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Bridging Dao and Digital Fabrication: A Symbiotic Framework of Eastern Craft Philosophy and Smart Manufacturing

1st Sun Ming*
Guangzhou Institute of Technology
sun_ming_2008@hotmail.com

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***Abstract*—The global design field faces a binary dilemma between cultural logic and technological logic. Modern smart manufacturing is centered on efficiency and standardization, while traditional crafts are rooted in physical practice and cultural metaphor. These two logics have long been positioned as "protection" versus "replacement" in design practice, rather than in symbiosis. This study proposes the Dao-Vessel Symbiosis framework, which translates core concepts of Eastern craft philosophy (e.g., harmony between humanity and nature, artifacts carrying cultural ideas) into the Triadic Haptic-Semiotic Model—an operable framework for industrial design and smart manufacturing systems. The model consists of three progressive layers: the physical layer (quantitative acquisition of material tactile parameters), the behavioral layer (motion coding of craftsmen's body movements), and the semantic layer (cultural decoding of tactile metaphors), establishing a translatable pathway between cultural logic and technological logic. This research validates the framework using two typical intangible cultural heritage (ICH) crafts in Lingnan, China: Huisu (lime sculpture) and Guangcai (Canton enamelware). For Huisu, motion capture and semantic decoding of "pushing, pressing, and smoothing" gestures extract the tactile cultural genes of steadiness, thickness, and smoothness. For Guangcai, physical tactile measurement of "gold-threading and piling jade" techniques translates the cultural semantics of golden splendor, thinness, and complexity. The extracted cultural tactile factors are applied and tested in two real smart manufacturing scenarios: automotive interior CMF (Color, Material, Finish) design and digital cultural tourism interactive equipment. Results confirm that cultural logic is not a decorative supplement to smart manufacturing, but a structural element that enhances product emotional value, reduces homogeneous competition, and extends product lifecycle. The framework provides a transferable methodological pathway for global traditional crafts to empower regional smart manufacturing upgrades.**

Keywords*—Dao-Vessel Symbiosis; Haptic Semiotics; Cultural Logic; Smart Manufacturing; Intangible Cultural Heritage Craft; CMF Design

1. Introduction

1.1. Global Design Dilemma: Binary Separation of Cultural Logic and Technological Logic

Modern smart manufacturing follows efficiency, standardization, and replicability as core logics, while traditional crafts are based on physical practice, cultural metaphor, and regional specificity. These two systems have long been trapped in a binary opposition of "protection" versus "replacement." Recent sustainable design studies in Big.D have addressed the integration of technological innovation and community-engaged design [1], as well as applications of deep neural networks in analyzing digital interface interactions [2], yet a systematic theoretical framework for deep integration of cultural logic into technological systems remains absent.

Internationally, haptics—as one of the most primal human sensory channels—has been systematically reduced to physical comfort or functional feedback in design, rather than a carrier of cultural meaning [3]. Haptic devices developed by the MIT Media Lab can capture micro-scale physical parameters but fail to interpret the wealth-related metaphors in Guangcai's "gold-piling" techniques. This paradox between technological precision and cultural emptiness constitutes the starting point of this study.

In China, numerous efforts have been made in the digitalization of ICH. He Renke's team proposed a human-centered intelligent design big data system that integrates human factors and cultural data across three layers: data, tools, and platforms, advancing industrial design toward Industry 4.0 [4]. However, this system currently focuses primarily on visual cultural factors and physiological data, lacking a systematic haptic semiotic decoding dimension. Similarly, design practices in Guangzhou's intelligent connected vehicle sector face a corresponding absence of cultural haptics—researchers have utilized user big data for automatic extraction of behavioral and psychological features, providing a viable method for revealing the mechanisms between user behavior and design needs [5]. Yet, the systematic extraction and application of cultural haptic factors remains to be further explored..

*Sun Ming, Guangzhou Institute of Technology, sun_ming_2008@hotmail.com

1.2. Research Questions

Core question: How can cultural logic and smart manufacturing logic achieve symbiosis instead of conflict?

Three sub-questions:

1. How can core concepts in Eastern craft philosophy be translated into design parameters interpretable by industrial design systems?
2. How can the physical practice of traditional craftsmen be decoded into quantifiable haptic symbols?
3. Is this translation mechanism valid in real smart manufacturing scenarios?

1.3. Research Significance

Theoretical significance: This study fills the theoretical gap in the relationship between cultural logic and technological logic in design, promoting a disciplinary shift from visual iconography to embodied practice theory.

Practical significance: It provides a transferable methodology for traditional crafts to empower regional smart manufacturing upgrading.

1.4. Research Scope and Boundaries

The core objective of this study is to construct a methodology around a specific problem: in the haptic dimension of ICH craftsmanship, how can the cultural logic carried by the craftsman's embodied practice be translated into design parameters that are understandable and operable by smart manufacturing systems. Based on this delineation, the present paper has clear boundaries in its scope of treatment. First, the paper focuses on the decoding and translation of haptic symbols and does not attempt to cover all sensory dimensions (auditory, olfactory, etc.), nor does it attempt to construct a universal Eastern design epistemology. Second, the methodological validation of this paper is conducted using two ICH crafts from Lingnan, China—Huisu and Guangcai—as case studies, without claiming that the framework is already applicable to all craft types. Third, the application scenarios of this paper are represented by automotive interior CMF design and digital cultural tourism interactive equipment, illustrating the injection pathway of design factors, without attempting to comprehensively cover all aspects of smart manufacturing. This focused scope setting is intended to provide an operable methodological proposal centered on the core problem of culture-to-manufacturing translation.

