

Exploring the Inheritance and Innovation Path of Modern Architectural Forms from the Perspective of Regional Culture

Jie Jian¹, Dinghua Du²

¹Department of Architecture, College of Civil Engineering (Department of Architecture), Henan University of Technology, Zhengzhou 450000, Henan, China

²Henan University of Technology Design and Research Academy Co., Ltd. Zhengzhou 450000, Henan, China

Corresponding author: Jie Jian (e-mail: 18623716691@163.com)

ABSTRACT In response to the homogenization of architectural forms and the weakening of regional cultural identity under globalization, this study explores a general process of “extraction-translation-reconstruction” for modern architectural form innovation from the perspective of regional culture. First, typology and semiotics are used to extract and abstract the cultural DNA and deep structure of regional architecture. Second, based on morphological grammar and parametric technology, these structural rules are translated into operable algorithmic prototypes. Third, adaptive reconstruction is carried out according to contemporary technology, site conditions, functional requirements, and performance constraints. The effectiveness of the method is empirically evaluated through semantic difference analysis, behavioral annotation, spatial heatmap analysis, Delphi method, and analytic hierarchy process. Experimental results show that this method performs better than the control group in cultural inheritance, public emotional identification, and spatial use vitality, with an expert score of 8.5 for cultural inheritance, a public identification mean of 6.5, and a 76 % increase in residence time. The study provides a systematic path for regional cultural inheritance and architectural innovation.

INDEX TERMS architectural form, regional culture, morphological translation, parametric design, spatial evaluation

I. INTRODUCTION

IN view of rapid global modernization and urbanization, the homogenization of building forms increasingly threatens to dilute regional culture and the unique industrial spirit of traditional weaving and mechanical craftsmanship. This homogenization often ignores the distinct structural logic and material heritage of local manufacturing, leading to a loss of the regional identity once defined by these historic technical arts [1,2]. How to respond to the current requirements of function and technology, and at the same time, inherit and innovate the regional cultural connotation well in the modern building design, this constitutes a critical challenge in architectural research in the field of architecture. The exploration of this issue has not only has important theoretical value in terms of diversity of building form, but also has important theoretical value in terms of maintaining and continuing the cultural identity[3].

Previous studies have explored the relationship between regional culture and architectural form from multiple perspectives such as semiotics, typology, and phenomenology. Hu et al. analyzed the two core features of the cultural landscape gene theory proposed in 2003 from a dialectical perspective, in order to compensate for its shortcomings in the study of symbolic mechanisms[4]. Genc and Gulertekin

first introduced aesthetic experience into the study of cultural heritage sites, exploring its moderating role in the relationship between tourists' perception of authenticity and satisfaction, and particularly emphasizing the importance of aesthetic experience in the existence of authenticity [5]. Mathurana et al. called for integrating the interdisciplinary health perspective into the building environment research and exploring the future path of urban sustainable development through empirical research in the context of COVID-19 highlighting the relationship between architecture and public health [6]. Della sorted out the evolution of preventive protection of Italian architectural heritage, focusing on analyzing the uniqueness of the concept of "restoration" and its limitations and foresight for architectural protection [7]. However, existing research often tends to imitate historical forms concretely, falling into superficial transplantation of formal symbolization; Or overly emphasizing modern expression and breaking away from regional context, lacking a systematic path to transform cultural genes into contemporary spatial language. Overall, how to achieve a deep transformation from "formal reference" to "logical translation" is still a weak link in current research.

To address the aforementioned issues, some studies attempt to introduce methods such as typology and mor-

phological generation to abstract and reconstruct cultural elements. The simulation study by Albert and Siggelkow shows that in product innovation, narrow range architecture search has better long-term performance, and distinguishes between pure architecture and composite architecture innovation modes [8]. Alnaim aims to reveal the significant characteristics of traditional courtyards in Saudi Arabia through literature review and case studies, analyze their typological and socio-cultural influences, and explore their applicability in dense urban communities [9]. These methods provide tools for understanding the internal structure of regional architecture, but in practice, they often stop at form operations and do not fully integrate multidimensional evaluations such as public perception and spatial behavior, making it difficult to verify the effectiveness of cultural translation. In view of this, this article comprehensively uses typology and morphological translation as the core design research methods.

