports shoes must respond to two core demands: safety monitoring and playful interaction. The embedded intelligent positioning module derives from safety concerns during children's outdoor activities and addresses parents' needs for location tracking and basic monitoring. The flexible LED interactive module responds to children's preference for visual feedback and immediate interaction through step displays, positioning-status prompts, and motion-incentive animations. These functions are not technological stacking. Instead, within the boundaries of not interfering with footwear comfort and not damaging pattern integrity, the smart modules are controlled in relatively suitable structural areas such as the tongue, heel, and side of the shoe, so that functional realization remains subordinate to children's wearing experience and the overall aesthetic order.

At the level of integration, this design establishes an internal correspondence between cultural symbols and modern technology through a narrative association of "pattern meaning–functional response." The Ruyi cloud pattern symbolizes "auspiciousness and wishes fulfilled," corresponding to the "safety protection" function of intelligent positioning. The Baoxiang flower pattern connotes "completeness and prosperity," corresponding to the "comprehensive protection" of the parental monitoring app. The water-wave pattern symbolizes "endless vitality," corresponding to the "vitality encouragement" in the LED display. This association is made explicit through function naming, interface prompts, and shoe-surface layout, so that Song brocade patterns are not

merely decorative motifs but become media through which children understand traditional culture, perceive safety companionship, and participate in sports interaction.

Thus, the design practice also responds to the theoretical propositions discussed previously regarding art–craftsmanship integration, AI-assisted design, and the continuous evolution of tradition. First, the aesthetic and auspicious meanings of Song brocade patterns constitute the core of "art" at the cultural level, while parametric modeling, embroidery craft, material compounding, and smart-module integration constitute the support of "craftsmanship," together achieving the unity of traditional aesthetics and product function. Second, the entire practice adopts a human–machine collaborative mode: AI is responsible for skeletal extraction, parametric variant generation, and multi-scheme iteration; designers are responsible for aesthetic composition and product-context control; and inheritors participate in the verification of craft feasibility, avoiding cultural distortion or craft disconnection caused by purely AI-generated outputs. Finally, as patterns shift from brocade fabric to children's footwear, traditional configuration rules are explicitly preserved through digital-intelligence methods and acquire new functional meanings in smart children's products, reflecting the continuous evolution of tradition in a modern technological environment.

The concept of "With Brocade, Grow with Kids" transforms static ICH patterns into dynamic media that can be worn, interacted with, and perceived. This practice moves beyond the single mode of "museum-style protection" for ICH, integrates Song brocade culture into children's everyday lives, achieves a shift in inheritance from static viewing to living participation, and provides a referential design path for the contemporary everyday, youthful, and intelligent transformation of traditional handicrafts.

5. Discussion: Cultural Authenticity, Craft Translation, and the Boundaries of Smart Design

5.1 Cultural Authenticity: Semantic Retention and Contemporary Translation of Traditional Patterns

This study utilizes the Ruyi cloud and Baoxiang flower patterns of Song brocade as core visual genes and consistently treats cultural-semantic authenticity as the primary principle in digital-intelligence reconstruction. Unlike simple pattern replication or AI style transfer, this design extracts pattern skeletons, typical curves, color ratios, and auspicious-meaning tags to establish a "form–meaning" mapping relationship. This approach ensures that the reconstructed patterns remain recognizable in terms of Song brocade's elegant temperament, symmetrical order, and auspicious connotations after simplification and child-oriented treatment.

In the case practice, the cultural semantics of the Ruyi cloud pattern symbolizing "auspiciousness and wishes fulfilled," the Baoxiang flower pattern as "completeness and prosperity," and the water-wave pattern as "endless vitality" are translated from static patterns into dynamic experiences through shoe-surface layout, LED interaction prompts, and function naming. The results indicate that digital-intelligence reconstruction does not diminish tradition; rather, it completes the contemporary adaptation of pattern semantics while retaining the cultural core. Excessive simplification leads to a loss of recognizability, whereas excessive realism makes it difficult to adapt to the lightweight and concise visual demands of children's products. Balancing these two competing demands is the key to maintaining cultural authenticity.

5.2 Methodological Boundaries and Collaborative Mechanism of AI-Assisted Design

In stages such as Song brocade pattern extraction, parametric reconstruction, embroidery translation, and smart-function integration, AI demonstrates advantages in efficient iteration, parameter control, and multi-scheme generation, while also revealing distinct methodological boundaries.

In the pattern-extraction stage, AI can rapidly identify contours, extract skeletons, and quantify colors, significantly improving efficiency. However, the weaving logic, local symbolic meanings, and traditional aesthetic rhythm behind the patterns still require calibration by designers and cultural inheritors. In the parametric reconstruction stage, variants generated based on shape grammar ensure structural compliance and weavability. However, AI cannot actively understand pattern hierarchy, visual breathing, or child-oriented adaptation, so manual selection and adjustments to proportion, curvature, and density are needed. In the embroidery-translation stage, AI can generate vectorized pattern drawings and adapt embroidery stitch distance and density, yet the control of stitch type, thread color, and textural layers still depends on footwear craft practitioners' experiential judgment regarding materials and techniques. In the smart-function integration stage, AI assists with structural optimization and ergonomic parameter adjustment, though the narrative association between function and pattern meaning—such as linking the Ruyi cloud pattern to safety protection—still needs to be constructed by the design team.

Therefore, the human–machine collaborative mechanism formed in this study is clear: AI is responsible for efficient execution, while designers and cultural inheritors are responsible for cultural gatekeeping, aesthetic decision-making, and craft verification. This collaboration not only avoids the problems of cultural distortion and craft infeasibility that may arise from pure AI generation, but also overcomes the low efficiency and slow iteration of traditional hand drawing, thereby providing a replicable collaborative paradigm for implementing Song brocade patterns in smart products.