1.5. Paper Structure

Section 2 constructs the Dao-Vessel Symbiosis framework. Section 3 introduces the Triadic Haptic-Semiotic Model. Section 4 validates the method using Lingnan Huisu and Guangcai. Section 5 tests applications in smart manufacturing scenarios. Section 6 discusses symbiosis mechanisms and transferability. Section 7 concludes theoretical and practical contributions.

2. Theoretical Framework: Dao-Vessel Symbiosis

2.1. Core Propositions of Eastern Craft Philosophy

Three classical propositions form the philosophical foundation of Dao-Vessel Symbiosis.

"Harmony between humanity and nature": The symbiotic relationship between materials and humans. As recorded in The Artificers' Record, "Timeliness, geography, material quality, and craftsmanship must integrate to produce excellence" [6]. The character "integrate" reveals the collaborative essence between natural endowments and human wisdom in craft activities—the material, under the craftsman's guidance, completes its morphological transformation by following its own carbonation laws, rather than passively receiving shaping. Lingnan Huisu craftsmen mix lime, straw, glutinous rice flour, and other ingredients in specific proportions, let the lime paste rest and ferment, and then beat it with wooden mallets to achieve pliability and fineness [7]. This logic of following nature resonates with the "human-centered" philosophy in smart manufacturing, constituting the practical foundation of Dao-Vessel Symbiosis.

"Vessels as carriers of the Dao": Artifacts as materialized manifestations of cultural concepts. The Book of Changes (Xici) states: "What is above form is called the Dao; what is below form is called the vessel" [8]—the vessel is not a lower form of the Dao but its concrete carrier. The "gold-threading and piling jade" technique of Guangcai porcelain [9] is not merely decoration, but a materialized expression of the wealth consciousness and cultural confidence of Guangzhou merchants during the Thirteen Factories foreign trade era.

"Skill approaching Dao": Technological practice itself as the embodiment of the Dao. In Zhuangzi: The Secret of Caring for Life, the cook Pao Ding dissects an ox "with his spirit encountering rather than his eyes observing" [10]—the haptic experience of the hands transcends visual judgment to become the primary perceptual tool. This classical allegory reveals a core proposition: when technological practice reaches refinement, bodily haptics themselves can become the carrier of the Dao—this resonates across time and space with the analytical paradigm of "design and craft thinking as embodied cognition" in contemporary embodied cognition research [11]. This provides a critical philosophical foundation for understanding the embodied practice of ICH craftspeople.

2.2. Definition of Cultural Logic and Technological Logic

Cultural logic: Values, embodied practice, metaphor systems, and collective memory embedded in traditional crafts, characterized by regionality, implicitness, holism, and emotional attachment.

Technological logic: Efficiency, precision, replicability, and modularity pursued in modern smart manufacturing, characterized by universality, explicitness, decomposability, and function orientation.

The spectrum of their relationship: Conflict (cultural protectionism holds that technology inevitably erodes cultural uniqueness) → Coexistence (a compromise path where each performs its own function) → Symbiosis (the position of this paper)—symbiosis does not mean eliminating differences, but rather, while preserving the uniqueness of cultural logic, transforming it into a design language that can be understood and operationalized by technological systems.

2.3. The Dao-Vessel Symbiosis Framework

Based on the above philosophical foundations, this paper proposes three symbiotic levels within the Dao-Vessel Symbiosis theoretical framework.

Cognitive Symbiosis: Eastern philosophy provides value rationality for technological systems, expanding smart manufacturing from the technological question of "what can be done" to the cultural question of "what ought to be done".

Practical Symbiosis: The craftsman's body provides a source of haptic parameters for industrial design, encoding the craftsman's hand-feel into design parameters recognizable by smart manufacturing systems, producing modern craft products that integrate handmade soul with industrial efficiency.

Ecological Symbiosis: Cultural-emotional value extends product lifecycles—when a product carries recognizable cultural haptic memory, the user's psychological ownership strengthens, replacement frequency decreases, and resource consumption correspondingly declines. Big.D's sustained focus on sustainable design and circular economy receives, in this sense, a supplementary theoretical dimension from the perspective of cultural emotion.

3. Methodology: The Triadic Haptic-Semiotic Model

3.1. Model Design Principle

The translation from "cultural logic" to "technological logic" requires an intermediary layer—the haptic symbol. Haptic symbols possess a dual nature: they are simultaneously cultural carriers (the craftsman's embodied practice) and physical parameters (quantifiable indicators of material tactility), thus enabling them to perform the translation function between these two logics.

