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VISUAL ANALYSIS OF RESEARCH ON WEAVING AND EMBROIDERY ART BASED ON KNOWLEDGE MAP

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Abstract: This study employs knowledge graph visualization analysis to conduct scientometric and comparative analysis of academic literature on textile and embroidery art research from 2004 to 2024. Differing from traditional literature reviews that are limited by subjective judgments, the research utilizes computer science data analysis tools to present the knowledge structure, core themes, and cutting-edge trends in textile and embroidery art research, while proactively identifying deeper research gaps and interdisciplinary intersections. Macroscopically, the CiteSpace data analysis software is employed to examine the diachronic spatial dimensions of textile and embroidery art research development. Microscopically, the LDA topic model is applied to the literature dataset for data modeling, exploring implicit thematic structures within the dataset. This study provides objective and quantifiable empirical evidence for future research in textile and embroidery art, promoting the integration of traditional humanistic speculation with scientific data computation in academic research, and offering methodological references for other art and humanities disciplines.
Keywords: Weaving and embroidery art; Visual analysis; LDA topic model; Topic evolution

1 INTRODUCTION

As an important component of China's excellent traditional culture, intangible cultural heritage carries the genes and bloodline of the Chinese nation, representing irreplaceable and non-renewable resources of China's excellent civilization [1]. In 2023, the National Conference on Propaganda, first proposed emphasizing the need to "focus on continuing the Chinese cultural lineage, promoting the creative transformation and innovative development of China's excellent traditional culture, and strengthening international communication capabilities to facilitate civilizational exchanges and mutual learning" [2]. Weaving and embroidery art is a comprehensive art form that integrates technology, culture, aesthetics, and practicality, primarily achieved through the use of diverse textile materials for weaving, knitting, or embroidery. In China's national intangible cultural heritage list, there are 77 items related to weaving and embroidery [3]. Among the 630 UNESCO intangible cultural heritage items, 42 belong to the textile and apparel category, accounting for approximately 8% of the total and involving 40 countries [4]. This art form is not only a precious intangible cultural heritage of the world but also carries profound historical memories, serving as an important carrier rich in cultural symbolism.

However, with the global economic development and accelerated modernization in China, many traditional textile and embroidery arts are on the verge of extinction. This phenomenon has drawn significant attention from both academic circles and the public, particularly regarding the preservation of these arts in ethnic minority regions. Currently, the inheritance and development of textile and embroidery arts are severely constrained by a lack of innovation in traditional handicrafts, insufficient market demand, and a serious shortage of skilled inheritors.

In recent years, domestic research on textile and embroidery arts has focused on historical evolution, technical exploration, symbolic image analysis, and related cultural values. For instance, Guo and Zhang employed documentary research and pattern analysis to examine the artistic characteristics of fish motifs in Ming and Qing dynasty textiles and embroidery [5], while exploring the underlying folk culture. Jiang et al. utilized Saussure's semiotic theory to analyze folk textile patterns in Shanxi [6], uncovering their cultural significance during creation. International studies on textile and embroidery arts demonstrate interdisciplinary characteristics, with sociologists, materials scientists, and even economists contributing multidimensional perspectives. For example, Stoppa and Chiolerio highlighted recent advancements in smart textiles [7], emphasizing material composition and manufacturing processes. Rogale et al. introduced the concept [8], development, structural framework, and general features of two-generation smart clothing with adaptive thermal insulation. These achievements offer new possibilities for contemporary textile and embroidery arts. However, current research predominantly relies on qualitative analysis, with limited systematic quantitative studies and macro-level comprehensive analyses. Additionally, as research literature continues to accumulate and visualization technologies for documentary studies improve, efficiently integrating and analyzing these resources to reveal knowledge structures and explore industry trends has become an urgent challenge.

This study systematically analyzed academic journal data on textile and embroidery arts from 2004 to 2024, both domestically and internationally. Using CiteSpace software and LDA topic modeling, we conducted thematic mining and identified key research trends to trace the evolution of academic themes. The research aims to explore effective pathways for innovation in this field, providing valuable insights and references for its future development.

2 DATA SOURCES AND RESEARCH METHODS

2.1 Data Sources

To explore the thematic evolution in the field of textile and embroidery art research both domestically and internationally, and to further analyze its hotspots and cutting-edge topics, this paper uses the China National Knowledge Infrastructure (CNKI) database and the Web of Science core database as data sources. Domestic data were obtained by performing an advanced precision search in the CNKI database using the keywords "embroidery" and "textile," with a time range of 2004 to 2024, yielding a total of 710 relevant articles. After manual screening, 310 non-academic documents such as news articles, book reviews, and works were excluded, leaving 400 valid academic articles. The foreign data for this paper were sourced from the Web of Science core database. By entering the subject terms "EMBROIDERY" (embroidery) AND "TEXTILE" (textile) in the advanced search function, with a time range of 2004 to 2024 and setting the language to English, only the articles in the search results were retained, ultimately obtaining 278 papers related to textile and embroidery.

2.2 Research Methods

2.2.1 Theoretical basis

CiteSpace software, with its powerful visualization and serialization capabilities for knowledge graphs, clearly reveals the intricate interactions, overlaps, and evolutionary relationships among different knowledge communities and information sources, thereby helping users gain a deeper understanding and analysis of the inherent patterns in scientometrics.

LDA (Latent Dirichlet Allocation), also known as the latent Dirichlet distribution, was first proposed by Blei, Ng, and Jordan in 2003. As a widely used topic modeling method, it consists of three Bayesian layers: document, topic, and feature words. This probabilistic document topic generation model extracts a set of keywords from a collection of documents as topics [9-10]. Currently, the LDA topic model has been extensively applied in information retrieval, text mining, and social network analysis. The method proposed in this project features strong capabilities, effectively processing large-scale, unstructured data without requiring specific syntactic or semantic features, making it suitable for topic extraction.

2.2.2 Research process

This paper uses CiteSpace6.2R6 combined with Excel to conduct visual analysis of the collected academic literature data in the field of textile embroidery from the perspectives of publication trends, institutional co-occurrence, and keywords. Since bibliometric methods such as CiteSpace and VOSviewer are highly influenced by the subjective judgment of authors when selecting keywords, and may overlook low-frequency keywords, leading to unscientific results [11], this study adopts the LDA model to deepen the exploration of the field of textile embroidery art. The study uses the China CNKI database and the Web of Science core database as data sources, performs preprocessing such as text segmentation, de-stopwording, and word bag construction, and then applies the LDA topic model for modeling to quantitatively analyze the evolution of topics and identify research hotspots in the field of textile embroidery art. Figure 1 illustrates the research workflow framework.

