

Research on Intelligent Extraction of Visual Symbols and Creative Transformation Methods in the Digital Inheritance of Intangible Cultural Heritage

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ABSTRACT Digital inheritance of intangible cultural heritage requires efficient extraction of visual symbols while preserving morphological details and cultural integrity. Current manual tracing and shallow image-processing approaches are inefficient and may lose symbolic structure or cultural meaning during extraction and transformation. This study proposes an intelligent visual-symbol extraction and creative transformation framework based on deep feature fusion. Representative intangible cultural heritage samples, including paper-cutting, shadow puppetry, and batik, are collected and analyzed from four dimensions: morphology, color, texture, and cultural semantics. A feature database is built to support model training and transformation design. The extraction model integrates convolutional neural networks and generative adversarial networks, with non-stationary fingerprint constraints, multi-window deconvolution decoupling, overlapping masks, delay compensation, and topological consistency constraints to achieve multi-scale feature extraction, interference suppression, and precise segmentation. A Cultural Preservation Index is introduced to evaluate whether extracted symbols retain expert-verified cultural gene templates. Based on extracted symbols, a multidimensional creative transformation strategy is designed, including simplified reconstruction, meaning translation, and scene adaptation. Experiments on 800 visual-symbol samples show an extraction accuracy of 92.7%, significantly higher than single-CNN extraction, while average processing time is reduced to 0.8 s per sample. User recognition of transformed works reaches 86.2%. The framework provides an image signal processing and intelligent visual-design method for digital cultural-resource systems.

INDEX TERMS visual symbol extraction, deep feature fusion, image signal processing, generative adversarial network, cultural heritage digitization

I. INTRODUCTION

AGAINST the backdrop of rapid iteration of digital technology and increased cultural confidence, the digital inheritance of intangible cultural heritage (hereinafter referred to as “ICH”) has become an important measure to safeguard cultural roots and promote cultural innovation. As an intuitive carrier of intangible cultural heritage culture, visual symbols of intangible cultural heritage cover Paper Cuttings patterns, shadow puppets, batik patterns and other forms. They are the core media to convey regional characteristics, national aesthetics and spiritual beliefs. Their digital extraction and creative transformation are key links to achieve the living inheritance of intangible cultural heritage. This article aims to address the pain points of inefficient extraction and weak transformation of visual symbols in the

current digital inheritance of intangible cultural heritage, and to construct a scientific and efficient intelligent extraction and creative transformation method system, filling the gap of “technology application and cultural inheritance disconnection” in existing research, promoting the innovative application of intangible cultural heritage visual symbols in modern scenarios, and possessing both theoretical exploration and practical application value.

At present, although there has been some progress in the digitization of intangible cultural heritage, with the establishment of multiple intangible cultural heritage databases and the widespread coverage of new media communication, there are still prominent problems in the digital processing of visual symbols. On the one hand, traditional visual symbol extraction relies on manual tracing and shallow

image processing, which is not only time-consuming and labor-intensive, but also difficult to adapt to the digital needs of large-scale intangible cultural heritage resources. It is also prone to problems such as loss of symbol details and misinterpretation of cultural connotations, and cannot accurately preserve the core cultural genes of intangible cultural heritage visual symbols; On the other hand, existing creative transformations often remain at the level of simple copying and pasting, lacking in-depth interpretation of the cultural connotations of symbols. The homogenization of transformed works is severe, and their adaptability to modern aesthetics, life scenarios, and market demands is insufficient, resulting in the difficulty of truly integrating intangible cultural heritage visual symbols into contemporary life and achieving effective living inheritance. In addition, existing research often separates the extraction and transformation processes, lacks systematic method design, and fails to form a complete closed loop of “extraction analysis transformation application”. The synergy between technology application and cultural inheritance is insufficient, which is also a key bottleneck restricting the improvement of the quality of digital inheritance of intangible cultural heritage.