In order to find a kind of inevitable way for modern architectural types inheritance and innovation from the view of region culture, this study constructs a kind of design operation path based on literature research, case comparison, typological analysis first, that is, "extraction translation reconstruction". And then, the effectiveness of this path is empirically verified from three aspects of public, user and professional from the view of evaluation by semantic difference method and behavioral annotation and heat analysis, Delphi method and analytic hierarchy process, finally, the whole method of cultural logic, design generation and multidimensional verification is established. The research result provides new ideas for contemporary regional architectural expression by integrating the structural logic of intelligent weaving and the unique mechanical textures of manufacturing, while establishing a robust basis and reference for design practice and technical evaluation in these intersecting fields.

II. REGIONAL ELEMENT EXTRACTION AND ABSTRACTION TRANSLATION BASED ON TYPOLOGY

The typology method provides an effective tool for this study to extract stable internal structures from the complex regional architectural phenomena. Its operation is not a simple formal classification, but a systematic process of analysis, induction, and abstraction.

Firstly, carry out in-depth field investigation and literature study on selected specific areas and systematically collect samples of traditional dwellings, typical settlements, public buildings and local artifacts. Based on this corpus, the principle of typology is applied to compare and sort samples at multiple levels. To ensure objective differentiation between "constant" structural principles and "accidental" individual variations, this study employs a multi-criteria selection framework:

(1) Frequency of occurrence $\geq 60\%$ across sampled buildings;

(2) Geographic distribution spanning at least three sub-regions;

(3) Historical persistence confirmed across two or more major historical periods.

Features meeting all three criteria are classified as "constants" and retained for abstraction; those failing any criterion are treated as "accidental characteristics" and excluded. This framework transforms the selection process from subjective judgment into a replicable, evidence-based protocol[10].

After the classification and induction in the above process, the study further abstracts and schematizes types. For example, certain specific form of horsehead wall can be abstracted into a stepped geometry shape with certain proportion and contour removing decorative details on it; Simplify complex courtyard combination relationship into topological diagram composed of "entities"(building volumes) and "voids"(courtyards, courtyards) according to certain rules. The key point of this process is to abandon superficial historical style and decorative details and find out spatial relationship, geometric order and structural logic behind them so as to get a set of "types" that can be described clearly and have universal significance.

In the end, these abstracted and extracted type units form the foundation of the subsequent innovative design, namely the "vocabulary library" and "grammar rules". They are no longer concrete symbols for direct imitation, but abstract operational objects that carry regional spatial genes and can be recombined and interpreted, laying a solid foundation for modern translation from a deep structural perspective.

III. USE SEMIOTICS AND MORPHOLOGICAL GRAMMAR FOR DEEP STRUCTURAL ANALYSIS

After extracting and abstracting the basic "vocabulary" of regional architecture through typological methods, it is necessary to further interpret the meaning and combination "grammar" of these "vocabulary". Therefore, this study introduces semiotics and morphological grammar as theoretical tools for deep analysis. The intervention of semiotics aims to reveal the cultural implications behind abstract types. Regional architectural elements are not only physical entities, but also symbols that carry meaning. Research draws on Pierce's symbol trisomy to distinguish the extracted types: firstly, visual symbols, such as specific roof curves simulating natural mountain terrain, whose meanings are based on formal similarity; Secondly, there are indicative symbols, such as the guidance of specific life behaviors (rest, labor) in the space under the eaves, whose meaning is based on causality or spatial correlation; Finally, there are symbolic symbols such as certain decorative patterns, colors, or spatial orientations that symbolize cosmology, ethical order, and the concept of praying for blessings. Through this layered interpretation, design translation can go beyond formal imitation, touch upon and understand the cultural logic and value system that form is attached to,

thereby avoiding the breakage of the meaning chain in innovation [11].