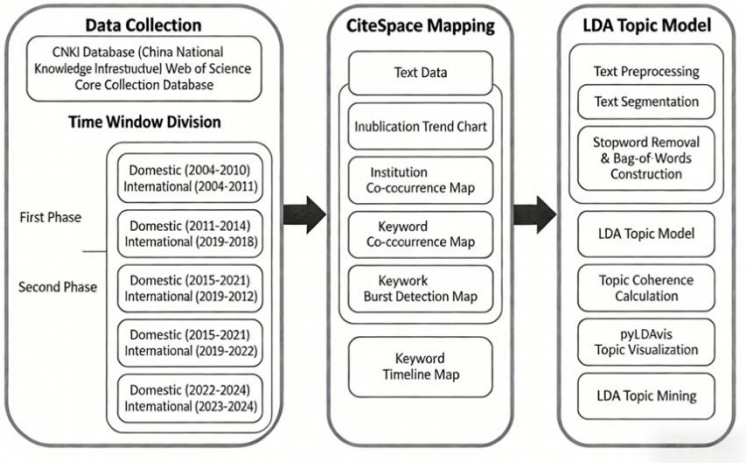

Figure 1 Research Process Framework

3 THE CURRENT RESEARCH STATUS OF WEAVING AND EMBROIDERY ART

3.1 Document Issuance Trends

The research on textile and embroidery art primarily adopts art and design as its academic orientation, encompassing disciplines such as sociology, history, and anthropology. A comprehensive review of the literature on this subject reveals that from 2004 to 2024, the number of publications has shown a consistent upward trend, peaking in 2023 and maintaining a steady growth pattern.

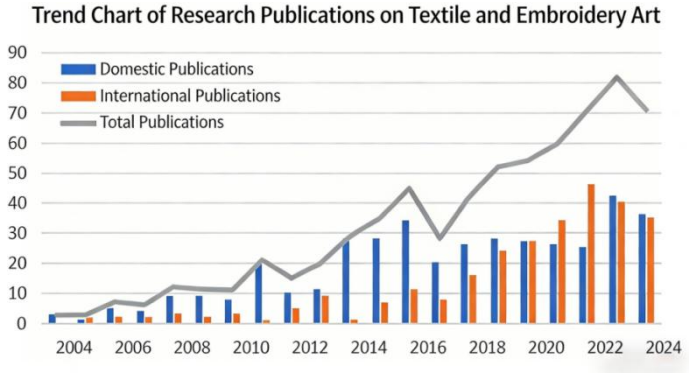

Figure 2 Trend Chart of Publications on Embroidery Art Research

Figure 2 shows that domestic research on embroidery art started earlier than that abroad. After 2009, domestic research on embroidery art experienced a slight increase, mainly due to the fact that the traditional spinning, dyeing, weaving, and embroidery techniques of the Li ethnic group were officially listed by UNESCO as intangible cultural heritage in urgent need of protection in 2009 [12]. This significant event attracted widespread attention from all sectors of society, greatly promoting the progress of research and academic investment in this field. Foreign research on embroidery only began to show an upward trend after 2014, due to Germany's proposal of the Future Textile Initiative (futureTEX) in 2014, which aimed to drive innovation and development in the textile industry, particularly in the research and application of smart fibers. This emerging research field attracted a large number of academic resources and researchers, significantly accelerating the rapid growth of related research in the embroidery field [13]. From 2018 to 2023, domestic and international research on embroidery art showed a fluctuating upward trend. The reason is likely the hosting of the Chaozhou International Embroidery Art Biennale in 2018, the first national and international embroidery art biennale [14]. This exhibition provided a top-tier platform for display, exchange, and innovation in embroidery, promoting the integration of intangible cultural heritage into contemporary life and international fashion trends, and facilitating the exchange and collision between China's embroidery culture and global embroidery culture. In October 2023, the "List of National Intangible Cultural Heritage Representative Project Protection Units" announced that the Li ethnic group's traditional spinning, dyeing, weaving, and embroidery techniques passed the evaluation [15]. This evaluation result indicates that the intangible cultural heritage of weaving and embroidery has successfully achieved revitalization and inheritance, greatly enhancing the research vitality in this field. Although the number of publications slightly declined in 2024, this year saw the Li ethnic group's traditional spinning, dyeing, weaving, and embroidery techniques transferred from the "List of Intangible Cultural Heritage in Urgent Need of Protection" to the "Representative List of the Intangible Cultural Heritage of Humanity". The Embroidery Art Exhibition Week opened at the China Embroidery Art Museum in Suzhou High-tech Zone, inviting 45 intangible cultural heritage embroidery projects from 25 provinces across the country and 68 embroidery inheritors to participate [16]. The SITME Surat International Textile Machinery Expo was grandly held at the Surat International Exhibition and Convention Center in India [17]. The ITM exhibition took place at the TUYAP Fair Convention and Exhibition Center in Istanbul, Turkey [18]. This demonstrates that the art of weaving and embroidery still holds significant value, and its influence has not diminished. It is likely that research on the art of weaving and embroidery has achieved relatively comprehensive results in terms of traditional history and techniques, entering a phase where in-depth exploration becomes more challenging. Based on the above, both domestic and international efforts are actively dedicated to inheriting and developing the art of weaving and embroidery, and it can be anticipated that the trend of publications in the field of weaving and embroidery will continue to rise in the future.

3.2 Temporal Characteristics

In the keyword timeline graph, node size reflects the frequency of a research topic's occurrence, while the connecting lines indicate relationships between topics. By examining the publication order and earliest publication date of keywords within each cluster topic, one can gain insights into...

Figure 3 Timeline of Key Terms in Chinese Embroidery Art

The dynamic evolution of domain knowledge research [19]. Based on the analysis of global and domestic publication trends in textile and embroidery arts (as shown in Figures 3 and 4) and the keyword timeline, domestic research can be categorized into four phases: the budding stage (2004–2010), the developmental stage (2011–2014), the flourishing stage (2015–2021), and the stable stage (2022–2024).

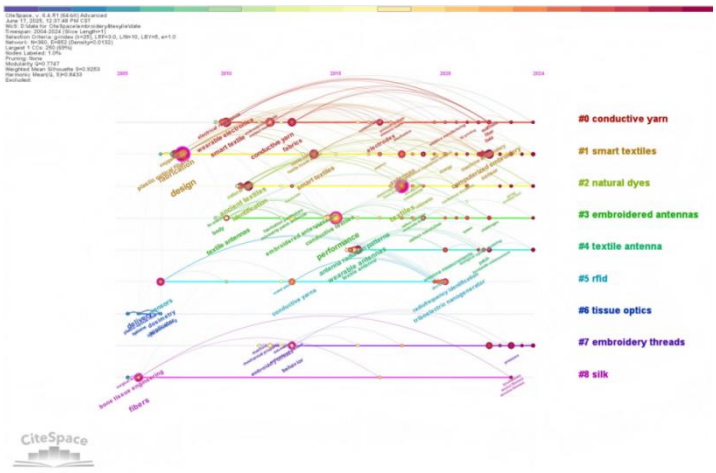

Figure 4 Timeline of Key Terms in Foreign Embroidery Art

Similarly, international research can be categorized into four phases: the nascent stage (2004–2011), the developmental stage (2012–2018), the flourishing stage (2019–2022), and the stabilization stage (2023–2024).

3.3 Key Word Characteristics

Combined with the growth stage distribution of the research texts of domestic and foreign embroidery art and the keywords of the research in this field, and combined with the background characteristics of each stage, the corresponding development situation is obtained by using CiteSpace to carry out keyword visualization analysis.

3.3.1 Key words of domestic embroidery art

The first phase, spanning 2004 to 2010, was the nascent stage of Chinese textile and embroidery art. As evidenced by the co-occurrence graph of keywords (Figure 5), this period saw a concentration of terms like 'embroidery,' 'patterns,' and 'clothing' —the foundational elements of this art form.