3.2. Three-Layer Model Construction

- Layer 1: Physical Layer – Quantitative Acquisition of Material Tactile Parameters

Acquisition dimensions include surface roughness (Ra value), hardness, thermal conductivity coefficient, and texture periodicity. For Huisu materials, the foundational raw material is lime, which through multi-layered superposition forms a rich tactile sequence: straw-reinforced lime base layer → paper-reinforced lime middle layer → colored lime surface layer. For Guangcai materials, the "gold-threading and piling jade" technique creates a stark tactile contrast between the raised gold lines and the smooth surface of the white porcelain body. In terms of technical reference, He Renke's team has accumulated data acquisition methods in the field of cultural heritage digitization, including "ultra-high-definition scanning, high-precision three-dimensional reconstruction, and motion capture" [12], providing a technical framework reference for the data acquisition pathway of this study. Haptic perception thresholds follow the universal standards established by Kappers et al.—these standards cover dimensions such as roughness, hardness, friction, and thermal sensation, providing theoretical basis for the physical parameter measurement in this study [13].

- Layer 2: Behavioral Layer – Motion Trajectory Encoding of Craftsmen's Body Movements

The craftsman's techniques of "pushing, pressing, smearing, and scraping" are translated into quantifiable motion trajectory parameters, including applied force magnitude (N), movement speed (mm/s), trajectory curvature, and operational angle. Data acquisition employs inertial motion capture systems combined with three-dimensional force sensors, synchronously recording hand movement trajectories (spatial coordinates, angular velocity, acceleration) and applied force parameters, with a sampling frequency not lower than 100 Hz. Internationally, mature reference practices already exist: Partarakis et al. (2020) established a reference gesture dataset for traditional crafts based on motion capture, providing a technical platform for standardized encoding and semantic annotation of craftsmen's movements [14]. This team further proposed a digital ethnography framework integrating motion capture and three-dimensional scanning to record craft actions and material behaviors [15].

In recent years, multiple domestic teams have successfully applied motion capture technology to the digital recording of ICH body movements. In the digital rescue project for the Jiaodong seaweed-thatched house construction technique, researchers fitted elderly craftsmen with inertial motion capture equipment and electromyography (EMG) signal sensors, precisely capturing parameters such as the angular velocity of wrist movements when turning seaweed, the subtle adjustments of core muscle groups when maintaining balance on steep roofs, and the nuanced rebound between person and material during "one-insert-one-pat" movements. This successfully transformed the craftsmen's tacit knowledge—"hands have the knack, but the mouth cannot articulate the method"—into an analyzable digital "skill movement library" [16]. Additionally, the Yunnan ICH dance multimodal acquisition project has completed high-precision motion capture of several ICH dances, including the Yi people's Left-Foot Dance and the Wa people's Wooden Drum Dance, generating 20 sets of motion data and preserving high-fidelity 2D/3D digital models of representative inheritors [17]. The craftsman technique encoding paradigm adopted by the National Social Science Fund project on "Hubi" writing brushes (2020BH00977)—which treats craft activity as a material manifestation of cultural concealment—provides a methodological precedent for this model [18]. These practices demonstrate that motion capture technology for recording ICH body movements is technically mature and has been validated across different ICH categories, including architectural crafts and dance. The behavioral layer data acquisition framework of this study represents a further extension based on these existing technological practices—expanding the acquisition objects from architectural craftsmanship and dance movements to the fine handcraft domains of Huisu and Guangcai.

Data Acquisition Plan. Based on the above existing practices, this study has designed the following systematic data acquisition protocol, to be implemented progressively in subsequent research. Regarding acquisition subjects, inheritors of Huisu and Guangcai will serve as the core subjects (at least 6 inheritors, including 3 core inheritors with over 30 years of experience and 3 young apprentices with 5–10 years of experience), with additional inclusion of craftsmen from other Lingnan crafts such as Duan inkstone, to form a cross-craft haptic behavior dataset. Regarding equipment, an inertial motion capture system (e.g., Vicon Vantage V5, 12 high-speed infrared cameras, accuracy 0.1 mm, sampling frequency 120 Hz) combined with three-dimensional force sensors (e.g., Delsys Trigno wireless EMG signal sensors) will be employed to synchronously record hand movement trajectories and applied force parameters. Specific parameters to be acquired include: single-operation duration for each core technique, peak and mean applied force, radius of motion trajectory curvature, operational angle range, and technique adjustment amplitude under different material humidity conditions. Regarding semantic annotation, through on-site interviews and video playback sessions, inheritors will describe the "hand-feel" of each operation using the local dialect, forming a corresponding annotated corpus of behavioral parameters and haptic semantics. The reliability of semantic coding will be evaluated through Cohen's Kappa coefficient with dual coder agreement. This plan has already undergone preliminary validation through a non-contact motion capture pre-experiment conducted with a Duan inkstone craftsman in Zhaoqing, confirming the feasibility of the technical route.

- Layer 3: Semantic Layer – Cultural Decoding of Tactile Metaphors

This constitutes the core distinguishing feature of this model from purely technical approaches. The tactile parameters of physical surfaces do not possess a priori cultural meanings; they are assigned specific semantics only within particular cultural contexts and traditions of embodied practice. The force of the Huisu craftsman's "mud-pushing" is not an isolated mechanical parameter, but an embodied expression of the Cantonese spirit of "seeking progress while maintaining stability." The thickness of the Guangcai painter's "gold-piling" is not merely a standard of technical precision, but carries the wealth narrative of Guangzhou as a hub of foreign trade during the Thirteen Factories era.