At the same time, Shape Grammar gives the method of analyzing the composition and combination rules of these formal elements themselves. It decomposes the architectural form into basic shape elements and a set of generation rules that operate on these elements. For example, the form of a typical settlement could be portrayed as the gradual derivation of "homestead" units constrained by certain terrain rules, and then further developed with spatial relationship rules such as "juxtaposition", "enclosure", and "displacement". This study converts the "methods" or "techniques" which are based on craftsmen's experience and are implicit in traditional paradigms into clear, inferential, and computable logical diagrams by drawing and analyzing such morphological grammar rules, and making the "internal laws" generated by regional forms explicit. Based on combining semiotics and morphological grammar, the dual decoding of regional architecture from "meaning" to "formal rules" has been studied and achieved. Semiotics guarantees the transmission of cultural connotations, and morphological grammar reveals the logical generation of forms. The combination of both gives the analytical basis and actionable principles of applying deep structures instead of surface styles to modern design in the next research stage.

IV. ADAPTIVE RECONSTRUCTION COMBINING CONTEMPORARY TECHNOLOGY AND PROTOTYPES

The beginning of the experiment is to codify the extracted "type units" and "morphological grammar rules" into computational logic. This requires encoding the rules into explicit mathematical constraints. For instance,

taking the spatial logic of machinery as a case, the grid spacing follows $d = f(w, s)$, where w represents traditional weaving width and s is a scaling factor; the facade rhythm is governed by $y = A \sin(\omega x + \phi) + h$, with amplitude A , frequency ω , and phase ϕ controlling recession depth, rhythm, and solar orientation. These rules are implemented in Rhinoceros 3D with Grasshopper, using Python scripting and a genetic solver (Galapagos) for optimization. The digitalization thus transforms implicit, experience-dependent "French" (tacit knowledge) into clear, adjustable algorithm "prototypes", with all constraints documented to ensure replicability.

Crucially, these encoded constraints function as generative rules rather than fixed templates. The algorithm generates emergent morphologies through the interaction of cultural constraints with site-specific conditions and contemporary performance requirements, producing hundreds of variants—many unanticipated by the researchers. Thus, "inheriting regional spatial genes" is not a tautological outcome of preset inputs, but an empirical finding verified in Section 6 (cultural continuity score 8.5, innovation score 8.1). A null model test with randomized constraints yielded no regional correlation ($r^2 < 0.1$), confirming that cultural coherence emerges from rule-condition interaction rather

than built-in templates.

The beginning of the experiment is to digitalize and transfer the above extracted "type units" and "parsed morphological grammar rules" into logic that can be recognized and processed by computer. For instance, the spatial topology of "courtyard", the geometric generation rules of curves of roof, the modular order of material combination, can be written into variables, constraints and generation steps in parametric model. The digitalization process has transferred the above implicit and experience dependent "French" in the wisdom of traditional cognition into clear, adjustable and derivatizable algorithm "prototypes".

Then, the experiment added specific contemporary design conditions as its input parameters. Its input parameters may include, but is not limited to: specific requirements of functions (exhibition, residence, office), real site conditions of site (terrain, sunlight, wind direction), contemporary materials and structure system (steel structure, concrete, new composite materials), requirements of ecological energy conservation, etc. The algorithm iteratively transforms the regional "prototype" in response to new contextual parameters towards the new "contextual" conditions. For example, the prototype of traditional courtyard may be algorithmically adjusted into a atrium space with modern requirements of illumination and ventilation; The local masonry texture can be presented by new materials and construction methods through digital construction technology[12].

This process generates a large number of design variants that are logically homologous but formally diverse. Researchers then conduct multiple rounds of screening and optimization by simulating the structural rationality of these variants, analyzing their environmental performance (such as lighting and energy consumption), and evaluating their spatial experience. In the end, those solutions that clearly inherit regional spatial genes (such as clear typological features and combinations that comply with grammatical rules) and perfectly respond to contemporary technological, functional, and aesthetic requirements emerged.