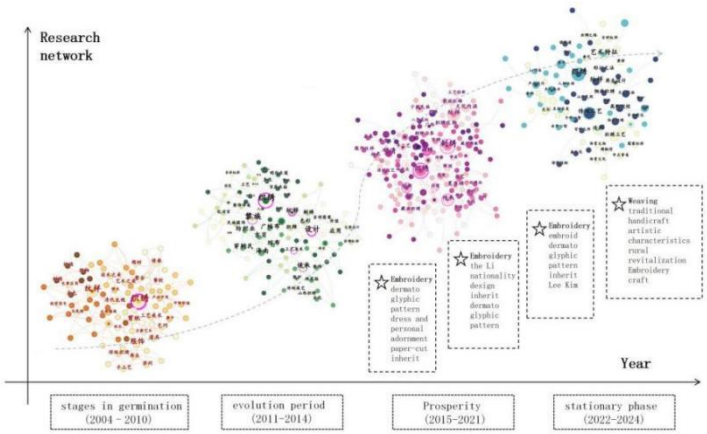

Figure 5 Co-occurrence Chart of Keywords in Domestic Weaving and Embroidery Art

At this time, the study of textile and embroidery arts was in its infancy, and the academic community began to show awareness of protecting traditional culture. In 2004, China published an authoritative illustrated history of China's textile and embroidery clothing— "The Complete Collection of China's Textile and Embroidery Clothing" —which comprehensively presented the millennium-long development of China's textile and embroidery techniques, pattern evolution, and clothing systems through systematic compilation, rigorous archaeological research, and interdisciplinary studies. Xu analyzed the dyeing and weaving patterns of the Wei, Jin, Southern and Northern Dynasties to illustrate the extensive integration among ethnic groups, cultural exchanges between China and foreign countries [20], and the introduction and prevalence of Buddhism during this period. Wang and Zhao explored the historical and contemporary significance of Han Dynasty silk auspicious patterns by analyzing their characteristics [21]. Xu and Liao conducted in-depth discussions on how traditional Suzhou textile and embroidery and clothing handicrafts adapted to the development of modern society. Under the impact of globalization [22], traditional handicrafts such as textile and embroidery arts declined. Clarifying their fundamental components, such as the symbolic meanings of patterns on clothing and their inheritance lineage, laid a cognitive framework for subsequent in-depth research, representing an initial manifestation of cultural rescue documentation.

The second phase, spanning 2011-2014, marked the development stage where keywords expanded to include "Li ethnic group," "design," and "application." During this period, driven by intangible cultural heritage protection policies, research on weaving and embroidery shifted focus from basic compositional elements to exploring distinctive regional cultures. Li ethnic weaving and embroidery gained attention for their unique artistic styles. Luo provided a detailed account of the craftsmanship, artistic characteristics [23], and cultural significance of Li brocade patterns. Lin proposed a digitalization roadmap for traditional Li textile techniques [24], offering a practical model for preserving intangible cultural heritage. Concurrently, the rise of the cultural and creative industries prompted academic exploration of weaving and embroidery's potential in modern design and industrial applications, aiming to bridge traditional and contemporary practices while addressing societal demands for cultural value monetization and revitalization of traditional crafts. Fan investigated the inheritance and transformation of Jin embroidery's cultural resources [25], seeking boundless possibilities for integrating contemporary art design with traditional craftsmanship.

The third phase, the flourishing period (2015–2021), saw sustained focus on "embroidery," "pattern inheritance," and "Li brocade," which emerged as research hotspots. With accumulated intangible cultural heritage (ICH) protection efforts, these traditions were revitalized as new research themes. Research on weaving and embroidery art shifted from documenting technical processes to exploring the aesthetic adaptation of patterns to modern design. Pattern inheritance emphasized symbolic decoding and fashion transformation, transitioning ICH from static preservation to dynamic activation. Zhang conducted a concise analysis of the types [26], characteristics, and formal features of Zhuang brocade patterns, noting that as daily necessities, they possess not only practicality but also visual artistry. Their diverse decorations and patterns can be appreciated as visual art symbols. Liao and Wu and colleagues demonstrated the revitalization and practical application of Xinyu summer fabric embroidery in daily life [27], elaborating on the creative approaches and possibilities for derivative designs.

The fourth phase, the stabilization period (2022-2024), saw "traditional craftsmanship," "rural revitalization," and "artistic characteristics" emerge as key themes. Research became more systematic, integrating textile embroidery into the broader framework of traditional crafts while clarifying its artistic features and technical logic. The rural revitalization strategy has endowed embroidery with new missions, positioning it as a catalyst for rural economic and cultural revitalization, reflecting academic research's alignment with national strategies. Chen argues that embroidery workshops empower rural spaces and cultural empowerment for women [28]. Zhang, from an arts and crafts perspective [29], explores the relationship between traditional textile embroidery patterns and modern fashion design, enhancing their practical applications in clothing. Cross-disciplinary integration deepens collaborations between textile embroidery and cultural creative design, demonstrating traditional crafts' adaptation to modern social ecosystems and sustainable development. This evolution also signifies the transformation of embroidery from cultural heritage to a social development resource.

In conclusion, the developmental trajectory of domestic textile and embroidery art research stems from the interplay of cultural preservation needs, policy guidance, industrial advancement, and societal strategic coordination. This progression—from foundational understanding to diversified applications, and ultimately to systematic integration and strategic responses—demonstrates the harmonious alignment between traditional craft studies and contemporary demands. It provides a clear roadmap and dynamic reference for the inheritance, innovation, and academic deepening of textile and embroidery art.

3.3.2 Key words of foreign embroidery art

The first phase, spanning 2004-2011, marked the embryonic stage of textile art. As evidenced by the co-occurrence map of foreign textile art keywords (Figure 6), this period saw keywords revolving around "plastic optical fibers", "fabrication", and "design". At the dawn of the 21st century, when material science and textile technology began converging, international research focused on functional material applications. McQuaid explored interdisciplinary innovations integrating technology with textiles [30], highlighting embroidery techniques 'critical role in addressing "smart" and "electronic" textile challenges, demonstrating textiles' seamless integration with contemporary craftsmanship. Roh et al. developed wearable textile antennas with multiple resonant frequencies [31], utilizing conductive embroidery yarns (MCEY) on polyester substrates to receive FM signals. This shift from traditional decoration to smart sensing materials represents the initial cross-disciplinary application of textile research, laying the groundwork for future intelligent textiles.

