

Research on Technical Pathways and Methodologies for AIGC-Enabled Mining and Translation of Rural Cultural Elements

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Abstract:

The preservation and innovative transformation of rural cultural elements have long been constrained by three systemic challenges: information fragmentation, difficulty in decoding tacit knowledge, and low efficiency in innovative translation. The breakthrough progress in Generative Artificial Intelligence (AIGC) technology provides unprecedented technical possibilities for addressing these challenges. This study aims to construct a systematic AIGC-enabled technical pathway and methodology to achieve lossless transformation and innovative application of rural cultural elements, from the mining of their original forms to design translation. The research first analyzes the essential characteristics of rural cultural elements, such as their high degree of pluralistic integration and deep attachment of tacit knowledge, and the resulting deep-seated transformation barriers. It then systematically elaborates on how the core capabilities of AIGC in multimodal learning, semantic parsing, and creative generation form precise coupling with these challenges. Based on this, the study constructs a standardized technical processing chain covering multi-source data preprocessing, cross-modal feature extraction, cultural semantic mapping, design rule generation, and prototype validation iteration.

Keywords:

Generative Artificial Intelligence, Rural Culture, Cultural Element Mining, Design Translation

1. Introduction

As a vital root of Chinese civilization, the protection and innovative transformation of rural cultural elements constitute a core issue for continuing historical context and empowering rural revitalization. Against the backdrop of rapid contemporary globalization and urbanization, rural cultural elements carrying unique regional genes face unprecedented survival crises and transformation challenges: non-material cultural resources such as oral histories and traditional crafts are rapidly disappearing, while material carriers are increasingly fragile due to temporal erosion; existing mining methods often remain at the superficial level of symbolic collection, struggling to reach the deep spiritual core and emotional value of the culture; a significant gap exists between traditional elements and modern design languages as well as industrial application needs, leading to inefficient and obstructed paths for

creative transformation. This series of systemic dilemmas severely constrains the revitalization of rural cultural vitality and the effectiveness of design innovation.

In recent years, the breakthrough progress in Generative Artificial Intelligence (AIGC) technology has opened new technical pathways for solving the aforementioned challenges. However, existing research often treats AIGC as an isolated auxiliary tool, lacking systematic exploration of its deep coupling mechanism with the characteristics of rural culture, and has not yet constructed a complete, replicable technical pathway from raw cultural data to innovative design applications. How to systematically translate the technical potential of AIGC into an operable methodology, achieving the lossless transformation of rural cultural elements from physical form to digital form and then to innovative application, remains a key issue urgently requiring in-depth exploration. [1]

2. Characteristics of Rural Cultural Elements and the AIGC Coupling Mechanism

2.1. Essential Characteristics of Rural Cultural Elements and Transformation Dilemmas

Rural cultural elements are not static symbols existing in isolation but are dynamic cultural representations deeply rooted in specific geographical environments, historical changes, and community life practices. Their inherent characteristics profoundly shape the systemic dilemmas they face in being effectively mined and creatively translated in the contemporary context.

Firstly, rural cultural elements possess a high degree of pluralistic integration, which directly leads to the risk of information fragmentation. Taking rural Liaoning, China, as an example, the historical large-scale migration wave of “Chuang Guandong,” the traditions of indigenous ethnic groups like the Manchu, and diverse geographical environments such as coastal, plain, and hilly areas have collectively given rise to distinctive cultural forms: the thatched-roof architecture and fishing/hunting patterns of southern Liaoning, the Manchu paper-cutting and shamanic ritual symbols of eastern Liaoning, and the stone-built dwellings and shadow play narratives of western Liaoning. [2] These elements have formed a rich regional cultural genealogy through long-term integration, but simultaneously, this has led to a high degree of dispersion of cultural information across carriers, forms, and spatial distribution.