Data sources for semantic decoding include: semi-structured in-depth interviews with craftspeople (guided by haptic metaphors), folk literature (Cantonese craft classics, craft descriptions in local gazetteers), and on-site observation notes. The decoding results are presented in the form of a "Haptic Metaphor Dictionary," with each entry containing three layers of information: physical parameters, behavioral characteristics, and semantic interpretation.

3.3. Cross-Modal Mapping Mechanisms

Visual-haptic synesthetic mapping: The visual order of Guang embroidery patterns correlates with the physical parameters of silk tactility. Behavior-semantic translation: The behavioral trajectory of the craftsman's "mud-pushing force" carries folk semantic meaning. Physical-cultural calibration: Material physical parameters are endowed with design emotional value through the cultural metaphor dictionary.

3.4. Operational Definition of the Model

Input: Embodied practice of traditional craftspeople (behavioral observation + interviews + literature) → Processing: Triadic decoding and cross-modal mapping → Output: Cultural haptic design factors that can be called upon by industrial design systems.

4. Case Study: Lingnan Heritage Validation

4.1. Case Selection Rationale

This study selects Huisu and Guangcai from China's Lingnan region as methodological validation cases. Huisu is a traditional architectural decorative craft of the Lingnan region, using lime, oyster shell ash, and other primary materials, forming a rich surface tactility through multi-layered modeling. Guangcai, or "Guangzhou gold-decorated polychrome porcelain," is known for its dense composition, rich colors, and resplendent gold decoration, particularly noted for its unique decorative techniques of "gold-threading" or "gold-threading and piling jade."

Both crafts possess clear haptic genes and exhibit complementary characteristics—Huisu emphasizes the three-dimensional tactility of large-scale architectural components and full-body craftsman movements, while Guangcai emphasizes the fine tactility of small-scale objects and finger movements. A note on case positioning: this paper uses Lingnan ICH as methodological validation cases; the validation objective is the effectiveness of the framework, not the writing of a Lingnan ICH chronicle.

4.2. Huisu Case: Cultural Decoding of Craftsman Haptic Behavior

Craft Background: Huisu mostly uses locally sourced materials—oyster shells and cockle shells burned into shell lime, mixed with straw, brown sugar, glutinous rice, etc. in specific proportions, manually pounded into a paste for architectural decoration [11].

Physical Layer Acquisition: The foundational raw material of Huisu is lime, which through multi-layered superposition forms a unique tactile sequence. Preliminary experiments have validated the technical feasibility of data acquisition.

Behavioral Layer Acquisition: The core techniques of the Huisu inheritor include "pushing, pressing, smearing, and scraping," each technique corresponding to different motion trajectories and craft functions.

Semantic Layer Decoding:

- "Steadiness" of mud-pushing → "Seeking progress while maintaining stability" spirit of the Pearl River merchant community
- "Thickness" of mud-pressing → "Embracing virtue with great depth" architectural meaning
- "Smoothness" of surface-smearing → Practical wisdom of "smooth and clean for moisture prevention" in the Lingnan climate

Cultural Logic Extraction: The haptic gene of Huisu craft can be summarized as the three-character code: "steadiness, thickness, and smoothness" (wen, hou, guang)

4.3. Guangcai: Semantic Translation of Material Tactility

Craft Background: Guangcai originated around the mid-to-late Kangxi period of the Qing Dynasty, benefiting from Guangzhou's "single-port trade" advantage to become export porcelain shipped to Europe. Its "borrowed-body with added-color" production model—high-temperature white porcelain bodies from Jingdezhen shipped to Guangzhou, where craftsmen applied polychrome decoration according to foreign merchants' demands and fired at 700°C–750°C [10]—gives Guangcai's haptic genes an inherent cross-cultural dialogue property.

Physical Layer Acquisition: The "gold-threading and piling jade" technique creates a stark tactile contrast between the raised gold lines and the smooth white porcelain surface.

Semantic Layer Decoding:

- "Gold-piling jade" texture → Symbol of wealth from the Thirteen Factories foreign trade

- "Thin as cicada wings" porcelain body → Refined and pragmatic aesthetic of Cantonese culture

Cultural Logic Extraction: The haptic gene of Guangcai craft can be summarized as the three-character code: "golden splendor, thinness, and intricacy" (jin, bo, fan).

4.4. *Comparative Analysis of Huisu and Guangcai Haptic Genes*

Based on the preceding case analyses of Huisu and Guangcai, the haptic genes of these two crafts exhibit clear differentiation across two dimensions—craft practice and cultural semantics—while forming a complementary system.