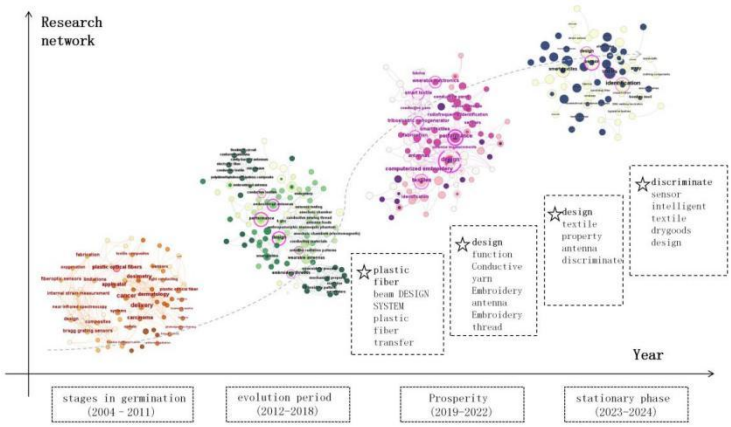

Figure 6 Co-Occurrence of Keywords in the Incipient Period of Foreign Embroidery Art

The second phase, the development stage (2012-2018), saw keywords like "performance," "smart textiles," and "conductive" gain prominence. With the rise of IoT and wearable devices, market demand for smart textiles surged. Kaufmann and Fumeaux proposed a wearable textile antenna operating at approximately 5GHz [32], featuring a semi-mode substrate integrated with a semi-circular cavity mode. This design demonstrated low manufacturing complexity, excellent human isolation, and strong deformation robustness. The study also provided design guidelines, investigated practical manufacturing challenges, and achieved a 7.2dB gain through well-aligned simulation and test results, validating the antenna concept. Berk optimized CAD embroidery parameters to develop a user-friendly [33], wearable pain management system for manufacturing high-performance dry transcutaneous electrical nerve stimulation (TENS) electrodes. Textile embroidery research focuses on performance optimization and intelligent design, addressing the miniaturization and flexibility demands of tech products while attempting to endow textile products with interactive functions. This approach transforms traditional craftsmanship into flexible carriers for smart hardware, demonstrating the synergy between technological industry needs and artistic design, and propelling textile embroidery from decorative layers into functional innovation.

The third phase, the flourishing period (2019–2022), saw intensive integration of "identification," "sensors," and "embroidery." With the accelerated deployment of 5G and artificial intelligence, wearable devices and smart healthcare scenarios demanded upgraded flexible recognition and precise sensing capabilities. Moradi et al. developed metamaterials using diverse textile materials to control signal propagation in smart textiles [34]. Their study reported the performance of composite structures featuring embroidered yarn conductive transmission lines with open-ring resonator geometries on felt and cotton substrates. Varma et al. proposed two compact textile-based planar dipoles and loop antennas for wearable communication applications operating in the 2.4GHz Industrial [35], Scientific, and Medical (ISM) radio frequency band. The embroidered textile antennas demonstrated suitability for various body-centered wearable applications in indoor environments. The deep integration of embroidery with sensors enabled physiological signal acquisition and environmental recognition, leveraging both the flexibility of embroidery techniques for body-adapted wearability and technological empowerment to expand application boundaries. This phase marked technological innovation driven by niche market demands, achieving profound convergence between art and technology.

The fourth phase, the stabilization period (2023-2024), centers on "intelligent design" and "textile design." Liu et al. proposed an interactive algorithm that generates machine-manufacturable embroidery patterns from multi-color images

with user-specified directional fields [36]. Imran et al. tested various conductive yarns and embroidery-based textile strain sensors [37], discovering that polypropylene/steel wire sensors with a two-thread square wave design performed optimally. Integrating these into sportswear enables measurement of compression during different body movements, facilitating the development of specialized athletic undergarments. After initial technological integration, the research entered a systematic phase: on one hand, intelligent design algorithms were incorporated into textile embroidery to optimize functional integration and aesthetic presentation; on the other hand, vertical-scenario-focused textile embroidery sensing systems were implemented, demonstrating a shift from technological experimentation to practical, scenario-driven development. This transition reflects the tech industry's evolution from breakthroughs to ecosystem implementation, requiring textile embroidery techniques to standardize and industrialize in niche scenarios, achieving a closed loop of artistic, technical, and commercial value.

In summary, the evolution of international research on textile and embroidery arts fundamentally stems from the continuous synergy between technological demands—such as material science, the Internet of Things, and artificial intelligence—and the inherent flexibility and adaptability of traditional weaving techniques during the wave of technological revolution. This progression, from fundamental material studies to scenario-based intelligent applications, demonstrates how technology drives artistic innovation while art adapts to technological needs.

The logic of the research provides a reference for the traditional embroidery technology to graft modern technology and expand the industrial boundary, and also reveals the key role of interdisciplinary integration in the inheritance and innovation of the craft.

3.4 Research Institutions

The study utilized the Institution analysis feature of CiteSpace software to generate a co-occurrence network of academic institutions publishing research on textile and embroidery arts. The number of connecting lines in the network reflects the level of collaboration between institutions, with increased connections indicating more frequent and intensive cooperation. The domestic co-occurrence network identified 297 nodes with 82 connecting lines, exhibiting an overall network density of 0.0019. The top institutions in terms of publication volume were Beijing Institute of Fashion Technology, Tsinghua University, Jiangnan University, and Hainan University. The international co-occurrence network identified 198 nodes with 206 connecting lines.

The overall network density was 0.0106. The research institutions with the highest publication output were, in descending order, Universitat Politecnica de Catalunya, Hong Kong Polytechnic University, Kaunas University of Technology, and École Nationale Supérieure des Arts et Industries Textiles (ENSAIT) (Figure 7).

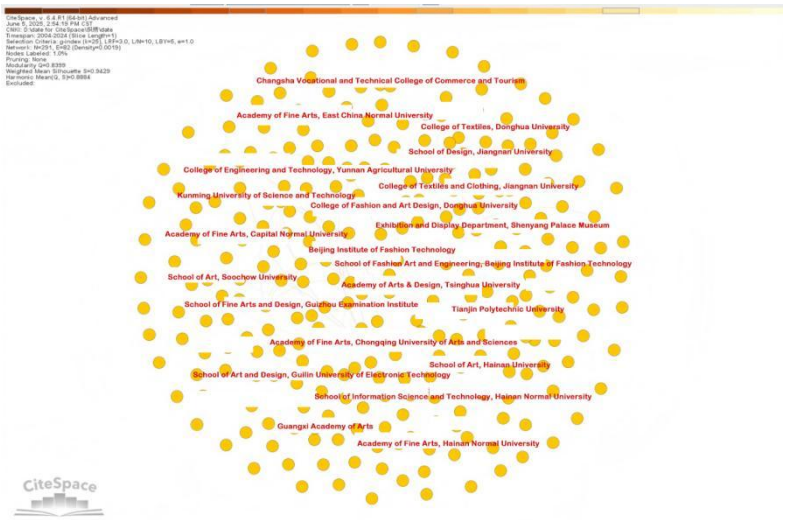

Figure 7 Co-Occurrence of Domestic Research Institutions on Weaving and Embroidery Art

From the perspective of collaborative networks, domestic publishing institutions exhibit relatively loose cooperation networks, indicating relatively low collaboration density. This phenomenon stems from the interplay of multiple factors including domestic research systems, evaluation mechanisms, resource competition, and disciplinary barriers. The core issue lies in the mismatch between the benefits and costs of collaboration. The academic, resource, or evaluation benefits obtained by publishing institutions from collaborations are insufficient to cover the costs of coordination, communication, and benefit distribution, ultimately resulting in low network density and loose collaboration. In contrast, the collaborative networks among foreign publishing institutions demonstrate...

Higher density and closer collaboration. Foreign publishing institutions should reduce cooperation costs through institutional design, enhance cooperation benefits via ecosystem development, and further facilitate collaboration by leveraging geographical and policy advantages, thereby making inter-institutional collaboration a routine practice.

