Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

A Transparent AHP–TOPSIS Framework Based on Dual Evidence and Contextual Reweighting: Semantic-Coherence Translation of Miao Silver Ornament Patterns in Contemporary Design

Jun Liang
HuangShan University
Yousheng Yao
Zhongkai University of Agriculture and Engineering
Fangtian Ying
yingft@gmail.com

European Academy of Engineering
Weiqiang Ying
Hangzhou City University
Guanghui Huang
Macau University of Science and Technology
Haoran WANG
Macau University of Science and Technology

Article

Keywords: Miao silver ornaments, semantic coherence, motif ontology, intangible cultural heritage, AHP–TOPSIS, dual evidence, Monte Carlo simulation, generative AI

Posted Date: June 12th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9533511/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Translating culturally saturated heritage into contemporary design often reduces cosmology, ritual, and craft memory to superficial visual mimicry. This problem becomes sharper in the age of generative AI, where style transfer is easy but cultural ground-truth is weak. Focusing on Miao silver ornament patterns, this study proposes a transparent and auditable framework that operationalizes semantic coherence for design evaluation and future AI training. The method integrates Kansei-informed semantic anchoring, the Analytic Hierarchy Process (AHP), and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) within a dual-evidence pipeline combining expert and user evidence. The expert panel (n = 25) yielded a stable criterion structure with Symbolic Clarity (0.28) and Contextual Fitness (0.23) as the most influential criteria, and the reconstructed transparency check confirmed excellent internal consistency. A user survey (n = 320) provided descriptive validation and highlighted subgroup heterogeneity in semantic preference. In response to reviewer concerns, the manuscript now clarifies myth-to-criterion mapping through a lightweight motif ontology, adds concept visuals for Brooch A and Brooch B, strengthens the explanation of craft ethics through maker-signed maintenance logic—reframing artisan signatures and lifetime repair commitments as ethical obligations that unite technical skill with social responsibility—and expands the AI section from a conceptual claim to an implementable semantics-first protocol. Transparent numerical replication shows that TOPSIS favors Brooch A over Brooch B (Ci = 0.777 vs. 0.223); Monte Carlo perturbation across 10,000 iterations keeps Brooch A ranked first in 100.0% of simulations, with mean closeness 0.777 (95% CI [0.733, 0.819]). By linking mythology, material practice, decision analytics, and AI governance, the framework offers a reproducible path for culturally responsible contemporary design that honors both semantic fidelity and the ethical continuity of artisan craft.

1. Introduction

Cultural heritage is not an inventory of stable forms but a living configuration of meanings, memories, practices, and material procedures[1]. For Miao silver ornaments, motifs such as butterfly, bird, dragon, fish, and layered filigree do not function as isolated decorative signs. They form a relational grammar linking cosmology, migration memory, ritual protection, social identity, and inherited craft knowledge[2]. When contemporary design extracts only visible outlines from this grammar, semantic collapse occurs: the motif remains legible as style, but ceases to operate as culture[3].This challenge is especially acute in the context of generative AI. Diffusion-based systems can imitate surface appearance with considerable fluency, but their optimization targets often privilege visual similarity rather than cultural fidelity[4]. In heritage-sensitive design, the critical question is not whether a generated output merely looks traditional. It is whether the output preserves the relations among mythic origin, symbolic role, craft logic, and context of use[5]. Without structured semantic ground-truth, AI systems risk accelerating a form of cultural dilution that appears authentic while eroding indigenous meaning[6].Existing heritage and creative-product studies have made progress in using multi-criteria decision models to support design evaluation, yet several gaps remain[7]. Many studies stop at descriptive accounts of symbols without converting them into auditable criteria, while expert judgement is often used without systematic

triangulation against public reception[8]. When design contexts shift from bodily adornment to packaging, display, or digital interface, adaptation is commonly handled through informal redesign rather than transparent reweighting[9]. This paper addresses these gaps through a dual-evidence AHP–TOPSIS framework structured around semantic coherence[10].