The most practical dilemma manifests in the efficiency bottleneck of innovative translation. [3] Even after successfully mining and interpreting cultural elements, significant obstacles are encountered when transforming them into design schemes with contemporary vitality that meet modern aesthetic, functional, and industrial needs. This is manifested, on one hand, as a disconnect between form and function transformation, where practice easily falls into simple replication or forced grafting of traditional symbols, lacking an effective methodology for organically integrating cultural genes into modern design languages, while also struggling to solve the adaptation problem between the original functions of traditional elements and modern spatial usage or product functional requirements. On the other hand, there is a severe deficiency in processing efficiency and systematicity.

2.2. Technical Characteristics and Enabling Potential of AIGC

As a frontier breakthrough in artificial intelligence, the core capability characteristics of Generative Artificial Intelligence (AIGC) exhibit a natural and powerful alignment with the deep-seated needs of rural cultural mining and translation, providing a solid foundation of technical feasibility for its enabling role.

The primary characteristic of AIGC technology lies in its exceptional multimodal learning and data integration capabilities [4]. The carriers of rural cultural information are extremely diverse and scattered, encompassing local chronicles, old photographs, oral recordings, architectural survey drawings, artifact images, and even scattered records on social media. This massive, multi-source, heterogeneous, and unstructured data constitutes a processing barrier difficult to overcome with traditional methods. AIGC, particularly multimodal large models based on the Transformer architecture, can break down semantic barriers between different modal data such as text, images, audio, video, and 3D point clouds, achieving unified understanding and relational analysis of them.

Building upon data integration, AIGC demonstrates profound potential in semantic parsing and contextual understanding, directly targeting the core challenge of decoding tacit knowledge. Large Language Models (LLMs), leveraging their deep semantic understanding, contextual reasoning, and knowledge association capabilities acquired through training on massive corpora, can transcend superficial recognition of cultural symbols to perform deep-level semantic mining and logical deduction. Combined with training or fine-tuning on text data specific to a region, such as local chronicles, oral histories, and folktales, AIGC can simulate the generation of new narrative fragments consistent with that cultural context, assisting in reconstructing the historical scenes and social relationships surrounding elements, thereby aiding in understanding the collective memory, emotional value, and community identity carried behind symbols.

2.3. Deep Coupling Mechanism between AIGC and Rural Culture

The relationship between the technical characteristics of AIGC and the deep-seated dilemmas of rural cultural mining and translation is not a simple tool-application relationship but forms a precise, profound, and logically inherent deep coupling. This coupling is reflected in full-chain empowerment from the data foundation to the creative apex.

Firstly, AIGC's data integration capability forms a precise interface with the dilemma of rural cultural information fragmentation. Faced with the massive, multi-source, heterogeneous data fragments derived from the pluralistic integration of rural culture, traditional methods are akin to attempting to manually piece together a giant puzzle scattered across a vast area—inefficient and struggling to see the whole picture. AIGC's multimodal learning capability acts like an efficient intelligent puzzle system, capable of automatically identifying, classifying, and associating these “cultural fragments” from different carriers such as text, images, audio, and 3D scans. It can not only associate photographs of painted boat hulls from southern Liaoning fishing villages with related oral nautical taboo texts but also semantically align the pattern features of eastern Liaoning Manchu paper-cutting with descriptions of ritual ceremonies recorded in local chronicles.

3. Construction of the Core Technical Pathway for AIGC Empowerment

3.1. Overall Framework of the Technical Pathway

Based on the deep coupling analysis of rural cultural characteristics and AIGC enabling potential, this study constructs a systematic, standardized technical pathway for AIGC-enabled mining and translation of rural cultural elements. The core of this pathway lies in establishing a complete, closed-loop processing chain from raw cultural data to innovative design applications. Its overall framework follows the core logic of “data-driven, semantic integration, rule transformation, human-machine collaboration,” aiming to achieve the lossless transformation and innovative leap of rural cultural elements from digital acquisition of physical forms to intelligent parsing of deep semantics, and then to the generation of design rules meeting modern needs and prototype validation.