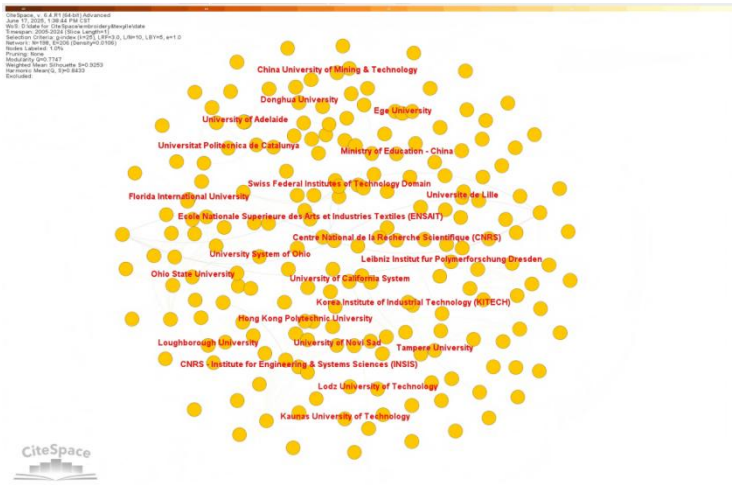

Figure 8 Co-Occurrence of Foreign Research Institutions on Embroidery Art

In terms of issuing institutions, domestic entities are predominantly universities, with most focusing on relatively concentrated disciplinary areas.

In single-discipline fields such as fashion, light industry, and design, disciplinary barriers hinder cross-disciplinary collaboration, necessitating the promotion of interdisciplinary and diversified research efforts. Although foreign publishing institutions are predominantly university-based, collaboration between universities and enterprises remains crucial.

The ecosystem is more mature, with complementary functions among different types of institutions. For instance, Aalto University in Finland, as a core academic partner, collaborated with H&M on the EU Horizon 2020 project 'New Cotton Project', where it was responsible for

The project developed technology to extract regenerated cellulose fibers from textile waste. Its flagship product, Infinna fiber, has been adopted by H&M and Adidas for commercial use. Meanwhile, Aalto University released the Circular Textile White Paper [38].

It provides technical basis for EU policy making.

Based on the above analysis, domestic institutions in the field of textile and embroidery art research should align with international counterparts, break down disciplinary barriers to conduct interdisciplinary and diversified research, which will contribute to the innovative development of the domestic textile and embroidery art field.

4 RESEARCH TOPICS ON WEAVING AND EMBROIDERY ART

While keyword co-occurrence analysis provides a macro-level overview of textile and embroidery art research, it fails to reveal evolutionary trends, identify emerging hotspots, or delve into the academic depth of this field. This necessitates a micro-level approach employing the Latent Dirichlet Allocation (LDA) topic model. Leveraging robust text processing capabilities, this method investigates the evolution of textile and embroidery art themes within corpora. By statistically analyzing word distributions in document sets, the LDA model infers thematic distributions and word distributions, thereby uncovering underlying thematic structures within the document corpus [39].

4.1 Data Preprocessing

In this study, the abstracts of the retrieved literature were preprocessed using the Jieba library in Python for tasks such as word segmentation and destop word removal. The Harbin Institute of Technology Chinese destop word list and a self-built destop word list were employed to eliminate characters that could not convey the thematic content, including numbers, punctuation marks, and meaningless Chinese vocabulary. The results were then combined with word frequency statistics.

4.2 Determination of Optimal Number of Topics

After preprocessing the text data, we sorted it chronologically from 2004 to 2024. Using Python's sklearn library, we trained an LDA model on the preprocessed abstract texts with parameters set to α=50, β=0.01, and max_iter=1,000. The optimal number of topics was determined by perplexity, a metric that evaluates a model's explanatory power—the lower the value, the stronger the model's ability to interpret the data [40]. Using Python's lda.perplexity function, we calculated the perplexity corresponding to each topic number (see Figures 9 and 10).

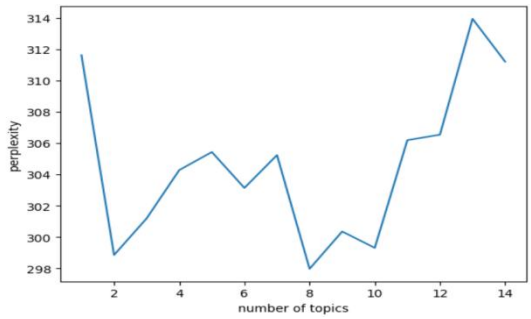

Figure 9 Confusion Degree of Research Topics in Domestic Embroidery Art

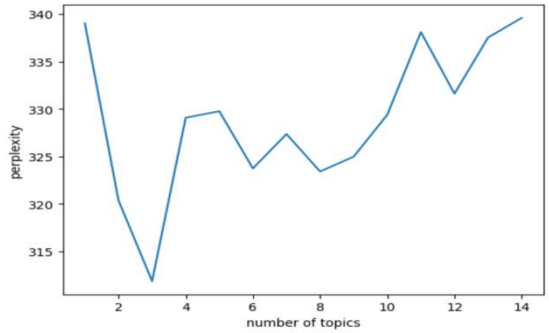

Figure 10 Confusion Degree of Research Topics in Foreign Embroidery Art

In the initial phase, a higher number of topics corresponds to a lower model perplexity, indicating improved performance and more accurate topic recognition. Theoretically, a smaller K value with lower perplexity should be selected. However, with limited sample size, overfitting may occur. Therefore, the first inflection point is universally adopted as the K value of 6.

4.3 Data Results and Analysis

Through keyword and weight analysis of the research topics of the art of weaving and embroidery, this study found that the keywords in the topics had some repetition, but their weights showed differentiation, so the focus of each topic was slightly different. During the model operation, 25 keywords were set, and the top 10 keywords were shown in Table 1 and Table 2.

In the field of domestic research on textile and embroidery arts, the keywords most closely related to Theme 1 are "embroidery", "culture", and "art", thus Theme 1 is categorized as "Cultural Heritage of Embroidery Arts". The keywords most relevant to Theme 2 are "patterns", "embroidery", and "culture", with relatively higher proportions, hence Theme 2 is classified as "Symbolic Art of Embroidery Patterns". Theme 3 primarily focuses on the embroidery techniques of the Li ethnic group, so Theme 3 is categorized as "Embroidery Techniques of Ethnic Minorities". As shown in Figure 11's thematic bubble chart, Theme 1 and Theme 4 exhibit significant overlap but with slightly different emphases, thus Theme 4 is categorized as "Development of Embroidery Cultural Arts". Although Theme 5 shares keywords with the previous themes, its proportion is relatively small and relevance limited, hence Theme 5 is classified as "Artistic Expression Forms of Embroidery". Theme 6 leans towards newer thematic research, primarily based on keywords such as "kesi (a type of silk weaving)", "painting", and "decoration", thus Theme 6 is categorized as "Diverse Integration of Embroidery Arts".