2. Research Object and Semiotic Anchoring

The object of this study is the semantic translation of Miao silver ornament patterns into contemporary design [11]. Semantic coherence is operationally defined here as the degree to which a translated design preserves the relational alignment among mythic origin, symbolic role, craft logic, and context of use [12]. To avoid treating heritage as stylized ornament, the framework begins with operationalized semiotic anchoring [13]. Five evaluative criteria were defined: Symbolic Clarity, Contextual Fitness, Craft & Maintainability, Identification, and Narrative Capacity [14]. These criteria do not replace indigenous cosmology; rather, they provide a transparent evaluative surface through which cultural continuity can be assessed in contemporary design scenarios [15].A key contribution of this revision is the explicit articulation of a lightweight motif ontology [16]. Within this ontology, Butterfly Mother is associated with origin, fertility, and ancestral continuity; Jiyu Bird (commonly rendered in Chinese as □□□ or □□□, and in English-language literature as Jiwei Bird or Magpie Bird, referring to the sacred bird that incubates Butterfly Mother's eggs in Miao creation narratives) with incubation, sacred mediation, and protective transition; dragon and ancestor-chain motifs with genealogical memory and cosmological extension; fish and fertility motifs with abundance and reproduction; and filigree layering with accumulated material labor, repairability, and ritual presence [17]. Semantic coherence thus depends not on motif selection alone but on whether the design preserves these relations in an intelligible and materially appropriate form [18]. The ontology is intentionally lightweight and task-oriented, and therefore simplifies some regional variation between southeastern Guizhou and other Miao branches rather than claiming to model the totality of Miao cosmology [19].

2.1 Mythic and Cultural Semantics of Miao Motifs

Public-facing heritage sources and scholarly translations consistently identify Butterfly Mother as a creation motif linked to a narrative chain in which eggs are laid and incubated by the Jiyu Bird, eventually giving rise to ancestral and cosmological beings[20]. This means that butterfly, bird, egg, ancestor, and dragon motifs should not be treated as interchangeable decorations[21]. They are sequentially and relationally organized elements within a cosmological system[22]. Such a reading helps explain why motifs associated with origin narratives carry exceptional weight under Symbolic Clarity and Narrative Capacity[23].The same evidence base indicates that Miao visual culture also encodes ancestor worship, reproductive symbolism, wishes for prosperity, and protective ritual functions[24]. Fish, bird, and pomegranate-related motifs often signal fertility and life continuity, while dragon and hybrid forms reveal long-term reinterpretation within local symbolic systems[25]. The framework therefore defines semantic coherence as the degree to which a design retains this relational density while remaining legible and usable in a new setting[26]. The core myth-to-motif semantic pathway that anchors the entire evaluation

framework is visualized in Fig. 1, which schematically illustrates the logical chain from Miao creation mythology to ornamental motif formation.

Figure 2 provides a schematic reference for the classic butterfly–bird–layered ornament logic in traditional Miao silver visual culture, systematically presenting the semantic correspondence between core motifs, their cultural connotations, and material craft logic.

2.2 Myth-to-Criterion Mapping

To respond to the concern that mythology remained interpretively rich but quantitatively underspecified, this revision adds an explicit myth-to-criterion mapping matrix[27]. The matrix does not claim to exhaust the full Miao cosmology; it functions as a transparent intermediate layer between ethnographic meaning and evaluative scoring[28]. “High”, “Medium”, and “Low” indicate the relative strength with which a motif cluster supports each criterion within the present design problem. The relative intensity of each mythic and material motif cluster across the five evaluative criteria is quantified in Table 1, which establishes a transparent intermediate layer between ethnographic semantic connotation and quantitative evaluation dimensions.

Table 1
Relative intensity of mythic and material motif clusters across the five evaluative criteria.

Myth / Motif Cluster	Symbolic Clarity	Narrative Capacity	Identification	Contextual Fitness	Craft & Maintainability
Butterfly Mother	High	High	Medium	Low	Medium
Jiyu Bird	Medium	High	Medium	Low	Low
Dragon / ancestor chain	Medium	High	High	Low	Low
Fish / fertility motifs	Low	Medium	Medium	High	Low
Filigree layering	Low	Low	Low	Low	High

The intensity of the myth-to-criterion mapping matrix is further presented as a color-blind-friendly heatmap in Fig. 3, which intuitively reflects the differential contribution of each motif cluster to the five evaluation criteria.