First of all, this paper combs and analyzes the visual symbols of intangible cultural heritage, clarifies the types, morphological characteristics, cultural connotation and extraction difficulties of typical visual symbols of intangible cultural heritage, such as Paper Cuttings, shadow puppets, batik, and builds a database of visual symbol characteristics of intangible cultural heritage, providing a basis for subsequent extraction and transformation; Secondly, an intelligent extraction model is constructed based on deep neural networks, integrating the advantages of convolutional neural networks (CNN) and generative adversarial networks (GAN). To handle irregular pattern noise, the model utilizes non-stationary fingerprint annotation, multi-window deconvolution decoupling, and topological consistency constraints. Specifically, the topological consistency is defined by the energy function $E = \sum \|V_i - V_j\|^2$, which ensures the geometric structure remains intact during segmentation, and other technologies are introduced to achieve multi-scale feature extraction, interference suppression, and accurate segmentation of intangible cultural heritage visual symbols, ensuring that the extracted symbols retain both detailed features and fully carry cultural genes; Once again, design a multi-dimensional creative transformation strategy based on the cultural connotations and morphological characteristics of symbols, divided into three levels: simplification and reconstruction, semantic translation, and scene adaptation. Combining modern design concepts and digital technology, achieve creative transformation of symbols, and develop works that are suitable for cultural and creative products, digital media, architectural decoration, and other scenes; Finally, the performance of the extracted model was verified through experiments, and creative transformation practices were completed through case studies. User feedback and expert evaluations were collected, and the method system was

optimized to form a scalable and reusable digital inheritance plan for intangible cultural heritage visual symbols.

II. RELATED WORK

In the field of intelligent extraction of visual symbols and creative transformation methods in the digital inheritance of intangible cultural heritage, numerous scholars have conducted in-depth explorations. Cunha et al. [1] demonstrate how deep learning can detect subtle visual anomalies in complex medical imaging, providing a methodological framework for high-precision feature extraction that can be adapted to the intricate patterns of ICH; Fernández Camporro et al. [2] used visual cues for pathological diagnosis of skin diseases. Their method of analyzing visual features to achieve accurate judgment has enlightening significance for the precise extraction of intangible cultural heritage visual symbols; Souza's [3] research on two visual communication modes, pictograms and Brazilian sign language, provides a perspective for the diversity of visual symbol communication methods in intangible cultural heritage; Koonin and Crysta's [4] study on the representative meanings of visual symbols in Time magazine's 9/11 helps to understand the connotation communication of visual symbols in different contexts, and has reference value for exploring the connotation of intangible cultural heritage visual symbols; Zhao et al. [5] studied the impact of the number of security personnel on the efficiency of detecting accident warning signs under visual obstruction, providing environmental considerations for the recognition and presentation of intangible cultural heritage visual symbols in different environments; Quintero et al. [6] studied political cartoons as visual symbols, demonstrating the creative expression forms of visual symbols under specific themes, which has reference value for the creative transformation of intangible cultural heritage visual symbols; Lieberman's [7] research on the role of visual modalities in sign language learners provides theoretical support for the study and inheritance of intangible cultural heritage sign language visual symbols; Awalin et al. [8] improved visual information by creating a signage system, and their system creation method has guiding significance for the construction of intangible cultural heritage visual symbol systems; Chavan et al. [9] developed a sign language dynamic image recognition system based on artificial neural networks, which achieves the conversion to audio and visual output, providing a practical example for intelligent extraction and creative transformation technology of intangible cultural heritage visual symbols; Similarly, the research by Hilgert et al. [10] on multimodal analysis of visual impairment offers insights into how algorithms handle noisy visual data—a common challenge when processing aged or damaged batik and shadow puppetry samples. However, currently, other researchers on this topic mostly focus on single technologies or specific types of intangible cultural heritage, lacking research on extraction methods that balance “cultural integrity” and “intelligent efficiency”. Moreover, the extraction and transformation processes are

disconnected, and a closed loop system from symbol extraction to creative implementation has not been formed.