5.3 Craft Translation: Adapting Song Brocade Weaving Logic to Modern Footwear Craft

The core value of Song brocade lies not only in its patterns but also in its rigorous weaving techniques. This study does not seek to reproduce the complex weaving of Song brocade directly. Instead, it explores the translation of cultural texture: high-precision embroidery replaces traditional weaving, embroidery stitches simulate the layered texture of interlacing warp and weft, and thread luster restores the texture of the original textile, thereby realizing a craft translation that seeks spiritual resemblance rather than formal imitation.

The case verification shows that embroidery offers flexible adaptation, lightweight construction, controllable cost, and feasibility for mass production. It can adapt to the curved, bending, and wear-resistant requirements of children's sports shoes, overcoming the limitations of traditional Song brocade fabric, such as heaviness, wrinkling, and difficulty of application in sports products. At the same time, the adaptation of patterns from 2D planes to 3D shoe surfaces, the balance between embroidery stitch density and material strength, and the design to prevent interference between patterns and smart modules all demonstrate systematic adaptation from traditional craft logic to modern product craft, rather than simple pattern superimposition.

5.4 Boundaries of Smart Design: Balancing Traditional Aesthetics and Smart Functions

In the design of smart children's sports shoes, traditional aesthetics, foot physiology, and intelligent safety must be coordinated rather than compromised. This study defines the boundaries of smart design as follows: smart functions serve children's safety and playful experience, traditional aesthetics guide the visual style, and foot-physiological adaptation determines the structural foundation.

In practice, the flexible LED screen only provides simple prompts for step counts and positioning status, without disrupting the overall elegance of the Song brocade patterns. Smart modules are embedded in non-core visual areas such as the tongue and heel to avoid damaging pattern integrity. Lightweight materials and ergonomic structures ensure

children's wearing comfort and sports safety. The results show that smart design should be restrained and functionally integrated, avoiding technological stacking, while traditional aesthetics should be simplified and adapted to avoid excessive complexity. Only by balancing these two can ICH, smart technology, and children's needs be organically integrated.

6. Conclusion

This study focused on the integration of art and craftsmanship in the design of Song brocade patterns in the digital-intelligence era. Centering on the core question of how Song brocade patterns can simultaneously accommodate cultural expression, craft adaptation, and functional integration in modern smart products, this study examined Suzhou Song brocade Ruyi cloud and Baoxiang flower patterns and completes the design practice of the "With Brocade, Grow with Kids" smart children's sports shoes through digital-intelligence gene extraction, parametric reconstruction, embroidery craft translation, and smart-module integration.

The following primary findings were obtained: First, digitization, digital intelligence, and intelligentization exhibit clear hierarchical boundaries. Digitization is the foundation, focusing on information preservation; digital intelligence is the core, emphasizing controllable reconstruction through human–machine collaboration; and intelligentization is the future and emphasizes autonomous innovation. These three concepts should not be confused, and digital intelligence represents the most suitable path for the current innovative design of ICH patterns. Second, art–craftsmanship integration in the context of ICH is essentially a bidirectional and in-depth collaboration between traditional artistic cores and modern engineering technologies: "art" guides cultural semantics, aesthetic style, and auspicious meanings, while "craftsmanship" supports pattern reconstruction, craft translation, functional implementation, and smart integration. The two empower each other, and neither can be neglected. Third, the key to cultural authenticity in Song brocade patterns lies in semantic retention rather than formal replication. By extracting visual genes, establishing form–meaning mapping, and simplifying patterns for contemporary scenarios, the youthful and living translation of traditional patterns can be achieved. Fourth, embroidery provides a feasible path for translating Song brocade patterns into modern footwear products, as it addresses cultural texture, craft feasibility, and mass-production adaptability. Fifth, AI-assisted design has clear methodological boundaries, and human–machine collaboration is an effective mode: AI is responsible for efficient extraction, parametric generation, and multi-scheme iteration, while designers and cultural inheritors are responsible for cultural gatekeeping, aesthetic decision-making, and craft verification. Their collaboration balances efficiency with cultural authenticity, as well as innovation with craft feasibility. Finally, the design of traditional patterns in smart products should adhere to the principles of culture as the core, function as the application, and aesthetics as the form. Smart functions should be integrated in a restrained manner, traditional aesthetics should be simplified and adapted, and user needs, cultural inheritance, and technical implementation should be considered holistically, to transform ICH from static viewing into an everyday and experiential inheritance.

Based on these findings, this study clarifies the hierarchical boundaries of digital intelligence at the theoretical level, specifies the core connotation of art–craftsmanship integration in ICH, and constructs a theoretical framework for the digital-intelligence design and smart-product transformation of Song brocade patterns. At the practical level, it establishes a complete design process of "gene extraction–digital-intelligence reconstruction–craft translation–smart integration" and implements a smart children's sports shoe that combines cultural, aesthetic, functional, and technological attributes, providing a reference paradigm for the modern product transformation and youthful living inheritance of Song brocade and similar traditional brocades.

However, this study has several limitations. The design practice remains at the level of scheme and prototype, lacking target-user experience feedback and market validation.

The integration of Song brocade weaving parameters with digital-intelligence models is still insufficient, and industrialization issues such as industry–university–research collaboration mechanisms and standardized process construction have not been examined in depth.

Future studies should conduct user testing and market research, optimize design schemes, deepen the integration of weaving parameters and AI models, improve pattern weavability, and collaborate with enterprises, inheritors, and research institutions to promote the industrial implementation of design outcomes, thereby continuously exploring further possibilities for the digital-intelligence inheritance of ICH.

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