From the perspective of craft practice, Huisu uses oyster shell ash and lime as raw materials, forming three-dimensional tactility through multi-layered modeling (straw-reinforced lime → paper-reinforced lime → colored lime). Craftsmen employ full-body coordinated movements of "pushing, pressing, smearing, and scraping" to complete large-scale architectural component shaping. Guangcai, relying on Jingdezhen white porcelain bodies, uses the "gold-threading and piling jade" technique to form distinctly uneven fine tactility, with craftsmen performing precise fingertip operations to complete gold-threading, line-drawing, and other procedures. The former conveys the haptic qualities of "steadiness, thickness, and smoothness," meeting the practical needs and climatic characteristics of Lingnan architectural decoration. The latter highlights the haptic features of "golden splendor, thinness, and intricacy," aligning with the aesthetic demands of the export trade.

From the perspective of cultural semantics, the haptic expressions of Huisu decode the Cantonese merchant community's spirit of "seeking progress while maintaining stability" and the architectural meaning of "embracing virtue with great depth." The haptic details of Guangcai translate into the wealth symbolism of the Thirteen Factories foreign trade and the Cantonese aesthetics of "refinement and pragmatism." These two crafts—one three-dimensional and one fine, one pragmatic and one luxurious—both demonstrate the craft diversity of Lingnan ICH and validate the feasibility of the "Triadic Haptic-Semiotic Model" for analyzing ICH haptic genes. Table 1 presents the comparative analysis of haptic genes between the two crafts.

TABLE I. COMPARATIVE ANALYSIS OF HAPTIC GENES BETWEEN HUISU AND GUANGCAI

Craft	Core Gestures	Haptic Gene	Cultural Semantics
Huisu (Lime Sculpture)	Push, Press, Smooth, Scrape	Steadiness, Thickness, Smoothness	Steady progress, Endurance, Pragmatism
Guangcai (Canton Enamel)	Gold-threading, Piling jade, Line-drawing	Splendor, Thinness, Complexity	Wealth symbolism, Export trade aesthetics
Application	CMF door panel / Haptic interface	Micro-relief / Gold-thread -> feedback	Emotional durability / Lifecycle extension

5. APPLICATION SCENARIOS: SMART MANUFACTURING VALIDATION

5.1. *Scenario 1: Automotive Interior CMF Design*

Automotive interior haptic experience has become a critical dimension in global automotive brand differentiation. According to the 2024 J.D. Power China New Energy Vehicle Customer Experience Value Study, although GAC Aion performed prominently in after-sales service satisfaction, ranking among the top three, it still lagged behind brands such as Tesla in terms of the cultural-emotional value of interior materials [19]. The CAACS survey released the same year by the China Association of Automobile Maintenance and Repair also showed that Tesla, GAC Aion, and BYD occupied the top three positions in customer satisfaction, while user demand for "premium feel" and "cultural identity" in domestic brand interiors continued to rise [20]. This corroborates the finding in GAC Research Institute's 2024 user survey that the emotional value of interior materials was the second-largest complaint for domestic brands (accounting for 41.7%) [21]. These data indicate that domestic automotive brands urgently need to enhance the emotional premium of their products through cultural haptic design.

Design Translation Pathway: Inject the "fortune pattern" haptic parameters extracted from Huisu craft into automotive door panel material design, completing the CMF translation from traditional architectural decoration to modern automotive interiors. Translation dimensions include Color (Huisu's oyster-shell gray-white palette → interior warm gray tone), Material (lime paste breathing texture → door panel micro-relief tactility), and Finishing (irregular luster of hand-smearing → parametric surface texture generation).

GAC is already exploring technical pathways for enhancing haptic experience—the AION S MAX features a 90% soft-wrapped yacht-style cabin layout, with a T-shaped wood-trimmed dashboard using white oak grain, where nearly all touchable surfaces are soft materials. The AION V cabin employs extensive soft covering, with high-contact areas already possessing good foundational tactility [22]. Notably, the GAC Trumpchi M8 Qiankun series has begun integrating ICH crafts into automotive interior design: in its "Five-Sense Immersion" cabin concept, the haptic dimension employs landscape-quilted Nappa leather seats and millennium "pear-ground" lacquered white birch solid wood trim panels, integrating millennium-old Guangdong embroidery ICH techniques into the interior, exploring the fusion of traditional culture and modern mobility across the five senses of "sight, sound, touch, taste, and smell." However, the M8 Qiankun series practice focuses primarily on ICH visual elements (Guangdong embroidery patterns) and the surface decorative effect of traditional lacquer art, without yet touching upon the deeper haptic semantic dimensions of ICH craftsmanship—such as the force rhythm of Guangdong embroidery stitches and the hand-feel layering of lacquer art polishing, cultural genes carried by the craftsman's embodied practice. The Huisu "steadiness, thickness, and smoothness" haptic gene injection scheme proposed in this study represents a semantic-level deepening and expansion upon this foundation: not treating ICH elements as surface decoration, but translating the craftsman's hand-feel into CMF haptic parameters, upgrading traditional culture from "visual embellishment" to "haptic structure" [23].