Table 1 Keywords and Weight of Research Topics on Domestic Weaving and Embroidery Art

Theme keywords and weights	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6
Keyword 1	Embroidery (0.033882)	dermato glyphic pattern (0.010174)	the Li nationality (0.019994)	Embroidery (0.022053)	Embroidery (0.024922)	a type of weaving done by the tapestry method in fine silks and gold thread (0.026573)
Keywords 2	culture (0.029607)	Embroidery (0.009621)	skill (0.019716)	culture (0.012474)	silk cloth (0.019768)	embroid (0.012926)
Keyword 3	art (0.023899)	culture (0.008011)	culture (0.014164)	art (0.012339)	art (0.019683)	silk cloth (0.008687)

Key word 4	tradition (0.017719)	technology (0.006392)	inherit (0.012688)	dress and personal adornment (0.009595)	skill (0.019110)	drawing (0.007462)
Key word 5	Pattern (0.015131)	tradition (0.005807)	tradition (0.010558)	pattern (0.008230)	tradition (0.016438)	ornament (0.007445)
Key word 6	dress and personal adornment (0.013073)	design (0.005653)	technology (0.009400)	embroid (0.007739)	embroid (0.014202)	technology (0.007376)
Key word 7	cultural relic (0.011103)	dress and personal adornment (0.005611)	protect (0.007144)	tradition (0.006785)	museum (0.014055)	collect (0.005975)
Key word 8	museum (0.008858)	nation (0.005123)	Embroidery (0.006347)	develop (0.005622)	technology (0.012709)	skill (0.005931)
Keywords 9	history (0.008370)	pattern (0.005013)	Lee Kim (0.006070)	cultural relic (0.005205)	technology (0.011528)	porcelain (0.005700)
Keywords 10	embroid (0.007853)	art (0.004380)	dyeing and weaving (0.005840)	technology (0.005079)	grass cloth (0.009857)	works (0.005032)

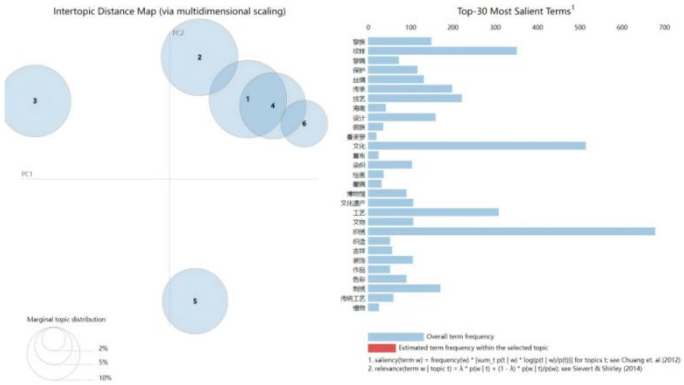

Figure 11 Bubble Chart of Domestic Embroidery Art

In the field of overseas research on textile art, the keywords most closely related to Theme 1 are "textile", "antenna", and "conductive". Thus, Theme 1 can be summarized as "Exploring Innovative Applications of Smart Textile Materials in Weaving Art". The keywords most relevant to Theme 2 are "embroidery", "textile", and "threads", leading to Theme 2 being defined as "Research on Weaving Art Creation Integrating Thread Techniques with Textile Materials". Theme 3, which involves textiles, sensors, and related developments, can be categorized as "Developing Weaving Art Forms Empowered by Sensing Technology". Theme 4 focuses on textiles, embroidery, and threads, emphasizing the use of threads in textile and embroidery processes, and can be summarized as "Research on Weaving Art Expression Integrating Thread Language with Textile Texture". Theme 5 centers on "embroidery", "conductive", and "materials", and can be summarized as "Innovative Exploration of Embroidery Art Media Driven by Conductive Materials". Theme 6 combines "textile", "sensor", and "embroidery", and can be concluded as "Interactive Art Product Development Integrating Sensing Technology with Weaving".

Table 2 Keywords and Weight of Research Topics on Foreign Embroidery Art

Theme keywords and weights	Topic 1	Topic 2	Topic 3	Topic 4	Topic 5	Topic 6
Keyword 1	textile (0.009996)	embroidery (0.020247)	textile (0.010294)	textile (0.018248)	embroidery (0.022251)	textile (0.017107)
Keywords 2	antenna (0.009783)	textile (0.011578)	sensor (0.006946)	embroidery (0.017251)	materials (0.004385)	sensor (0.011452)
Keyword 3	conductive (0.003493)	threads (0.010939)	developed (0.003924)	threads (0.011701)	conductive (0.014542)	embroidery (0.011239)
Key word 4	based (0.006917)	resistance (0.006327)	fiber (0.005130)	dyes (0.009974)	textiles (0.008981)	technologie (0.003856)

Key word 5	design (0.005872)	dyes (0.005714)	silk (0.004948)	antennas (0.009938)	resistance (0.007500)	based (0.007867)
Key word 6	human (0.005565)	process (0.004677)	triboelectric (0.004943)	frequency (0.008829)	printing (0.006823)	materials (0.006246)
Key word 7	electrodes (0.004394)	analysis (0.005019)	yarn (0.004908)	wearable (0.008340)	sensors (0.006782)	fiber (0.005692)
Key word 8	power (0.004067)	materials (0.004951)	wedding (0.004457)	proposed (0.008040)	parameters (0.006557)	manufacture (0.003731)
Keywords 9	coils (0.003819)	methods (0.004924)	filaments (0.004457)	sensor (0.008031)	design (0.006417)	humidity (0.005484)
Keywords 10	signals (0.003595)	samples (0.004795)	based (0.003930)	samples (0.008024)	study (0.005621)	designs (0.003422)

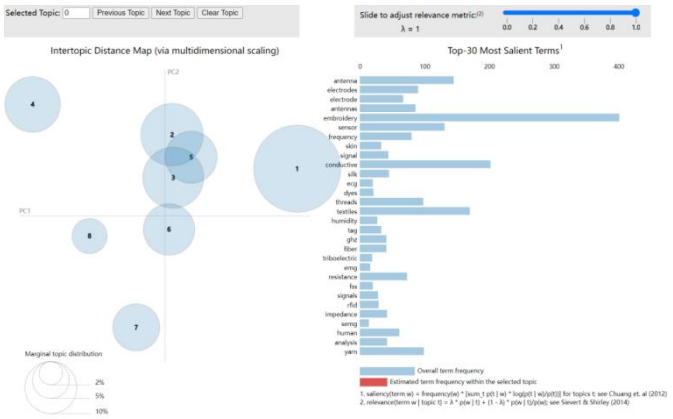

Figure 12 Bubble Diagram of Foreign Embroidery Art

The bubble chart of textile and embroidery art themes reveals that the right side displays 30 corresponding keywords, while the left side shows six distinct themes. Larger bubble areas indicate higher prevalence across all corpora and greater research relevance. The distance between bubbles reflects their correlation, with wider gaps indicating greater thematic dispersion. Analysis of the thematic relationships demonstrates concentrated research activity around Theme 1, Theme 2, and Theme 3, highlighting these three as the primary research hotspots in global textile and embroidery art studies (Figure 12).

