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Innovation of Digital Design of Intangible Cultural Heritage Based on Knowledge Graph and Multimodal Integration

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Abstract. This article aims to explore the path of digital design innovation for intangible cultural heritage (ICH), taking Li ethnic costumes in Hainan Province as an example. By constructing an ICH knowledge graph based on the Neo4j graph database and combining multimodal fusion technology with computer-aided design (CAD), traditional ICH elements can be innovatively applied in modern society. During the research process, relevant data on Li ethnic costumes were first collected and organized. The ICH knowledge graph was constructed using the Neo4j graph database and Cypher query language, achieving a visual presentation of knowledge. Subsequently, through multimodal fusion technology, different forms of data were organically fused, enriching the digital expression of Li ethnic costumes. Finally, with the help of CAD technology, traditional elements of Li ethnic costumes were digitally extracted and innovatively designed. The results indicate that the proposed method can effectively maintain the local structure of Li ethnic costumes and improve the contrast and stereo degree of clothing images. In terms of feature extraction precision, compared to traditional methods, the method proposed in this paper has achieved a maximum improvement of 28.45%. In terms of time consumption comparison, the traditional method's time consumption increases continuously with the increase of the number of feature information pixels. In contrast, the method proposed in this paper shows significant advantages.

Keywords: Intangible Cultural Heritage; Digital Design; Knowledge Graph; Multi-Modal Fusion; Li Ethnic Costumes
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1 INTRODUCTION

The widespread application of digital technology in the field of cultural heritage protection has not only injected new vitality into this ancient and precious field but also opened up an unprecedented path of innovation. The traces of its form, colour, texture, and even historical changes have left an indelible digital imprint for future generations. Digital technology can capture every detail of cultural heritage with high precision. With the continuous advancement of technology, the digitization of cultural heritage has not only become a feasible means of protection but also a bridge connecting the past and the future, promoting cultural inheritance and innovation. This recording method not only prevents physical wear and natural disasters from damaging physical heritage but also eliminates the limitations of time and space on the preservation of cultural heritage. This not only greatly expands the breadth and depth of cultural dissemination, but also promotes cross-cultural communication and understanding, providing strong support for education popularization and cultural inheritance. Digitization enables cultural heritage to cross the boundaries of regions and cultures. Through the Internet platform, global audiences can easily access these valuable cultural resources. This innovative presentation not only enhances the audience's sense of participation and satisfaction but also stimulates the public's interest and enthusiasm for the protection and inheritance of cultural heritage. By utilizing advanced technologies such as virtual reality (VR) and augmented reality (AR), digital cultural heritage can create immersive and interactive experience scenes, allowing audiences to feel as if they are in the long river of history and personally experience the charm of cultural heritage. Tourists can choose their own travel routes and experience projects according to their interests and preferences, and enjoy customized travel experiences. Digital technology also provides strong support for the intelligent management of the tourism industry. Through big data analysis and artificial intelligence technology, tourism managers can monitor tourism traffic in real-time, optimize tourism resource allocation, improve tourism service quality, and provide tourists with a more convenient and efficient tourism experience. In the long history of human civilization, Intangible Cultural Heritage (ICH), as the crystallization of national wisdom and creativity, carries rich historical memories and cultural genes [1]. However, with the acceleration of modernization, many precious ICH cultures are facing the risk of transmission breaks and disappearance. Therefore, exploring effective paths for ICH protection and innovation has become an important topic in cultural research today. Digital technology provides new opportunities for the transmission and development of ICH culture [2]. Through digital means, not only can the rich connotations of ICH culture be recorded and preserved, but also new vitality can be injected into it. As an important tool in the era of big data and artificial intelligence, the knowledge graph can efficiently organize and display complex knowledge systems by constructing network structures such as entities, attributes, and relationships [3]. In the transmission of ICH culture, the application of knowledge graphs can depict multi-dimensional information such as the historical origins, skill characteristics, and transmission lineages of ICH projects, providing researchers, transmitters, and the public with an intuitive and comprehensive knowledge platform. Neo4j, as a high-performance graph database, demonstrates significant advantages in constructing and managing complex network structures with its powerful data processing capabilities and flexible query language, Cypher, providing strong technical support for the construction of ICH knowledge graphs [4].