III. METHOD

A. METHODS FOR SORTING AND ANALYZING VISUAL SYMBOLS AND FEATURES OF INTANGIBLE CULTURAL HERITAGE

This article first combines literature research, field investigation, and expert interviews (as shown in Figure 1) to systematically sort out and analyze the features of intangible cultural heritage visual symbols, laying the foundation for subsequent intelligent extraction and creative transformation. The specific steps are as follows: First, determine the scope of research, select three representative intangible cultural heritage projects, namely Paper Cuttings, shadow puppet and batik, covering two forms of plane and three-dimensional, and take into account the visual symbols of different regions and styles; The second is data collection, which includes collecting 800 sets of visual symbol samples of various intangible cultural heritage through intangible cultural heritage databases, museum collections, and on-site collection of intangible cultural heritage workshops. At the same time, relevant cultural background information and interview records of inheritors are collected to clarify the historical origins, cultural meanings, and technological characteristics of the symbols; The third is feature analysis, which constructs a visual symbol feature system for intangible cultural heritage from four dimensions: form, color, texture, and culture. Form features include lines, contours, composition, etc. Color features include main tones, color combinations, and cultural symbolic meanings. Texture features include details, textures, and craftsmanship traces. Cultural features include core meanings, regional characteristics, and ethnic connotations; The fourth is to establish a feature database, standardize and annotate the parsed symbol features, input them into the database, including symbol samples, feature parameters, cultural explanations, and other information, to provide data support for the training and optimization of intelligent extraction models. At the same time, clarify the difficulties in extracting different types of symbols, and provide targeted guidance for model design.

B. INTELLIGENT EXTRACTION METHOD OF INTANGIBLE CULTURAL HERITAGE VISUAL SYMBOLS BASED ON DEEP FEATURE FUSION

This method takes deep neural networks as the core, integrates the advantages of CNN and GAN, introduces non-stationary fingerprint constraints, overlapping masks and other technologies, and constructs an intelligent extraction model that balances accuracy, efficiency and cultural integrity. The specific process is as follows: firstly, sample preprocessing, which uniformly processes the collected intangible cultural heritage visual symbol samples, including size normalization, grayscale correction, noise removal, and expands the sample size through data augmentation techniques (rotation, flipping, scaling) to improve the model's

generalization ability; The second step is to annotate non-stationary fingerprints and generate reference trajectories. The input image is dynamically sampled using a window sequence, and the time-frequency coherence of each sampling segment is calculated to generate a reference trajectory. Non stationary fingerprints are labeled in the overlapping area of the image as a reference for trajectory calculation to avoid interference signals; The third step is multi-scale feature extraction and decoupling, using CNN network to extract multiscale features of symbols (low-level texture features, mid-level morphological features, high-level semantic features), introducing asymmetric convolutional layers to reduce computational resource consumption and improve detail capture ability [11]. At the same time, through multi window deconvolution decoupling operation, the composite image trajectory is restored to a single window prototype trajectory, generating a set of time anchor points and recording offset parameters; The fourth step is feature alignment and interference suppression. Based on the set of time anchor points, a delay compensation map is constructed to align multi-scale features, generate overlapping masks, mask interference pixels in overlapping areas, quantify feature coupling strength through causal residual maps, locate interference kernel positions, and generate correction vectors; The fifth step is feature fusion and precise segmentation. Based on the correction vector, topological consistency constraints are established to map the semantic skeleton to the morphological structure grid. Weighted feature fusion is performed to suppress ghosting and boundary repetition. Finally, image reconstruction is achieved through a GAN network to achieve precise segmentation. To quantitatively evaluate 'cultural integrity', a Cultural Preservation Index (CPI) is introduced, which calculates the structural similarity (SSIM) and color histogram correlation between the extracted symbol and the expert-annotated 'cultural gene' templates. This ensures that the extracted symbols achieve a CPI score above 0.85, retaining both detailed features and demonstrating a verifiable alignment with documented cultural characteristics [12].