4.3.1 Hot topics in domestic research on weaving and embroidery art

(1) The Inheritance of Embroidery Art

Research on domestic textile art focuses on high-frequency keywords like "artistic techniques," "cultural heritage," and "creative expression," highlighting the emphasis on preserving this traditional craft. Scholars recognize textile art as both a vital form of ethnic memory and cultural narrative, having evolved as an intangible heritage that carries profound cultural significance. The preservation of textile art transcends technical transmission—it embodies cultural identity and value construction. Experts advocate leveraging education, government initiatives, and modern media to revitalize traditional crafts. Zhou and Wang proposes integrating design thinking into Li ethnic group's textile techniques through curriculum development [41], community workshops, expert mentorship, heritage bases, and digital platforms. Huang and Yuan analyzes the model's sustainability while addressing challenges [42], offering recommendations for entrepreneurial workshops through educational innovation, policy support, cultural exchange, and public engagement.

(2) Art of Embroidery and Embroidery Symbol

In the second research theme of domestic embroidery art studies, the field of pattern and symbol inheritance in Chinese textile art faces multiple challenges. These include fragmented interpretations of traditional pattern cultural connotations, forced appropriation of symbolic motifs in modern designs, and the risk of cultural disconnection caused by reliance on verbal instruction and personal teaching methods. These issues have gradually led to the neglect of historical cultural memories and ethnic symbolic values embodied in embroidery patterns. How to preserve cultural authenticity while adapting embroidery patterns to contemporary development environments has become a crucial research topic in current embroidery studies. To scientifically address this issue, domestic scholars have conducted in-depth explorations. Xu and Guo provided new perspectives and references for interpreting Jinxiu Pan Yao embroidery patterns from a semiotic angle [43], while also exploring methods and pathways for applying ethnic minority embroidery patterns in modern cultural and creative design. Cao utilized virtual reality technology to explore reform pathways for teaching systems of Hainan Li ethnic group's spinning [44], dyeing, weaving, and embroidery techniques.

(3) Ethnic Minority Weaving and Embroidery Art

Under the guidance of terms such as "Li ethnic group," "craft," and "culture," the weaving and embroidery art of ethnic

minorities has become the third major research hotspot in China. Represented by the Li ethnic group's weaving and embroidery art, this unique craft has been included in the national intangible cultural heritage list due to its distinctive spinning, dyeing, weaving, and embroidery techniques. Relevant studies not only focus on the unique craftsmanship, production processes, and artistic styles but also pay attention to the weaving and embroidery in ethnic cultural identity, social life, and historical memory. It is believed that ethnic minority weaving and embroidery possess cultural diversity, holding significant value for studying the diversity and unity of China's culture and playing an important role in the systematic organization and analysis of traditional ethnic cultural techniques. Scholars generally agree that ethnic minority weaving and embroidery carry rich cultural connotations and serve as a key entry point for studying the diversity and integrity of Chinese culture. Therefore, systematic organization and in-depth research on them not only contribute to the protection and development of traditional ethnic crafts but also provide important academic value and practical significance for intangible cultural heritage research. Guided by the theory of Chinese-style modernization, Liu and Tu argues that this craft must adhere to the principles of ecological revitalization, artistic refinement [45], and maintaining tradition while adapting to new circumstances, exploring sustainable development in harmony with nature to facilitate the realization of harmonious coexistence in Chinese-style modernization. Ma and Feng [46], starting from the current status of the protection and inheritance of Li dragon quilts, conducts an in-depth analysis of the integration of Li dragon quilts' inheritance with contemporary life, fully explores their cultural value, empowers technology to establish new standards for inheritance and development, gathers advantages from various sectors, and constructs a dynamic inheritance path for Li dragon quilts, providing necessary theoretical support for the construction and innovative inheritance of the Li dragon quilt knowledge system.

4.3.2 Hot topics in foreign weaving and embroidery art

(1) Exploration of Innovative Applications of Intelligent Textile Materials in Weaving and Embroidery Art

As highlighted in Theme 1, international scholars have demonstrated particular interest in the innovative cross-disciplinary integration of smart textile materials and embroidery art. Against the backdrop of deep technological-artistic convergence, breakthroughs in material technology have unlocked new possibilities for traditional craftsmanship, while embroidery art urgently requires technological empowerment to rejuvenate its vitality. Smart textile materials like conductive fibers and functional threads, with their unique electrical properties, enhance the practical value of traditional embroidery. This transformation elevates embroidery from static aesthetic art forms to interactive, functional composite art forms. Such evolution not only expands the expressive dimensions of embroidery art but also pioneers new applications in wearable design and spatial decoration. The creative revolution sparked by combining smart materials with embroidery techniques undoubtedly represents a significant breakthrough for contemporary embroidery development. Regarding their relationship, smart textile materials serve as innovative mediums for embroidery art, while embroidery art provides aesthetic expression platforms for smart materials. The two mutually reinforce each other: material functionality endows embroidery art with technological cores, while the craftsmanship of embroidery liberates smart materials from industrial rigidity, presenting artistic characteristics that blend technological sophistication with humanistic warmth.

(2) The Artistic Creation of Weaving and Embroidery Combining Thread Technology with Textile Materials

As highlighted in Theme 2, the art of embroidery and weaving confronts multifaceted challenges in integrating thread techniques with textile materials. These include the incompatibility between traditional rigid fabrics and fine silk threads, as well as the tension between modern elastic fabrics and traditional stitching methods. Such issues may lead to compromised texture quality and reduced craftsmanship stability, making the precise integration of both elements a critical research focus. In the context of contemporary embroidery's diversified development, threads serve as the artistic brushstrokes, while textile materials act as the creative canvas. Their interplay directly defines the boundaries of artistic expression. Scholars argue that textile materials naturally guide thread techniques, while thread techniques elevate the value of textile materials, creating a mutually reinforcing relationship between the two.

(3) Development of Embroidery Art Forms Empowered by Sensing Technology

Examining Theme 3 reveals that integrating sensing technology with international textile art presents multifaceted challenges. These include the compatibility between sensing materials and flexible textiles, the balance between sensory functionality and visual aesthetics in embroidered works, and the hurdles in technological implementation and mass production. Such cross-disciplinary artworks often remain experimental, failing to reach commercialization. A critical challenge is transforming sensing technology into a catalyst for innovation in textile art. Key issues involve harmonizing sensing materials with textile craftsmanship, designing interactive works with logical flow, and exploring viable pathways for technological adaptation. Addressing these challenges will clarify the symbiotic relationship between sensing technology and textile art, bridging the gap from technical innovation to artistic expression.

In summary, while domestic and international research on textile embroidery art originates from different academic backgrounds and practical needs, both fundamentally explore its contemporary significance and potential value. Domestic cultural preservation and inheritance emphasize dynamic transmission through educational programs, policy support, and public awareness campaigns, focusing on its "national memory" and cultural identity functions. Internationally, innovation-driven approaches highlight new technologies like advanced materials, thread embroidery, and sensor technology, shifting from static aesthetic appreciation to interactive research and transitioning from traditional craftsmanship to integrated technological-traditional studies. Although these approaches differ in focus and methodology, they complement each other in the interplay between preservation and innovation. This cross-cultural comparison provides valuable insights for developing interdisciplinary research models. As globalization, informatization, and technological advancement continue to progress, textile embroidery studies will increasingly

emphasize bidirectional cultural-technological interaction, meeting contemporary demands while preserving the artistic integrity and continuity of traditional culture.