In exploring the vast field of digitalization of cultural heritage, some scholars aim to re-examine and interpret the profound heritage of intangible cultural heritage by integrating advanced geographic information technology. Especially when facing ancient buildings that contain complex, intricate, and unique historical details, it is difficult to achieve perfect replication [5]. This process not only focuses on the multidimensional reconstruction and precise expression of the external form of heritage structure but also deeply reveals the vicissitudes and rich levels it has experienced in the long river of history [6]. As a key tool for digitizing cultural heritage, HBIM faces many challenges in its construction process. These components are derived from high-precision laser scanning data and point cloud fine segmentation generated by unmanned aerial vehicle photogrammetry and are directly integrated into the HBIM environment. The core advantage of this method is that it can gather massive amounts of information in a single, integrated digital model (i.e. HBIM), which covers all valuable data obtained from preliminary investigations to in-depth research processes. Therefore, it proposes an innovative strategy that cleverly integrates multiple 3D model components (such as. obj format files). This environment is built on top of intelligent objects, which are interconnected to form a highly intelligent model system that can meticulously reproduce every subtle detail in antique architecture. This integrated feature not only greatly improves the efficiency and convenience of data management, but also provides a powerful platform for researchers to deeply explore the evolution of building forms without frequent on-site investigations [7]. Multimodal fusion technology can organically integrate different forms of data such as text, images, videos, etc., achieving information complementation and enhancement. In the process of ICH digitization, the application of multimodal fusion technology can greatly enrich the manifestations of ICH culture, enabling viewers to experience the charm of ICH from multiple angles and in an all-around way. Through CAD technology, designers can perform precise digital extraction and reconstruction of ICH elements, realizing innovative designs of traditional patterns, colours, shapes, and other elements, and injecting new vitality into ICH culture.

In the vast field of digitalization of cultural heritage, machine learning technology is showing unprecedented potential, especially in the precise identification and analysis of pure pigments and complex mixed pigments in artistic works. The digital protection and analysis of cultural heritage require highly accurate capture and analysis of colour information in artworks. Some scholars have fused spectral data directly collected from pigment tubes with spectral features from the paintings of the Portuguese outstanding artist Amadeo de Souza Cardoso [8]. Not only did it deepen the understanding of pigment composition and its historical changes, but it also innovatively applied the principle of subtractive mixing to enhance data-driven pigment recognition capabilities. Specifically, the application of deep neural networks (DNNs), with their powerful feature extraction and pattern recognition capabilities, has successfully achieved precise differentiation between black and white pigments and even a wider range of pigment types, setting a new benchmark for digital colour analysis of cultural heritage [9]. In the study, the introduction of root mean square error (RMSE) provided a powerful mathematical tool for distinguishing complex mixtures containing white and black pigments, further enhancing the precision of analysis. This is crucial for revealing the creative techniques, temporal characteristics, and even preservation status of artworks. This provides art historians with an unprecedented detailed perspective, helping them delve deeper into the artist's creative intentions and colour application strategies. DNN can not only accurately reconstruct images based on estimated pigment mixtures but also reveal the types of base pigments in the artwork and their specific abundance at each pixel. In addition, by carefully selecting the activation function of the DNN output layer, the non-negativity of predicting pigment abundance is ensured. Meanwhile, the increase in network depth has significantly improved the accuracy of predictions, providing valuable technical support for research in the field of cultural heritage digitization. The digitization of cultural heritage is not only a digital replication of physical objects but also a deep exploration and dissemination of their intrinsic value and cultural significance [10].

This research aims to explore the digital design innovation path for ICH culture by constructing an ICH knowledge graph based on the Neo4j graph database, combining multimodal fusion technology and CAD, and using the Li ethnic costumes of Hainan Province as an example. Through this research, it is hoped that a new idea and method can be provided for the digital protection and innovative design of ICH culture, promoting the transmission and development of ICH culture in modern society. At the same time, it is also hoped that through the specific case of the Li ethnic costumes of Hainan Province, beneficial references can be provided for the digital protection and innovative design of other ICH projects.