C. MULTI DIMENSIONAL CREATIVE TRANSFORMATION METHOD FOR INTANGIBLE CULTURAL HERITAGE VISUAL SYMBOLS

Based on the extracted intangible cultural heritage visual symbols (as shown in Figure 2), combined with their cultural connotations and modern scene requirements, a multidimensional creative transformation method of "cultural analysis hierarchical transformation scene adaptation" is designed to achieve the dynamic application of symbols, which is specifically divided into three levels: first, simplification and reconstruction transformation. For the tedious and complex details in intangible cultural heritage visual symbols, flat and geometric design techniques are adopted on the basis of retaining core cultural genes and morphological features, simplifying processing, removing redundant decorations, and adapting them to modern simple and diverse aesthetic ori-

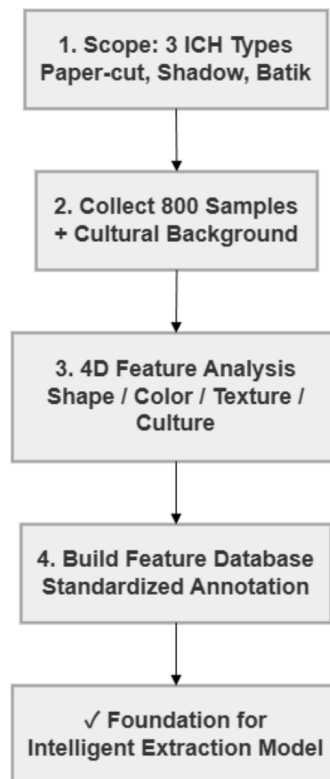


FIGURE 1. Methods for sorting and analyzing visual symbols and features of intangible cultural heritage

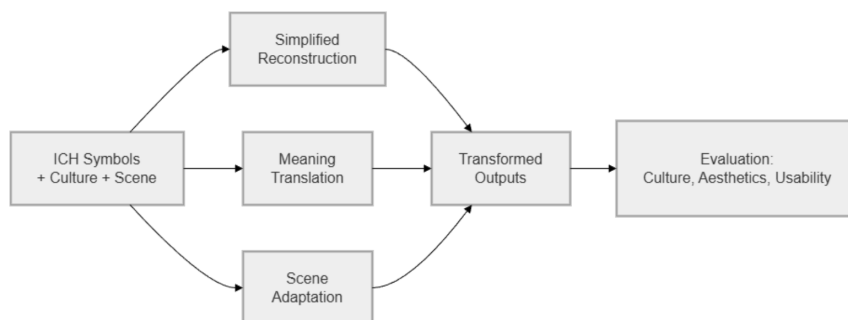


FIGURE 2. Multi dimensional creative transformation method for intangible cultural heritage visual symbols

entations, such as simplifying traditional complex patterns into simple decorative lines for modern product design; The second is the translation and transformation of meanings, deeply interpreting the core meanings of visual symbols of intangible cultural heritage, combining them with modern life concepts and emotional needs, and translating and extending meanings. For example, the meaning of “wealth and prosperity” of peonies can be simplified and integrated into home decoration through petal shapes, which not only preserves cultural connotations but also conforms to modern life; The third is scene adaptation and transformation. Based on different application scenarios (cultural and creative products, digital media, architectural decoration, fashion design), design differentiated transformation schemes to achieve deep integration of symbols and scenes [13]. For example, transforming shadow puppetry symbols into animated images, developing cultural and creative products

such as blind boxes and stationery; Combining wax printed pattern symbols with conductive fabrics to create touchable and glowing clothing, suitable for new media art exhibitions; The Paper Cuttings pattern symbols are integrated into the appearance design of modern home stay, giving the building a distinctive cultural identity. At the same time, establish a conversion evaluation mechanism to evaluate and optimize converted works from three dimensions: cultural integrity, aesthetic adaptability, and practicality, to ensure the conversion effect [14].