This technical pathway consists of five interconnected, sequentially progressive core stages. The first is the multi-source data preprocessing stage, which performs standardized cleaning and format conversion of raw cultural data from different carriers to build a high-quality structured data pool. The second is the cross-modal feature extraction stage, which utilizes specialized neural network models to automatically extract deep feature vectors containing cultural information from the preprocessed data. Next is the cultural semantic mapping stage, which builds a bridge from low-level visual/geometric features to high-level cultural semantics through knowledge graph embedding technology. Subsequently, the design rule generation stage combines abstract cultural semantics with specific industrial process constraints to generate executable design semantic rules.

3.2. Multi-source Data Preprocessing and Cross-modal Feature Extraction

Multi-source data preprocessing and feature extraction constitute the foundation of the entire technical pathway, aiming to transform the scattered, fragile, and diverse original information of rural culture into high-quality, structured features suitable for algorithm deep learning.

Confronted with the extreme diversity in form, medium, and preservation state of rural cultural carriers, this study establishes unified data ingestion and cleaning specifications. For material cultural elements, such as traditional architectural components, handicrafts, and stone carving patterns, high-precision 3D laser scanning and multi-angle high-definition photography become standard acquisition methods. Taking common stone carving components in Liaoning villages as an example, the point cloud data generated by scanning first needs to be registered to a global coordinate system using algorithms like Iterative Closest Point (ICP) to unify multiple local coordinate systems caused by multiple scans or component incompleteness, and statistical filtering is applied to remove outlier points caused by environmental dust or equipment noise, ensuring the point cloud model is both complete and clean.

Through this series of targeted feature extractions, originally heterogeneous multi-source cultural data are uniformly mapped into a series of computable, comparable deep feature spaces, paving the way for subsequent semantic mapping and rule generation.

3.3. Cultural Semantic Mapping and Design Rule Generation

After completing the deep feature extraction of multi-source data, the core challenge faced by the technical pathway is how to transform these feature vectors representing physical forms and surface information into semantic rules rich in cultural connotations that can guide design innovation. This process is undertaken by a “Cultural Semantic Mapping Engine,” whose essence is to build an intelligent bridge connecting data features with human cultural cognition.

Abstract cultural semantic associations cannot directly drive design. The next key task of the mapping engine is to combine the semantic relationships in the knowledge graph with specific industrial process constraints to generate executable design rules. This is achieved through a rule template generator. This generator embeds a series of predefined rule templates that translate abstract semantics into concrete, parameterized design instructions or constraint conditions.

More complexly, rule generation dynamically integrates physical and process parameters from the industrial end. Assuming the task is to translate a traditional wooden structural form into modern furniture, the mapping engine, while generating form evolution rules, simultaneously calls in parameters such as the bending strength of the wood, the stress characteristics of mortise and tenon joints, and the minimum fillet radius for CNC machining. These rules ensure that the generated design schemes are not only semantically accurate in a cultural sense but also feasible in physical realization.

3.4. Prototype Generation and Triple Validation Mechanism

The cultural semantics and constraint conditions contained within the design rule library ultimately need to be transformed into concrete, evaluable design schemes through a prototype generation and validation mechanism, thereby completing the final step from “cultural knowledge” to “innovative entity.” The core of this stage is human-machine collaborative creative generation and a rigorous multi-dimensional verification closed loop.”

For example, when using Stable Diffusion for text-to-image generation, the system encodes the feature vector of “Panchang pattern,” its mapped semantics of “endless continuity, auspicious eternity,” and the process constraints of ceramic firing (e.g., avoiding overly sharp corners to prevent cracking) together into a series of complex prompts and ControlNet control maps, guiding the model to generate multiple concept sketches that retain the continuous, revolving core skeleton of the Panchang pattern, conform to the ergonomics and aesthetics of modern tea sets, and meet production process requirements. For 3D products, the generation process might occur in parametric platforms like Grasshopper, where rules are translated into algorithmic logic driving morphological variation, automatically generating a series of structurally reasonable 3D digital models.