(1) ICH knowledge graph construction: Using the Neo4j graph database and Cypher language, a systematic ICH knowledge graph of Li ethnic costumes in Hainan Province was constructed.

(2) Application of multimodal fusion technology: Innovatively integrating multimodal data such as text, images, and videos to enrich the digital expression of ICH culture.

(3) Application of CAD in ICH Innovative Design: Applying CAD technology to ICH innovative design to achieve digital extraction and reconstruction of Li ethnic costume elements.

(4) Comprehensive path exploration: Propose an innovative path for ICH digital design based on knowledge graph and multimodal fusion, providing references for other ICH projects.

(5) Visual presentation and interactive enhancement: Implement visualization and interactive design of the ICH knowledge graph to enhance user engagement.

This study will first collect and organize relevant data on Li ethnic costumes in Hainan Province, including historical literature, pattern design, weaving techniques, and other information; Then, using the Neo4j graph database and Cypher query language, an ICH knowledge graph is constructed to visualize the presentation of Li ethnic histories knowledge; Next, through multimodal fusion technology, different forms of data such as text, images, and videos are organically fused to enrich the digital expression of Li ethnic costumes; Finally, with the help of CAD technology, traditional elements of Li ethnic costumes are digitally extracted and innovatively designed to explore their application and promotion in modern society.

2 RELATED WORKS

Luo et al. [11] proposed an innovative digital strategy for cultural heritage, cleverly utilizing rich image resources on social media platforms such as Twitter to perform large-scale, high-precision 3D reconstruction of global cultural heritage landmarks. As a global social media platform, Twitter not only carries users' daily life records but also becomes an important channel for travelers to share their travel experiences and capture the unique charm of cultural heritage. Effectively integrate cultural heritage image resources scattered in all corners of the Internet, providing rich data support for the digital protection of cultural heritage. At the same time, through intelligent image screening and 3D reconstruction technology, not only has the reconstruction efficiency and accuracy been improved, but the digital achievements of cultural heritage have also been presented to the public in a more vivid and three-dimensional manner, promoting the popularization and dissemination of cultural heritage knowledge. These vast and diverse image resources provide unprecedented opportunities for the digital protection and dissemination of cultural heritage. Mironova et al. [12] accurately extracted key information related to cultural activities and landmarks from unstructured tweets using natural language processing techniques and data mining methods. In the context of the digitalization of cultural heritage, its approach focuses on carefully designing and implementing three core steps. Intended to select the most representative and valuable cultural heritage images from a massive collection of images, laying a solid foundation for subsequent 3D reconstruction. The uniqueness of this method lies in fully utilizing the advantages of social media in cultural dissemination and information sharing. Finally, by utilizing the selected high-quality image set and combining advanced computer vision and graphics algorithms, fast and accurate 3D reconstruction of cultural heritage landmarks can be achieved. Secondly, based on content analysis technology, efficient image retrieval and intelligent filtering have been achieved.

With the increasing awareness of cultural heritage protection in society, the concept of super heritage has emerged, advocating the construction of unprecedented communication bridges for the perception, exploration, and data processing of cultural heritage. This process heavily relies on high-resolution roughness measurement and imaging tools, which are like digital microscopes for cultural heritage, capable of revealing beauty in details that traditional methods cannot achieve. Building high-resolution digital models of painted surfaces is not only an important milestone in the digitalization process of cultural heritage but also lays a solid foundation for subsequent artistic research, protection, and restoration work. In this context, the digital surface super heritage method, as a cutting-edge academic project, is leading a new round of innovation in the field of cultural heritage digitization. These digital models not only faithfully reproduce the physical form of the artwork but also contain rich creative information, such as the artist's brushstrokes, color usage, and subtle changes in the creative process. Driven by the digital surface super heritage method, Radosavljevi and Ljubisavljevi [13] delve into the connotation and value of artistic works, such as the meaning, creative background, style, and genre of masterpieces, and even the author's creative process. They are like imprints of time, allowing future generations to travel through time and space and engage in spiritual dialogue with ancient masters. This project focuses on the precise recognition of surface morphology in art painting. Integrating core concepts and advanced technologies of sensory rendering achieves comprehensive capture and analysis of surface features of artworks on micro and macro scales. At the same time, this method also promotes interdisciplinary cooperation, integrating knowledge and technology from multiple fields such as computer science, materials science, art history, etc., and jointly contributing to the protection and inheritance of cultural heritage.