5 THE FRONTIERS IN THE RESEARCH OF EMBROIDERY ART

5.1 Keyword Emergence Analysis

Keyword prominence analysis, a key feature of CiteSpace's scientific literature analysis tool, identifies sudden surges in scholarly attention to specific keywords through detailed examination of their temporal patterns and intensity. This function helps researchers track cutting-edge developments in their fields, uncover emerging research hotspots, and drive scientific progress. By analyzing keywords in domestic and international textile and embroidery literature, the study generates prominence maps covering the period from 2004 to 2023.

The domestic keyword prominence chart reveals that among studies on textile and embroidery arts, "traditional craftsmanship" (2010) has the highest prominence score of 2.99. The earliest prominent topics are "embroidery patterns" and "embroidery," with "Li ethnic group" also notable. The longest-lasting focus spans three years, covering "textile embroidery," "embroidery patterns," and "embroidery." Notably, "traditional craftsmanship" has remained a hot topic in academic research from 2022 through 2024.

The foreign keyword prominence chart reveals that the most notable research on textile embroidery art since 2015 has focused on "performance," with a prominence score of 3.94. The earliest prominent keyword was "textile antennas," while "embroidered antennas" maintained the longest prominence period at 6 years. The keyword "identification" has consistently remained a research focus from 2021 to 2024.

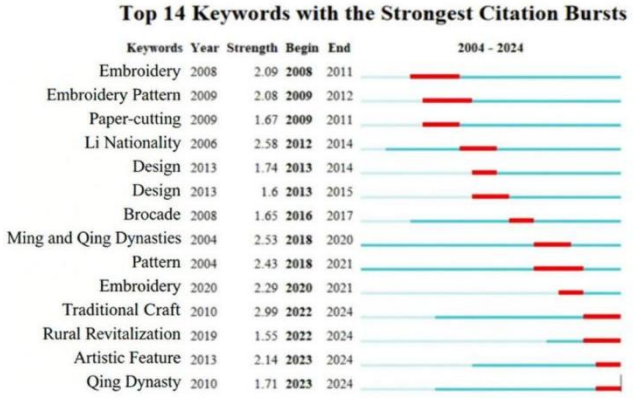

Figure 13 Keyword Highlighting in the Field of Domestic Embroidery Art Research

Through comparative analysis of textual materials, it is evident that domestic research on textile embroidery art has gradually shifted its focus from artistic characteristics such as "embroidery", "embroidery patterns", and "embroidery techniques" to more diversified fields including "design", "traditional craftsmanship", and "rural revitalization" over time. Internationally, research has expanded from material aspects like "performance" and "textile antennas" to more intelligent domains such as "identification" and "sensors". The absence of overlapping buzzwords in domestic and international studies between 2004 and 2024 highlights significant differences in research priorities. Analysis of emerging keywords from 2022 to 2024 reveals that domestic research focuses on "traditional craftsmanship" and "artistic features", while international studies emphasize "identification", "sensors", and "fabrication techniques" (Figure 13).

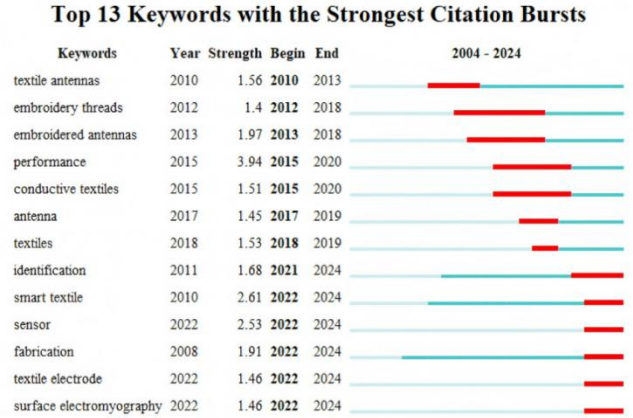

Figure 14 Keyword Highlighting in the Field of Foreign Embroidery Art Research

The domestic research tends to the connotation of the art of weaving and embroidery, while the foreign research tends

to the technology of the art of weaving and embroidery (Figure 14).

5.2 Research Trend Analysis

Through the text analysis of the research hotspots and trends in the field of weaving and embroidery at home and abroad, the following three future trends in the field of weaving and embroidery are summarized:
Interdisciplinary and diversified research in textile and embroidery studies. This interdisciplinary approach has become a prevalent methodology in contemporary academic research. By integrating cross-disciplinary theories and advanced technological tools, scholars can conduct multidimensional explorations of textile and embroidery fields. Strengthening collaborative networks and enhancing research collaboration among scholars from various disciplines will facilitate comprehensive analysis and solutions to challenges in preserving and advancing textile and embroidery traditions.
Research on Embroidery Design with Cultural Connotations. Embroidery art, a precious intangible cultural heritage in China and globally, carries profound cultural significance. This research not only showcases the contributions of embroidery art to human social development through design, but also provides innovative design perspectives. China's traditional embroidery art offers fresh design elements, expressing its cultural essence through creative expression. More artistic applications of embroidery design will emerge in public consciousness, making greater contributions to the preservation of embroidery art and the advancement of design practices.
Integrating digital technology into intelligent textile art research. With digital technology advancing at an unprecedented pace, smart solutions have permeated every aspect of human life. The future of textile art will inevitably evolve through intelligent digital integration, expanding traditional craftsmanship to achieve innovative development and transformative evolution. Academic research on textile art under intelligent digital technology will yield richer and more brilliant outcomes. By leveraging smart digital solutions, textile art in academic research will produce more diverse and high-quality scholarly achievements.

6 CONCLUSION

This study transcends the conventional scope of literature reviews by employing knowledge mapping and visualization techniques to conduct an objective, systematic, and structural in-depth exploration of textile embroidery art research. Grounded in digital innovation, the research reveals the holistic knowledge architecture and evolutionary patterns within this field, while comparing domestic and international research differences to gain new insights into its developmental trajectory. Utilizing CiteSpace for scientific literature analysis and LDA topic modeling, the study maps the thematic distribution and evolutionary paths of textile embroidery research globally. Domestic research focuses on cultural themes, patterns, and ethnic minority embroidery, emphasizing intangible cultural heritage preservation and cultural identity. International research centers on smart textile materials, sensor technologies, and cross-disciplinary craft innovation, prioritizing technological expansion of application boundaries. This dual approach of cultural narrative and technological empowerment drives the advancement of textile embroidery art. The study also identifies technological innovation gaps in domestic research and insufficient cultural representation in international studies, highlighting divergent orientations in academic traditions and societal needs. This disparity inevitably fosters greater interdisciplinary exchanges and cross-disciplinary integration.
The significance of this study lies not only in its objective compilation and in-depth analysis of over two decades of research literature on textile and embroidery arts, but also in its profound implications for the future development of such studies. On one hand, with the rapid advancement of big data and artificial intelligence, research in textile and embroidery arts should integrate emerging methodologies combining computer technology, breaking through traditional research limitations to explore deeper and broader research pathways. On the other hand, within a globalized context, textile and embroidery arts research must address major issues such as cultural heritage preservation, artistic inheritance, and innovation. This requires strengthening cross-regional and cross-cultural studies, establishing a diversified theoretical framework, and providing a solid foundation for practical research. This study aims to offer more systematic and multifaceted academic insights into understanding the evolution of textile and embroidery arts research under globalization and its contemporary research value, while also providing methodological references for other humanities and arts disciplines.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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