Pilot Study Protocol. To preliminarily examine the influence of cultural haptic design factors on the perception of automotive interior materials, this study has designed the following pilot study protocol, which is currently being progressively implemented. Mature experimental paradigms for tactile evaluation of automotive interior materials already exist in the domestic academic community for reference:

Tang Bangbei, Guo Gang, and Xia Jinjun (2017) proposed an industrial design material evaluation method based on user visual/haptic experience, constructing a user visual/haptic experience testing and evaluation system with a fuzzy comprehensive evaluation model, and verified the feasibility of the method through an experiment with 20 participants evaluating automotive seat fabric materials [24]; Yin Yanqing, Zhao Danhua, and Tan Zhengyu (2016), based on emotional design theory, conducted emotional semantic quantification through 30 users' evaluations of the texture of 6 automotive interior leather texture samples, verifying users' perceptual differences in interior material emotions under different sensory modalities from the perspectives of haptic unimodal perception and visual-haptic bimodal perception [25]. Internationally, there are also multiple relevant empirical studies: Marquez et al. (2022) evaluated 21 participants touching 18 in-car plastic texture samples under pure haptic and visual-haptic bimodal conditions, revealing the relationship between perceived roughness and emotional responses, and modeling the emotional dimensions of texture parameters [26]; an experiment at Delft University of Technology involving 33 participants receiving haptic and other multi-sensory stimuli in a simulated high-performance coupe cabin synchronously recorded physiological data such as electrodermal activity and pulse rate alongside subjective scales, with results indicating that participants' acceptance of haptic-auditory combined conditions was second only to the full multi-sensory solution [22]. Furthermore, existing research has established a theoretical framework for haptic processing in automotive user interfaces, integrating the complete chain from sensory perception to information processing into a unified model [23].

Building upon the above existing experimental paradigms, the pilot study protocol designed in this study is as follows: The experiment adopts a within-subject design, planning to recruit 12–16 participants (balanced gender, aged 18–45, right-handed). The experimental materials will use GAC Aion AION S MAX door panel material as the base sample, applying two haptic treatment conditions: (A) Huisu "fortune pattern" haptic parameters (surface roughness Ra = 8.5 μm, texture period = 4.2 mm, micro-relief height = 0.6 mm); (B) control group smooth surface (Ra = 1.2 μm, no texture). Participants will, under visually occluded conditions, slide their index finger across the surfaces of the two sample groups and subsequently complete three evaluations: (1) Haptic identifiability: through a two-alternative forced-choice task, judging whether the two sample groups can be distinguished solely by touch; (2) Semantic consistency: selecting the term that best matches the tactile description from four options—"steady and substantial," "light and modern," "luxurious and refined," and "simple and practical"; (3) Cultural-emotional added value: rating the "premium feel" and "cultural identity" of both sample groups on a 7-point Likert scale. Haptic perception thresholds follow the universal standards established by Kappers et al. [13]. The planned statistical analysis methods are: binomial test for haptic identifiability, Chi-square goodness-of-fit test for semantic consistency, and paired-samples t-test for cultural-emotional added value. The complete experimental data will be systematically presented in subsequent research.

Third-party evaluations provide both positive and negative feedback on interior material directions. On the positive side, the AION V's interior materials are of good quality, with high-contact areas possessing good tactility and feedback, the cabin atmosphere far exceeding its class, and driving experience ranking among the top three options in surveys of one hundred car owners' satisfaction [19][20]. On the improvement side, evaluation data also indicate cost-saving practices in GAC Aion interior materials, with user haptic experience still having room for enhancement. Overall, although Aion models perform prominently in hard technical dimensions (safety, intelligence, power range), the soft experiential dimensions of interior tactility and material cultural emotion cannot yet create clear distance from brands like Tesla. This provides a clear market gap and industry demand foundation for the application pathway of "injecting cultural haptic design factors into smart manufacturing products" proposed in this study.

5.2. Scenario 2: Digital Cultural Tourism Interactive Equipment

Design Translation Pathway: Inject tactile parameters of Guangcai silk-thread texture into the surface design of interactive controllers, completing the haptic translation from traditional export craft to modern cultural tourism equipment. At the tactile mapping level, the raised height of Guangcai gold lines serves as the basis for setting the haptic feedback intensity of the interactive panel. At the gesture translation level, the painter's "gold-piling" gestures are translated into gesture recognition logic for the interactive controller.

Technical Feasibility and Experimental Plan. Translating Guangcai's haptic genes into haptic feedback for interactive devices is already achievable under current hardware technology conditions. Piezoelectric actuators can provide millisecond-level response and micron-level amplitude control, capable of precisely reproducing the tactile details of Guangcai's "gold-thread elevation." Linear resonant actuators (LRA) and voice coil actuators (VCA) can be used to simulate the gradual feedback of different force levels in the painter's "gold-piling" gestures. The engineering feasibility of such actuators in immersive interaction has been systematically demonstrated in the haptics academic community, and their transformative potential in design contexts also provides a foundation for subsequent equipment development [27]. For example, the haptic controller prototype exhibited by Sony at the 2025 CIIE further validates the application potential of this technological pathway in cultural tourism scenarios; its controller can simultaneously simulate strong impacts, subtle vibrations, and changes in "weight sensation," exhibiting a direct correspondence in technical logic with the design pathway of translating Guangcai craftsmanship into interactive gestures in this study.