The uniqueness of cultural heritage, as its irreplaceable value, is particularly important in resisting threats such as time erosion, accidental destruction, and human destruction. Ramm et al. [14] innovatively proposed a comprehensive method that combines non-contact 3D shape acquisition with high-precision colour texture data. Through the collaborative work of structured light 3D sensors and cameras, every detail of cultural heritage is captured from different angles. The core of this method lies in its portability, which gives digital tools unprecedented flexibility to accurately record even fragile, large, or difficult-to-move cultural heritage on site. This process ensured that the resolution and accuracy of the model reached an unprecedented level of 0.1 millimeters, setting a new benchmark for the digital protection of cultural heritage. Trek [15] seamlessly integrates these dispersed 3D shapes with photographic data using advanced algorithms to generate a complete 3D model that includes geometric shapes and rich colour textures. In the process of seeking effective protection strategies, the digitization of cultural heritage as a non-invasive means of protection is increasingly demonstrating its irreplaceable importance. It aims to construct a detailed and realistic three-dimensional digital model of cultural heritage. These high-precision 3D models are like bridges spanning time and space, allowing scholars, experts, and even ordinary tourists from around the world to experience the charm of cultural heritage through online platforms or virtual museums. This unprecedented interactive experience not only promotes the dissemination of knowledge and cultural exchange but also opens up new avenues for the sustainable use and inheritance of cultural heritage.

3 CONSTRUCTION OF ICH KNOWLEDGE GRAPH BASED ON NEO4J

Through CAD technology, designers can accurately extract and reconstruct ICH elements digitally, achieving innovative designs of traditional patterns, colours, shapes, and other elements. CAD technology can be used for the digital modelling of ICH elements, automatic generation and deformation of patterns, intelligent colour matching, and other aspects. The application of these technologies can not only improve the design efficiency and quality of ICH elements but also inject new vitality into ICH culture. This study will comprehensively apply the theoretical basis and technical methods mentioned above, taking Li ethnic costumes in Hainan Province as an example to explore the digital design innovation path of ICH culture. Firstly, the ICH knowledge graph model is constructed using knowledge graph theory, and then the Neo4j graph database and Cypher query language are used to store and query knowledge. Next, different forms of data are organically fused through multimodal fusion technology to enrich the digital expression of Li ethnic costumes; Finally, with the help of CAD technology, traditional elements of Li ethnic costumes were digitally extracted and innovatively designed. In the digital protection and innovative design of ICH culture, the knowledge graph serves as an efficient information organization and management tool that can systematically integrate the diverse information of ICH resources, revealing their inherent correlations and structural characteristics. Neo4j, As a high-performance graph database designed specifically for graphic data processing, is an ideal choice for building ICH knowledge graphs due to its powerful data processing capabilities, flexible query language Cypher, and excellent visualization features.