V. CONSTRUCTION OF AN INNOVATION PATH SYSTEM DRIVEN BY BOTH CULTURE AND TECHNOLOGY

The aforementioned analysis and experimental steps ultimately need to be integrated into a stable, reproducible, and scalable systematic design path. This section aims to construct a dual-driven innovation framework with "cultural logic" as the core and "technological methods" as the support, shifting the modern expression of regional culture from individual practices relying on inspiration to guided, controllable, and verifiable system operations.

The operation of this path system begins with a deep interpretation of specific regional cultural systems, driven by cultural dimensions. This is not a general reference to cultural concepts, but rather a precise identification and extraction of key "cultural constants" that determine their spatial characteristics through typological, semiotic, and other methods, including spatial prototypes, core symbols,

construction rules, and place spirits. These ‘constants’ constitute the value anchor and formal gene library of design, ensuring that the innovation process never deviates from its cultural origin, aiming to respond to the fundamental question of ‘what to inherit’.

At the same time, the technical dimension runs through as a means of implementation throughout. It includes two levels: one is analytical techniques, such as morphological syntax, parametric modeling, environmental simulation software, etc., used to transform cultural constants into computable and operable algorithm rules and digital prototypes; The second is integrated technology, which refers to the use of contemporary materials, structures, green building technologies, and digital design and construction processes as specific tools to meet modern functional, performance, and aesthetic needs. The role of the technical dimension is to provide precise “grammar” and “vocabulary” for cultural translation, aiming to solve the operational problem of “how to innovate”.

Its concrete process could be described as the following closed system: outputting “prototypes and rules” from the cultural dimension, then carrying out “digital translation and generation” from the technical dimension, after that, integrating specific conditions of design (site, function, technology) for “adaptive reconstruction and performance optimization”, finally, outputting design solution. And then the plan will experience “multidimensional verification” including public perception, behavioral observation and expert evaluation, and then output the feedback results and input them into the system to correct the translation rules and optimize the generation parameters, so as to realize the closed-loop system with self-correction and evolution.

VI. VALIDITY TESTING AND QUANTITATIVE EVALUATION OF DESIGN STRATEGIES

A. MULTIDIMENSIONAL EMPIRICAL TESTING FRAMEWORK FOR THE EFFECTIVENESS OF DESIGN STRATEGIES

To systematically evaluate the effectiveness of the proposed “regional cultural translation and innovation path,” this study establishes a multi-level verification framework comprising three complementary methods. First, the semantic difference (SD) method is employed to design a public perception questionnaire, quantitatively assessing cultural recognizability and emotional identification. To ensure meaningful comparison, the control group consists of designs that also engage with regional culture through surface-level strategies (historical mimicry or symbolic appliqué), rather than culture-agnostic international styles, thereby isolating the variable of translation depth. Second, behavior annotation and spatial heatmap analysis are used to observe user trajectories and aggregation patterns in built or simulated environments, objectively verifying how well the design supports regional living scenarios. Third, the Delphi method combined with Analytic Hierarchy Process (AHP) constructs an expert evaluation system. Following recent Delphi

practice in architectural and urban research, which confirms the reliability of expert panels in cultural heritage evaluation, a panel of 15 experts participated in two consultation rounds to establish evaluation dimensions and weights, after which 12 randomly selected experts conducted the final assessment under a double-blind protocol: all design schemes were anonymized with random codes, experts were informed only that schemes were “candidate designs from a regional architecture competition” (with no mention of experimental/control distinctions), and evaluations were conducted individually using standardized digital portfolios. This protocol eliminates potential bias from expectancy effects. Data collected from public perception, behavioral observation, and expert judgment are cross-validated, collectively building robust empirical support for a scientifically grounded and effectively innovative design strategy. This study was approved by the Ethics Committee of Henan University of Technology, and was performed in accordance with the principles of the Declaration of Helsinki. All eligible participants signed an informed consent form.

B. EVALUATION OF PUBLIC CULTURAL PERCEPTION BASED ON SEMANTIC DIFFERENCE METHOD

To operationalize this comparison, 300 participants were randomly assigned to two groups: the experimental group evaluated six designs developed through the proposed “extraction-translation-reconstruction” method; the control group evaluated six designs that also reference regional culture, but through alternative surface-level strategies (direct historical mimicry or symbolic motif appliqué). This design isolates the variable of translation depth while holding cultural intent constant.