Generated prototypes are merely possibilities; their value must be confirmed through a systematic, three-dimensional validation mechanism.

The first validation is Innovativeness Verification, primarily assessing the novelty and value of the scheme in aesthetics and concept. This does not rely entirely on subjective judgment but involves preliminary algorithmic screening: using aesthetic evaluation models to score a large number of generated schemes, filtering out obviously crude or incoherent options; simultaneously, quantifying novelty by calculating the distance in feature space between generated schemes and existing

designs in the cultural database, avoiding the generation of simple replicas or overly outdated styles.

The second validation is Process Realizability Verification, a crucial step for grounding the scheme in reality. The system imports the geometric data of 3D models into Finite Element Analysis (FEA) software for virtual structural stress testing or simulates driving CNC carving paths from pattern vector files to check for unreachable dead corners or details exceeding machining precision. This verification strictly benchmarks against the industrial process thresholds input earlier; any scheme not meeting mass production requirements is flagged or automatically adjusted.

The entire validation mechanism is not a linear process but a dynamic iterative cycle. The reasons for failure of schemes that do not pass validation are analyzed and traced back, transformed into new constraint conditions or adjustment suggestions, and fed back to the design rule library or even the front-end semantic mapping engine, driving fine-tuning of rules and models. Excellent prototypes that pass validation proceed to the next stage, where they can directly drive rapid prototyping manufacturing (e.g., 3D printed prototypes) or generate final production files, thereby truly bridging the complete technical pathway from cultural data mining to innovative product realization, forming a self-evolving, continuously optimizing intelligent design system.

4. Conclusions

This study, addressing the three core dilemmas faced by rural cultural elements in contemporary inheritance and innovation—information fragmentation, difficulty in decoding tacit knowledge, and low efficiency in innovative translation—systematically constructs an AIGC-enabled technical pathway and methodology for mining and translating rural cultural elements. The research demonstrates that the capabilities of Generative Artificial Intelligence in multimodal learning, deep semantic parsing, and creative generation have a profound coupling relationship with the intrinsic characteristics and transformation needs of rural culture, providing a revolutionary technical lever for addressing the aforementioned dilemmas.

The core contribution of this study lies in constructing the standardized technical chain of “multi-source data preprocessing - cross-modal feature extraction - cultural semantic mapping - design rule generation - prototype validation iteration.” This technical pathway does not simply superimpose AIGC as an isolated tool but deeply embeds it within a systematic cultural cognition and design innovation framework, achieving lossless transformation and dynamic optimization from data to knowledge, from knowledge to rules, and from rules to innovative schemes. Firstly, it proposes standardized preprocessing and cross-modal feature extraction methods for the multi-source heterogeneous data of rural culture, providing a technical foundation for solving the information fragmentation problem. Secondly, it constructs a cultural semantic mapping engine based on a knowledge graph, realizing the intelligent transformation from low-level visual features to high-level cultural semantics, offering a new approach for decoding tacit knowledge. Finally, it establishes a design rule generation mechanism integrating industrial process constraints and a prototype validation closed loop focusing on the three dimensions of innovativeness, realizability, and semantic accuracy, effectively enhancing the efficiency and quality of innovative translation.

This research not only provides a solid, scalable technical foundation for the digital preservation, in-depth interpretation, and creative transformation of rural cultural resources but also offers new perspectives and methodological references for interdisciplinary research integrating design studies, cultural heritage studies, and artificial intelligence.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Author Contributions

Conceptualization: Wang Tao.; Methodology: Wang Tao.; Software: Fan Zuo Ning.; Validation: Wang Tao.; Formal analysis: Wang Tao.; Investigation: A.B.; Resources: Fan Zuo Ning.; Data Curation: Wang Tao.; Writing – original draft preparation: Wang Tao.; Writing – review and editing: Wang Tao.; Visualization: Fan Zuo Ning.; Supervision: Fan Zuo Ning.; Project administration: Fan Zuo Ning; Funding acquisition: Fan Zuo Ning.

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