3.1 Introduction to Neo4j Graph Database

Knowledge graph, as a structured knowledge representation method, organizes knowledge into a network structure through elements such as entities, attributes, and relationships, making it easier for computers to understand and process. In the inheritance of ICH culture, the application of a knowledge graph can depict the multidimensional information of ICH projects, such as historical origins, technical characteristics, inheritance lineage, etc., providing researchers, inheritors, and the public with an intuitive and comprehensive knowledge platform. The construction process of a knowledge graph includes steps such as data collection, preprocessing, entity recognition, relationship extraction, and attribute annotation, each of which requires refined operations and design. Neo4j is a high-performance graph database specifically designed for storing and querying graph-structured data. It demonstrates significant advantages in building and managing complex network structures with its powerful data processing capabilities and flexible query language Cypher. In the construction of the ICH knowledge graph, Neo4j can effectively store elements such as entities, attributes, and relationships, and support efficient query and traversal operations. Cypher query language provides an intuitive and easy-to-use way to describe and query graph-structured data, enabling users to easily construct and query ICH knowledge graphs. Multimodal fusion technology is a technique that organically fuses different forms of data, such as text, images, videos, etc. In the process of digitizing ICH, the application of multimodal fusion technology can greatly enrich the expression of ICH culture, enabling audiences to experience the charm of ICH from multiple perspectives and all angles. Multimodal fusion technology can extract the historical background and cultural connotations of ICH culture through text mining; Extract and analyze the patterns, colours, and other features of ICH elements through image processing techniques; Record and showcase the demonstration process of ICH skills through video processing technology. These different modalities of data complement and enhance each other, providing audiences with a more comprehensive and vivid ICH cultural experience. Neo4j is an open-source graphical database management system that uses a property graph model to store and retrieve data. Unlike traditional relational databases, Neo4j stores data in the form of Nodes and Relationships in a network structure, where each node and relationship can contain Properties. This storage method enables Neo4j to perform well in handling complex network structures and conducting deep association queries. In addition, Neo4j supports ACID transaction processing to ensure data integrity.

3.2 ICH Knowledge Graph Design

Before constructing the ICH knowledge graph, it is necessary first to conduct a conceptual design to clarify the entity types, relationship types, and attribute information contained in the graph (Table 1). Taking Li ethnic costumes in Hainan Province as an example, the ICH knowledge graph can include the following core entity types:

(1) ICH project: represents specific ICH projects, such as the production techniques of Li ethnic costumes.

(2) Clothing types: Different types of Li ethnic costumes, such as Tube Skirt, cardigans, etc.

(3) Pattern and pattern: The patterns and patterns on clothing reflect the cultural connotations and artistic characteristics of the Li ethnic group.

(4) Material technology: The materials and unique techniques used to make clothing.

(5) Regional culture: The cultural background of the region to which Li ethnic costumes belong, including geographical location, historical evolution, etc.

Core Entity Types	*Relationship Types*	*Attribute Information*
Intangible Cultural Heritage Project	BELONGS_TO	Project Name, Declaration Time, Protection Level, Inheritors, Geographical Distribution, etc.
Clothing Type	CONTAINS	Type Name, Style Characteristics, Historical Evolution, Popular Regions, etc.
Pattern and Design	USED_IN	Pattern Name, Design Elements, Symbolic Meaning, Production Techniques, etc.

Materials and Techniques	APPLIED_TO	Material Name, Collection Method, Processing Technology, Uniqueness, etc.
Regional Culture	OWNS/NURTURES	Region Name, Geographical Location, Historical Evolution, Cultural Characteristics, Related ICH Projects, etc.

Table 1: Entity and relationship design of ICH knowledge graph.

The relationship types include "belongs", "contains", "used", etc., which are used to connect the above entities and form a complete knowledge network.

3.3 Data Preparation and Import

Data is the foundation for building a knowledge graph. When constructing the knowledge graph of Li ethnic costumes in Hainan Province, it is necessary to collect multiple heterogeneous data sources such as ICH project information, clothing images, pattern descriptions, material and process descriptions, and regional cultural introductions. After data collection is completed, preprocessing, such as data cleaning, deduplication, and formatting, is required to ensure the quality and consistency of the data.

Assuming the ICH text dataset is D and the entity category set is C, the goal of entity recognition is to identify entities belonging to C from D. Using the Conditional Random Field (CRF) model for entity recognition:

$$P\ x_i \left| y_i, x_1, x_2, \ldots, x_{i-1}, x_{i+1}, \ldots, x_n \right. = \frac{\exp \sum_k \lambda_k f_k\ y_i, x_i, x_{i-1}}{\sum_{y' \in C} \exp \sum_k \lambda_k f_k\ y', x_i, x_{i-1}} \quad (1)$$

Among them, $e1$ represents the $e2$ th word, R represents the entity category corresponding to $e1$, $e2$ is the model parameter, and $r \in R$ is the feature function.

$$h_{rel} = \tanh\ W_r \left[h_{e1}; h_{e2}; h_{e1} \circ h_{e2}; h_{e1} - h_{e2} \right] \quad (2)$$

Among them, h_{e1} and h_{e2} are vector representations of entities $e1$ and $e2$, N_{new} ○ outer product operation, and W_r the weight matrix of relationship r.