Human Factors Adaptation. On the basis of feasible hardware technology, the multimodal human factors representation model provides the human factors engineering basis for human-computer interaction design, ensuring the functional compatibility of cultural tactile parameters within interactive equipment. Existing motion capture and digital acquisition practices in the arts and crafts field—taking wood and stone carving as an example, where tracking-type 3D scanners (Trackscan-P) can achieve 0.028 mm accuracy, digital cameras record decorative colors at 6K resolution, and drones acquire large-scale objects at millimeter-level accuracy—provide a mature technical bridging foundation for the entire chain from the acquisition of haptic design factors to their embedding in equipment. Figure 1 illustrates the complete CMF design transformation pathway from

Huisu haptic gene to automotive interior parameters, along with the pilot study setup.

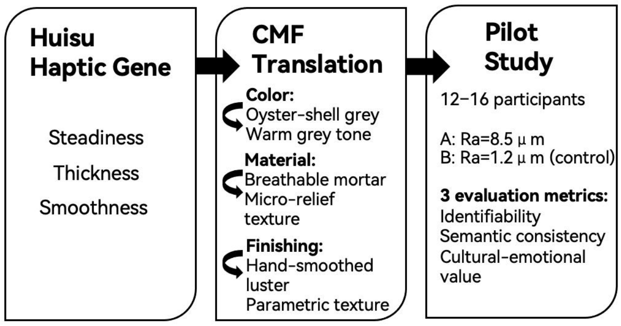

Figure 1. CMF design transformation pathway from Huisu haptic gene to automotive interior parameters, with pilot study setup

6. Discussion

6.1. Theoretical Contributions: The Three Mechanisms of Dao-Vessel Symbiosis

Cognitive Symbiosis: Eastern philosophy infuses value rationality into technological systems, making smart manufacturing upgrades not merely an efficiency revolution, but an opportunity for cultural self-renewal.

Practical Symbiosis: The craftsman's body provides a source of perceptual parameters for industrial design; the Triadic Haptic-Semiotic Model makes tacit knowledge explicit. Compared with existing research systems, He Renke's team has constructed intelligent design data infrastructure across three levels—data, tools, and platforms—focusing primarily on visual factors and human physiological data [4]; this study extends this foundation in depth toward the haptic dimension and cultural semantic dimension.

Ecological Symbiosis: Cultural-emotional value can promote sustainable manufacturing by extending product lifecycles. When a product enables users to generate recognizable cultural haptic memories, users' psychological ownership strengthens, replacement frequency decreases, and resource consumption correspondingly declines. In research on affective durability, the emotional bond between users and products has been confirmed as an important factor in extending product usage cycles and reducing resource waste [28]. Big.D's sustained focus on sustainable design and circular economy receives, in this sense, a supplementary theoretical dimension from the perspective of cultural emotion.

Notably, the Triadic Haptic-Semiotic Model established in this study is not only a unidirectional translation channel from culture to manufacturing, but also provides the possibility for reverse feedback from the manufacturing end back to the cultural end. When haptic design factors are injected into CMF parameters, users' subjective evaluation data on tactile sensations can flow back into the cultural metaphor dictionary of the semantic layer, enriching its interpretive dimensions and forming a bidirectional loop between cultural data and manufacturing parameters. This bidirectionality is precisely the concrete manifestation of "practical symbiosis" and "ecological symbiosis" within the Dao-Vessel Symbiosis framework in the context of transformative design.

6.2. Dialogue with Existing Research

Dialogue with Herzfeld's "Anthropology of the Body": The "Triadic Model" of this study transforms the discipline's theoretical concern with "the corporeality of skill" into an operable methodological tool for design studies [29].

Dialogue with international haptic cultural heritage research: Existing projects emphasize motion capture and reconstruction at the technical level, such as the immersive application of haptic gloves in cultural heritage interaction [30]. This study establishes a cultural decoding layer at the semantic level on this foundation, enabling haptic digitization to not only record "how one moves," but also to explain the cultural significance of "why one moves in this way."

Comparison with Existing Digital Craft Research Frameworks. Multiple international research teams have currently established methodological frameworks for the digitization of traditional crafts. The Triadic Haptic-Semiotic Model of this study is both related to and clearly differentiated from these frameworks. Partarakis et al. (2020) established a motion-capture-based gesture segmentation and semantic annotation method, segmenting craftsmen's actions into independent craft units through the AnimIO platform and performing semantic annotation [14]; however, this method did not incorporate haptic physical parameters into the encoding dimension, lacking a systematic transition from physical measurement to behavioral encoding. This team subsequently further proposed a digital ethnography framework integrating motion capture and 3D scanning to record craft actions and material behaviors [15], but still focused on the recording of actions and processes, without yet entering the level of cultural semantic decoding—which is precisely the core concern of the "semantic layer" in this study. In the field of architecture, Oral Karakoç (2024) proposed a typological encoding and parametric translation framework for craft knowledge, distinguishing parametric pathways for explicit and tacit knowledge [23]; this framework converges with the "physical layer → behavioral layer" direction of this study, but lacks the critical "behavior → semantics" translation step. In the field of haptic interaction, Gaffary & Lécuyer (2019) proposed a theoretical framework for haptic processing in automotive user interfaces, integrating the complete chain from sensory perception to information processing into a unified model [23]; however, its core objective is to enhance driving safety and reduce cognitive load, and the cultural dimension of haptic semantic translation falls outside its research scope.