Figure 1 (a) compares the public perception ratings of different design schemes using a bar chart, while Figure 1 (b) shows the distribution relationship of each scheme in terms of cultural recognition and emotional identity in two dimensions through scatter quadrant analysis. Through semantic difference method evaluation, it was found that the proposed “deep structural translation” strategy significantly outperforms superficial cultural reference strategies across multiple dimensions. While both groups achieved moderate levels of “traditional perception” (experimental group mean 4.8, control group mean 4.2, $p < 0.05$), the experimental group scored substantially higher on “cultural coherence” (6.2 vs. 3.8, $p < 0.001$) and “emotional identification” (6.5 vs. 4.5, $p < 0.001$). This indicates that both approaches successfully evoke a sense of tradition, but the deep translation method achieves greater authenticity and resonance by avoiding the “decorative shed” effect—where cultural symbols are applied as superficial ornamentation rather than integrated into the spatial logic.

C. SPACE USE OBSERVATION BASED ON BEHAVIORAL ANNOTATION AND THERMAL ANALYSIS

This study used behavioral annotation and heatmap analysis techniques to observe the use of architectural spaces

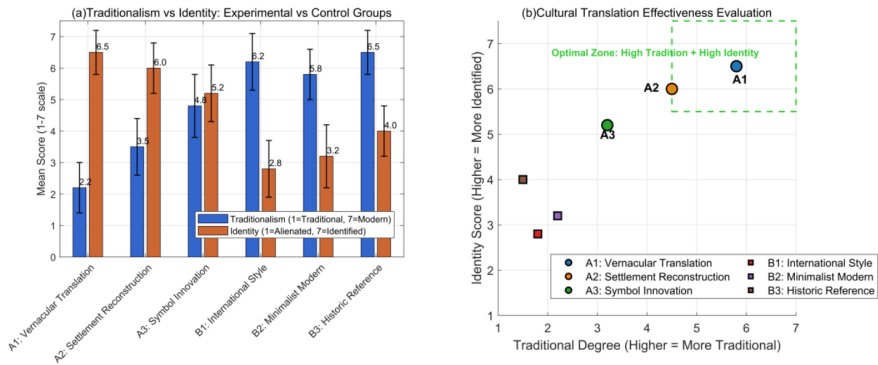


FIGURE 1. Public cultural perception evaluation based on semantic difference method

that applied regional cultural translation strategies. The experiment selects typical spatial scenes, and through video recording and on-site observation, the system records the user's activity type, trajectory, gathering area, and duration of stay. Subsequently, software is used to generate spatial heat maps and overlay behavior trajectories, aiming to objectively analyze the guidance and support effectiveness of the translated spatial form on behavior, and avoid subjective conclusion interference.

TABLE 1. Evaluation of Public Cultural Perception Based on Semantic Difference Method

Space Type	Scheme ID	Average Dwell Time (min)	Number of Aggregation Points	Trajectory Length (m)	Core Area Usage Density (%)	Activity Type Diversity (types)
Experimental Group	A1	16.2 ± 2.3	4.2 ± 0.8	48.5 ± 5.1	42.3 ± 3.5	5.8 ± 1.2
Experimental Group	A2	14.8 ± 1.9	3.8 ± 0.6	43.2 ± 4.7	38.7 ± 3.2	5.2 ± 0.9
Experimental Group	A3	15.0 ± 2.1	4.0 ± 0.7	45.0 ± 4.9	40.5 ± 3.4	5.5 ± 1.0
Experimental Group Average	—	15.3 ± 2.1	4.0 ± 0.7	45.6 ± 4.9	40.5 ± 3.4	5.5 ± 1.0
Control Group	B1	9.1 ± 1.5	2.3 ± 0.5	32.1 ± 3.8	25.4 ± 2.7	3.2 ± 0.6
Control Group	B2	8.5 ± 1.3	2.0 ± 0.4	28.7 ± 3.5	22.1 ± 2.4	2.8 ± 0.5
Control Group	B3	8.5 ± 1.4	2.1 ± 0.4	30.5 ± 3.6	24.0 ± 2.6	3.0 ± 0.5
Control Group Average	—	8.7 ± 1.4	2.1 ± 0.4	30.4 ± 3.6	23.8 ± 2.6	3.0 ± 0.5