Neo4j supports multiple data import methods, including direct import through Cypher query language, import through the graphical interface of Neo4j Desktop, and large-scale data batch import through Neo4j Data Import Tool (Neo4j import). For the construction of the knowledge graph of Li ethnic costumes in Hainan Province, an appropriate import method can be selected based on the size of the data. If the data volume is not large, it can be imported through Cypher query language or Neo4j Desktop. If the amount of data is large, it is recommended that the Neo4j import tool be used to improve import efficiency. Create an ICH project node using Cypher query language and set its properties:

1. CREATE (p: Project {name: "Li Nationality Clothing Craftsmanship,"
2. declarationYear: 2006, protection level: "National Level"})

3.4 Knowledge Graph Construction Process

(1) Create nodes: Use Cypher query language to create nodes in Neo4j that represent ICH projects, clothing types, pattern designs, material craftsmanship, and regional culture, and set corresponding

attributes for each node. For example, when creating an ICH project node, attributes such as project name, declaration time, and protection level can be set.

(2) Establish relationships: Based on the association information between entities, establish relationships between nodes in Neo4j. For example, a relationship can be established that "a certain ICH project belongs to a certain regional culture." The Cypher query statement is as follows:

1. MATCH (p: Project {name: "Li Nationality Clothing Craftsmanship"}), (c: Culture {name: "Hainan"})
2. CREATE (p)-[:BELONGS_TO]->(c)

Or the relationship of "a certain clothing type contains a certain pattern," Cypher's query statement is as follows:

1. MATCH (t: Type {name: "Tube Skirt"}), (d: Design {name: "Diamond Pattern"})
2. CREATE (t)-[:CONTAINS]->(d)

The establishment of relationships enables the information in the knowledge graph to be interconnected and form a complete network structure.

(3) Query and Validation: During the construction process, it is necessary to continuously use Cypher query language to query and validate the graph, ensuring its accuracy and completeness. For example, to query all ICH projects belonging to the "Hainan" regional culture:

1. MATCH (p:Project)-[:BELONGS_TO]->(:Culture {name: "Hainan"})
2. RETURN p

Or search for all the patterns and designs included in the "Tube Skirt" clothing type:

1. MATCH (:Type {name: "Tube Skirt"})-[:CONTAINS]->(d:Design)
2. RETURN d

By querying, it is possible to check whether the creation of nodes and relationships meets expectations and whether there are any omissions or errors.

(4) Optimization and Expansion: With the continuous accumulation of data and changing demands, the ICH knowledge graph needs to be continuously optimized and expanded. The content of the graph can be enriched by adding new entity types, relationship types, or attribute information. Meanwhile, Neo4j's indexing, constraint, and other features can also be utilized to optimize query performance and data consistency.

3.5 Visualization and Analysis of Knowledge Graph

Neo4j provides powerful visualization tools such as Neo4j Browser and Neo4j Bloom to showcase the structure of knowledge graphs and query results. Fusion is needed for the entities identified with the same name. Let the entity set be E, and the formula of entity fusion is as follows:

$$e_{merged} = \frac{1}{|E|}\sum_{e \in E} e \qquad (3)$$

According to the existing relationship and entity attributes, the potential relationship is predicted. Let entities $e1$, $e2$ and relation set R, and the formula of relation completion is as follows:

$$P\ \ r\left|e1,e2,R\right.\ = \frac{\exp\ \sum_{k}\beta_k g_k\ \ e1,e2,r}{\sum_{r'\in R}\exp\ \sum_{k}\beta_k g_k\ \ e1,e2,r'} \tag{4}$$

Where β_k is the model parameter and g_k is the characteristic function.

Through visualization tools, researchers can intuitively understand the relationship between entities and the overall structural characteristics in the Knowledge graph of Li Ethical Costumes in Hainan Province. In addition, Cypher query language can be used for complex data analysis, such as counting the number of ICH projects in different regional cultures and analyzing the correlation between clothing types and patterns, which provides strong support for the digital protection and innovative design of ICH culture.