IV. RESULTS AND DISCUSSION

A. EXPERIMENTAL RESULTS AND ANALYSIS OF INTELLIGENT EXTRACTION MODEL PERFORMANCE

In order to verify the performance of the intelligent extraction model (as shown in Figure 3), 800 groups of visual symbol samples (including 600 training sets and 200 test

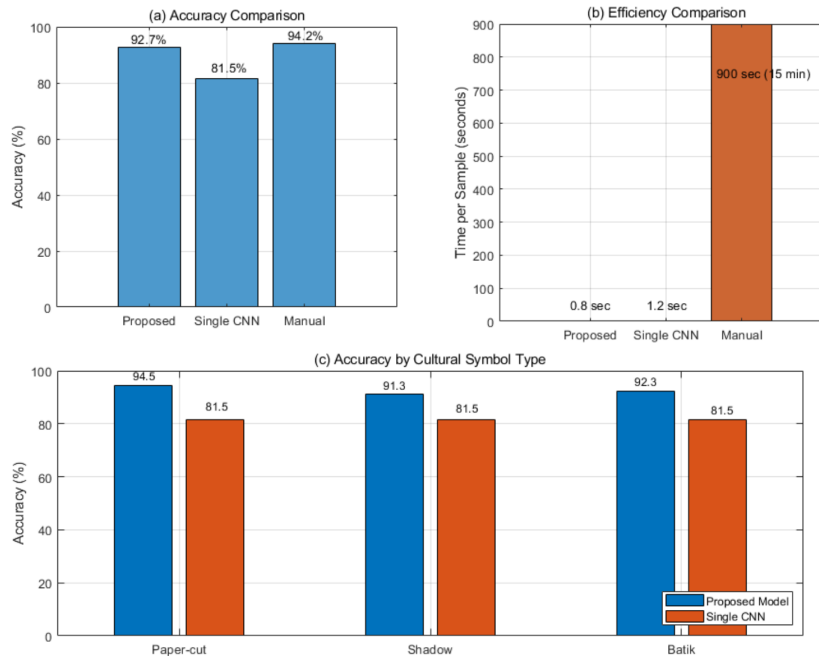


FIGURE 3. Performance Evaluation of Intelligent Extraction Model for Intangible Cultural Heritage Symbols

sets) of Paper Cuttings, shadow puppet and batik intangible cultural heritage were selected, and the extraction accuracy, extraction efficiency and cultural integrity were used as evaluation indicators to conduct comparative experiments with traditional manual extraction methods and single CNN extraction methods. The experimental environment is an Intel Core i7 processor, 16GB of memory, NVIDIA RTX 3060 GPU, Python 3.8 software, and TensorFlow framework. The experimental results show that the intelligent extraction model based on deep feature fusion proposed in this paper has an extraction accuracy rate of 92.7%, including 94.5% of Paper Cuttings symbols, 91.3% of shadow puppet symbols, and 92.3% of batik symbols; In terms of processing speed, extracting a single sample takes an average of 0.8 seconds, compared to approximately 15 minutes required for a manual artist to trace and digitize a similar pattern. While the automated model achieves a high speed-up ratio (1125:1), it serves as a technical aid to handle large-scale data throughput, whereas manual extraction remains the benchmark for deep cultural interpretation. Compared to a single CNN extraction method (accuracy of 81.5%, average time of 1.2 seconds), the accuracy is improved by 11.2% and the efficiency is improved by 33.3%.

Analysis shows that the main reason why this model can achieve better performance is due to the introduction of non-stationary fingerprint constraints and overlapping masking techniques, which effectively suppress interference signals in the multi-scale feature fusion process, avoid problems such as symbol ghosting and boundary misalignment, and improve extraction accuracy; Secondly, it integrates multi-scale features, capturing the underlying details and textures of symbols while preserving high-level semantic informa-

tion, achieving dual extraction of morphological features and cultural connotations; Thirdly, through data augmentation and model optimization, the generalization ability of the model has been improved, which can adapt to the extraction needs of visual symbols of intangible cultural heritage in different forms and backgrounds. Meanwhile, it was also found in the experiment that there is still room for improvement in the accuracy of extracting some intangible cultural heritage visual symbols with extremely complex forms and obscure cultural connotations. The main reason is that the feature annotation of such symbols is difficult, and the model's ability to capture deep cultural features needs further optimization.