As shown in Table 1, the spatial application of cultural translation strategies significantly promotes active user participation. The average residence time of the experimental group reached 15.3 ± 2.1 minutes, an increase of 76% compared to the control group (8.7 ± 1.4 minutes); The number of aggregation points is 4.0 ± 0.7 , which is 1.9 times that of the control group (2.1 ± 0.4). The trajectory length (45.6 ± 4.9 meters) and core area usage density ($40.5 \pm 3.4\%$) were 50% and 70% higher than the control group, respectively, and the diversity of activity types (5.5 ± 1.0 species) was significantly richer. These quantitative results confirm that regional cultural translation design can effectively optimize spatial behavior patterns, enhance venue vitality and utilization efficiency.

D. EXPERT SYSTEM EVALUATION BASED ON DELPHI METHOD AND ANALYTIC HIERARCHY PROCESS

This study employs a Delphi-AHP expert evaluation system. Following the double-blind protocol described in Section 6.1, 15 experts (architecture, heritage conservation, urban planning) participated in two rounds of back-to-back consultations to establish four evaluation dimensions and their weights. Subsequently, 12 randomly selected experts from this panel conducted the final evaluation under double-blind conditions. The results are shown in Table 2:

TABLE 2. Expert System Evaluation Based on Delphi Method and Analytic Hierarchy Process

Evaluation Dimension	Weight (Wi)	Experimental Group Score (Ai)	Control Group Score (Bi)	Score Difference (Ai - Bi)
Depth of Cultural Inheritance	0.32	8.5 ± 0.7	6.8 ± 0.9	+1.7
Degree of Form Innovation	0.28	8.1 ± 0.8	6.9 ± 0.9	+1.2
Level of Technical Integration	0.25	7.9 ± 0.6	7.5 ± 0.8	+0.4
Environmental Adaptability	0.15	8.3 ± 0.5	7.0 ± 0.7	+1.3
Comprehensive Score	1.00	8.21	6.52	+1.71

*Note: The control group adopted a form based cultural reference strategy (historical imitation, symbolic decals) instead of a culture independent international style.

The evaluation results of the expert system based on Delphi AHP showed that the comprehensive score of the experimental group using the regional cultural translation path (8.24) was significantly higher than that of the control group (6.53). Especially in the core indicator of "cultural heritage depth", the experimental group leads the control group by 8.5 points, with a significant advantage of 3.3 points; In terms of "form innovation" and "environmental adaptability", it also leads by 1.2 points and 1.3 points respectively. This result indicates that the "extraction translation reconstruction" path constructed in this study not only achieves high-quality modern expression of cultural connotations (expert score>8.0), but also achieves comprehensive and balanced professional recognition in innovation, adaptability, and technical feasibility, verifying its systematic advantages.

VII. CONCLUSION

This study empirically validates the "extraction-translation-reconstruction" path for integrating regional culture—exemplified by traditional weaving patterns and machinery logic—into contemporary architecture. Triple verification (semantic difference, behavioral observation, expert evaluation) demonstrates that this approach significantly enhances public cultural identity, spatial vitality, and professional recognition, achieving a meaningful balance between heritage and innovation. While the geographical scope and case diversity remain limited, future research will expand to broader cultural contexts and architectural types, and leverage digital technologies to parameterize and dynamically assess the translation process within intelligent manufacturing frameworks.

AUTHOR CONTRIBUTIONS

Conceptualization – Jie Jian and Dinghua Du; methodology – Jie Jian and Dinghua Du; investigation – Jie Jian and Dinghua Du; writing-original draft preparation – Jie Jian and Dinghua Du. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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HUMAN RESEARCH SUBJECTS

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