4 APPLICATION OF MULTIMODAL FUSION IN DIGITAL DESIGN OF ICH

In the process of digital design of ICH culture, multimodal fusion technology plays a vital role. By organically integrating different forms of data such as text, image and video, multimodal fusion technology can greatly enrich the expression of ICH culture, so that the audience can feel the charm of ICH from multiple angles and in all directions. Taking Li Ethical Costumes in Hainan Province as an example, the application of multimodal fusion technology in ICH digital design is mainly reflected in the following aspects.

4.1 The Fusion of Text, Image, and Video Data

In the digital design of Li ethnic costumes, a large amount of relevant textual materials were first collected, including historical documents, legendary stories, and descriptions of weaving techniques. These textual materials provide rich background information on the cultural connotations of clothing. At the same time, high-definition images of Li ethnic costumes and video footage of the weaving process were also captured. Through multimodal fusion technology, these text, image, and video data are organically fused to form a comprehensive and three-dimensional digital expression of Li ethnic costumes. Figure 1 shows several exquisite photos of Li ethnic costumes.

Figure 1: Li ethnic costumes.

4.2 The Application of CAD Technology in the Design of Li Ethnic Costumes

CAD technology has played an important role in the digital design of Li ethnic costumes. Through CAD technology, traditional patterns, colours, shapes, and other elements of Li ethnic costumes can be accurately digitally extracted and reconstructed to achieve innovative design.

Figure 2: Digital reconstruction of Li ethnic costumes.

In Figure 2, a Li ethnic costume pattern digitally reconstructed using CAD technology is shown. Through the powerful functions of CAD software, patterns can be enlarged, reduced, deformed, and adjusted for colour and texture, giving traditional patterns new vitality. This digital reconstruction preserves the essence of traditional patterns and injects modern aesthetic elements into them, making them more in line with the aesthetic needs of modern society.

4.3 Example Analysis: Digital Design of Li Ethnic Costumes

Next, a specific example will be used to demonstrate the digital design process of Li ethnic costumes based on multimodal fusion and CAD technology.

Firstly, a sample of the traditional clothing of the Li ethnic group was collected measured and photographed in detail. Then, using CAD technology, we digitally extracted elements such as patterns, colours, and shapes from the clothing. In Figure 3, it can be seen that the digitally extracted clothing pattern has smooth lines and bright colours, perfectly retaining the charm of traditional clothing.

Figure 3: Digital extraction of clothing patterns.

Subsequently, innovative designs were carried out on the extracted patterns. Through the transformation and recombination functions of CAD software, traditional patterns have been organically integrated with modern elements, forming a new pattern style. In Figure 4, the innovative design pattern can be seen, which retains the essence of traditional patterns while incorporating modern aesthetic elements, presenting a unique visual effect.

Figure 4: Generation of Li ethnic costume patterns.

Figure 5: Li ethnic costume design after multimodal fusion.

Finally, the innovative design pattern was applied to the new clothing design. Through multimodal fusion technology, the images, videos, and related textual descriptions of new clothing have been organically integrated to form a comprehensive digital expression. In Figure 5, the newly designed image of Li ethnic costumes can be seen, with novel patterns and harmonious colour matching, fully demonstrating the potential of multimodal fusion and CAD technology in ICH digital design.

4.4 Performance Test

Figure 6 shows the subjective assessment results of observers on Li ethnic costume design works. Observers generally believe that the Li ethnic costumes works designed using the method proposed in this article perform well in maintaining the local structural features of traditional Li ethnic costumes, especially in enhancing the contrast of clothing images and improving the stereoscopic visual effect of clothing and have received high praise.

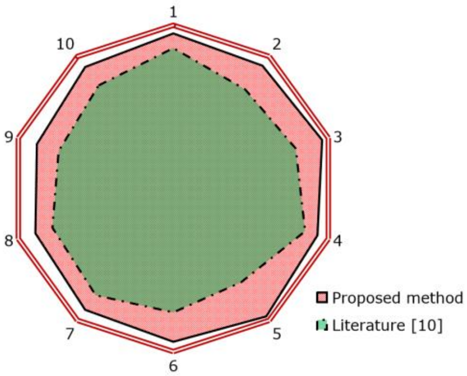

Figure 6: Subjective assessment of Li ethnic costume design works.