In summary, the above frameworks each have their own emphases but none have touched upon the core issue of concern in this study—how haptic behavior in craftsmen's embodied practice can be decoded into cultural semantics and translated into manufacturing parameters. The Triadic Model of this study represents a supplement precisely built upon these existing technological advances: under the premise that existing frameworks can accurately capture actions and physical parameters, this study further establishes a translation pathway between behavioral parameters and cultural metaphors, and through this, introduces cultural logic into the design process of smart manufacturing.

6.3. *Transferability of the Method*

The core logic of the Triadic Haptic-Semiotic Model—progressive movement from physical measurement to behavioral coding to cultural semantics—possesses theoretical applicability across multiple cultural regions. In African wood carving, the force of the carver's knife carries tribal memory (Physical Layer: wood hardness and grain acquisition; Behavioral Layer: carving force and knife trajectory coding; Semantic Layer: cultural metaphorical decoding of tribal totems). Big.D has already paid attention to the digital transformation of African traditional crafts [1], and the methodological framework of this study can provide new theoretical tools for this area. In Southeast Asian batik textile craft, the force of the canting tool and the rhythm of the patterns map onto regional nature worship. In Andean pottery, the hand-feel of paddle-shaping carries indigenous cosmology. For each craft, the embodied practice of craftspeople can be recorded by motion capture systems, material tactility can be quantitatively measured, and cultural metaphors can be supported by literature and oral history. The Triadic Model provides a reusable methodological pathway for ICH crafts in different cultural contexts moving toward smart manufacturing.

6.4. *Research Limitations and Future Directions*

Although this study has validated the effectiveness of the "Dao-Vessel Symbiosis" framework through the cases of Huisu and Guangcai, and completed application testing in two types of smart manufacturing scenarios, four limitations remain, with corresponding directions for future expansion.

Second, the sensory dimension research is singular. This study focused on the extraction and translation of haptic genes, without yet incorporating other sensory factors such as auditory and olfactory dimensions, and thus has not constructed a complete multi-sensory design system for ICH. Future research will expand multi-sensory design factor acquisition, supplementing content such as the sound of Huisu mud-pounding, the scent of Guangcai pigments, and ICH pattern visual symbols, to establish a "Lingnan ICH Multi-Sensory Design Factor Database. "

Third, the application scenario depth is insufficient. This study only preliminarily injected haptic design factors into two types of smart manufacturing scenarios, without yet achieving deep integration of the framework with the full smart manufacturing process. Future research will extend applications to fields such as smart home and wearable devices, simplify application procedures, provide lightweight translation tools, and explore integration pathways with low-carbon smart manufacturing in conjunction with sustainability principles.

Fourth, pilot study data remains to be systematically collected. The pilot study protocol reported in Section 5.1 of this study is currently being implemented, and large-scale user testing has not yet been completed. The statistical analysis and cross-participant validation of experimental data need to be systematically conducted in subsequent research, and the sample size must be expanded after formal approval through ethical review.

7. CONCLUSION

7.1. *Core Findings*

Cultural logic and smart manufacturing technological logic can achieve symbiosis rather than inevitable conflict; the "Dao-Vessel Symbiosis" theoretical framework provides an operable methodological pathway for such symbiosis; the Triadic Haptic-Semiotic Model serves as a translation tool connecting Eastern philosophy and industrial design; Lingnan ICH validation demonstrates that cultural haptic design factors can be successfully injected into automotive interiors and cultural tourism product design.

7.2. *Implications for Design Field*

Smart manufacturing need not be the "terminator" of cultural traditions, but can instead be their "symbiotic new carrier." The core concepts embedded in Eastern craft philosophy—"harmony between nature and humanity" and "vessels as carriers of the Dao"—offer the global design community a reference path distinct from Western technological determinism when asking "where does culture reside after technology?" At the same time, data-driven ICH digitization research is forming a new academic growth point on a global scale. The transferable methodological framework proposed in this study holds promise for contributing a research paradigm that combines theoretical depth with practical operability to this interdisciplinary field.

7.3. *Research Contributions and Outlook*

This study, at the intersection of Eastern craft philosophy, the Triadic Haptic-Semiotic Model and smart manufacturing applications, and CMF and interaction design, proposes a methodological framework that integrates traditional craft haptic factors with modern manufacturing technology, providing a transferable methodological tool for empowering contemporary smart manufacturing through traditional crafts. In the future, with the gradual refinement of the multi-sensory design factor database and the continued expansion of cross-cultural cases, this framework holds promise for providing more systematic theoretical support for global ICH digitization and sustainable manufacturing.

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AVAILABILITY OF DATA

Not applicable.

ETHICAL STATEMENT

This study does not involve direct human participation or animal experimentation. All case data were obtained from publicly available literature and documented craft practices.

AUTHOR CONTRIBUTIONS

Sun Ming conceived the framework, conducted case validation, analyzed applications, and wrote the manuscript.

COMPETING INTERESTS

The author declares no competing interests.