B. DISCUSSION ON THE ADVANTAGES AND DISADVANTAGES OF RESEARCH METHODS

The intelligent extraction and creative transformation method of intangible cultural heritage visual symbols proposed in this article has three significant advantages compared to existing research: firstly, it achieves a deep integration of technology and culture. The intelligent extraction model not only focuses on extraction efficiency and accuracy, but also ensures the cultural integrity of symbols through cultural feature analysis, avoiding the problem of disconnection between technology application and cultural inheritance; Secondly, a closed-loop system of "extraction conversion application" has been established, where extracted symbols can be directly used for creative conversion, improving conversion efficiency and consistency, and solving the pain point of disconnection between extraction and conversion in existing research; Thirdly, a multi-dimensional and differentiated creative conversion strategy has been de-

signed to adapt to different application scenarios, enhancing the practicality and dissemination of converted works, and solving the problem of homogenization in conversion.

At the same time, this paper also has some shortcomings: first, the scope of research is limited, and only three categories of intangible cultural heritage items, namely Paper Cuttings, shadow play and batik, are selected. For other types of intangible cultural heritage visual symbols (such as embroidery and pottery), the applicability of the method still needs to be further verified; Secondly, there is still room for improvement in the accuracy of intelligent extraction models for complex and obscure visual symbols of intangible cultural heritage, and the model's ability to capture deep cultural features needs to be optimized; The third issue is that the commercialization path of creative transformation is not perfect enough, and it has not fully combined with market demand to build a sustainable transformation model. The market influence of transformed works still needs to be further improved. In response to these shortcomings, future research can expand the scope of research, optimize the model structure, strengthen cooperation with enterprises and intangible cultural heritage workshops, improve the commercialization transformation path, and enhance the generalizability and practicality of research results.

V. CONCLUSION

This article focuses on the core pain points of intelligent extraction of visual symbols and creative transformation in the digital inheritance of intangible cultural heritage. Through systematic research, the problems of low efficiency in extraction, symbol distortion, homogenization of transformation, and disconnection between extraction and transformation in existing methods have been solved, and a complete method system of "feature analysis intelligent extraction creative transformation scene adaptation" has been constructed. The research concludes that an intelligent extraction model based on deep feature fusion, combined with non-stationary fingerprint constraints and overlapping mask technology, can effectively improve the accuracy and efficiency of extracting visual symbols of intangible cultural heritage, while fully preserving the cultural genes of the symbols; A multi-dimensional creative transformation strategy can achieve a deep integration of intangible cultural heritage visual symbols and modern scenes through simplified reconstruction, semantic translation, and scene adaptation, enhancing the cultural connotation and practicality of the transformed works. There are certain shortcomings in this article, and the research scope is limited. The accuracy of the model in extracting complex symbols and the commercialization path of the transformed works still need to be optimized. In theory, this article enriches the theoretical system of digital inheritance and visual symbol processing of intangible cultural heritage, providing reference for subsequent related research; In practice, it provides operational intelligent extraction and creative transformation methods, providing technical support for intangible cultural heritage

practitioners and designers, assisting in the dynamic inheritance of intangible cultural heritage visual symbols, and promoting the innovative development of intangible cultural heritage culture in the digital age. It has both theoretical value and practical significance.

AUTHOR CONTRIBUTIONS

Sihan Yue designed, collected and analyzed the data, and drafted the manuscript. Sihan Yue conducted the study, critically revised the manuscript for important intellectual content, and gave final approval of the version to be published. Sihan Yue participated fully in the work, take public responsibility for appropriate portions of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

CONFLICTS OF INTEREST

The author declares no conflict of interest.

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