Figure 7 provides a comparison of modelling precision for different algorithms in the feature extraction task of Li ethnic costumes. Through comparative analysis, it can be seen that compared with other traditional methods, the feature extraction method proposed in this paper has achieved significant improvement in precision, with the highest precision improvement reaching 28.45%, fully demonstrating the superiority of this method in feature extraction of Li ethnic costumes.

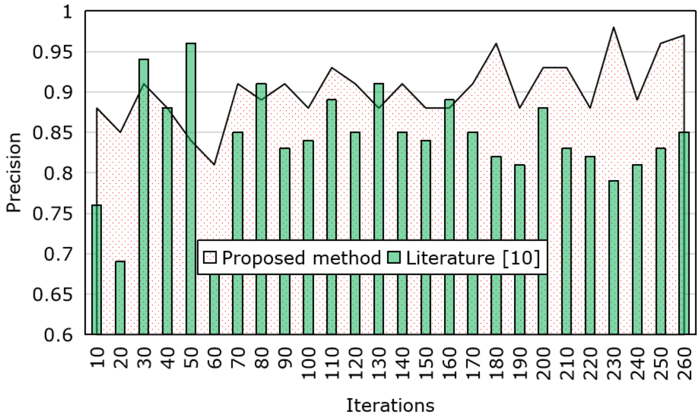

Figure 7: Precision of feature extraction using different methods.

In addition to precision comparison, an in-depth analysis was conducted on the time consumption of different methods in feature extraction of Li ethnic costumes, as shown in Figure 8.

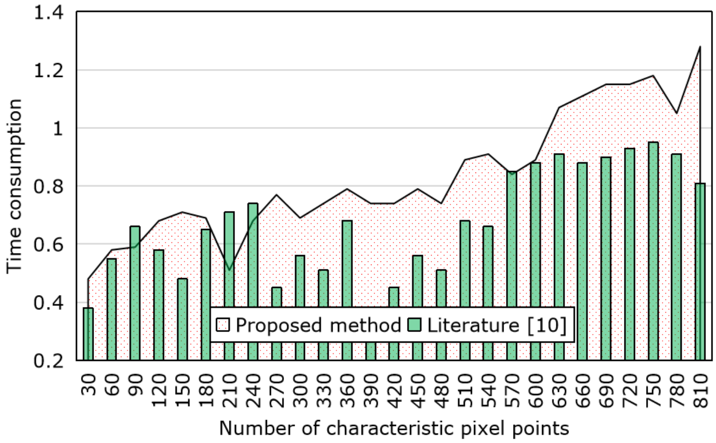

Figure 8: Time consumption of feature extraction using different methods.

As the number of feature information pixels increases, the time consumption of traditional methods sharply increases, exhibiting high time complexity. In contrast, although the feature extraction method proposed in this article has also increased in time consumption, the overall time consumption is much lower than traditional methods, demonstrating higher computational efficiency and processing speed. This advantage is particularly important in practical applications, especially in processing large-scale datasets or real-time feature extraction scenarios, which can significantly improve work efficiency.

5 CONCLUSIONS

This study takes Li ethnic costumes in Hainan Province as an example to explore the innovative path of digital design for ICH culture based on knowledge graphs and multimodal fusion. By constructing an ICH knowledge graph based on the Neo4j graph database, the systematic organization and visualization of knowledge related to Li ethnic histories have been achieved. This study utilizes multimodal fusion technology to fuse different forms of data such as text, images, and videos, greatly enriching the digital expression of Li ethnic costumes and enabling viewers to experience their unique cultural charm from multiple angles and perspectives.

In terms of digital design innovation, combining CAD technology, traditional elements of Li ethnic costumes were digitally extracted and innovatively designed, exploring their application and promotion in modern society. Through case analysis, it has been proven that the proposed method can inject modern aesthetic elements while maintaining the characteristics of traditional clothing, achieving a perfect combination of tradition and modernity.

In future research, ICH cultural digital design innovation based on knowledge graphs and multimodal fusion will demonstrate broader application prospects and profound cultural value.

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