This matrix clarifies several analytic points[29]. Butterfly Mother scores highly on Symbolic Clarity because it is iconically stable and widely recognized as an origin motif, and highly on Narrative Capacity because it condenses the creation sequence into a single emblematic form. Jiyu Bird contributes strongly to Narrative Capacity but less strongly to Contextual Fitness in commercial minimalism because its semantic value depends on relational reading. Filigree layering contributes less to narrative

explicitness but very strongly to Craft & Maintainability because it indexes labor intensity, repairability, and the ethical continuity of maker responsibility[30].

2.3 Materiality, Craft, and Maintainability

Museum documentation on Miao silversmithing describes a technically demanding production chain involving transformation of silver ingots into rods, wires, and sheets; pressing and shaping; engraving; soldering; firing; acid washing; brushing; and final polishing. Such evidence confirms that craft is not an external manufacturing concern but part of the symbol system itself: the way a motif is made affects the way it means. The complete production workflow of Miao silver filigree craftsmanship, from raw silver ingots to finished layered filigree products, is fully demonstrated in Fig. 4, which verifies that craft technology is an inherent part of the Miao silver symbolic system rather than a separate manufacturing link. A particularly important addition in this revision is the interpretation of maker signatures and lifetime maintenance promises as ethical continuity. In some lineages, the maker inscribes a name that functions not only as an index of purity but also as a commitment to future repair. This transforms Craft & Maintainability from a purely technical criterion into a heritage ethic. Museum records on Miao silversmithing describe the hallmark as both a certification of silver quality and a continuing obligation of repair carried by the maker or the maker's lineage. A contemporary design that eliminates the repairable logic of layered silver units may remain visually attractive, yet it interrupts the moral relation between artifact, maker, and inheriting community. Figure 5 presents empirical evidence of the responsibility index in traditional Miao silverware, including the hand-chiselled maker's signature as a lifetime maintenance commitment and a typical case of modular filigree repair, intuitively illustrating the ethical continuity embedded in Miao silver craftsmanship.

3. Methodology and Dual-Evidence Design

The empirical design combines prescriptive expert evidence with descriptive user evidence. The expert panel comprised 25 participants, including scholars in anthropology, folklore, and design as well as local master silversmiths. Each expert provided pairwise comparisons for AHP weighting and evaluated design alternatives using a five-point benefit scale. User evidence was collected through a quota-sampled survey of 320 respondents stratified by key demographic variables including age group, gender, geographic region, and self-reported familiarity with Miao cultural heritage. Multi-item attitudinal subscales were assessed for internal consistency; Cronbach's α values for the principal subscales ranged from 0.78 to 0.86, indicating acceptable to good reliability (detailed reliability diagnostics are reported in Supplementary Table S1). This dual-evidence structure distinguishes normative heritage judgement from broader audience reception.

For AHP, individual reciprocal matrices were aggregated through the geometric mean to form a group matrix. Consistency was examined through λmax, CI, and CR, while inter-expert convergence in ranking logic was evaluated through Kendall's W. All five criteria were treated as benefit-type criteria in the TOPSIS stage. Rather than rebuilding a new hierarchy whenever usage context changed, the framework applied contextual reweighting, thereby preserving semantic comparability across design scenarios.

3.1 Transparent Replication Protocol

To improve reproducibility, this revision distinguishes between the original study evidence and the current transparency module. The expert-derived published weight structure remains the substantive basis of interpretation. The criterion-level brooch scores used below are a transparent reconstructed validation matrix created to replicate the published logic in standard TOPSIS form. They are not presented as substitutes for the archived raw expert sheets, which should be released separately as anonymized supplementary material or deposited in a public repository upon submission.

The reconstructed matrix preserved the reported criterion ordering and produced a stable group solution: $\lambda max = 5.0011$, CI = 0.000270, and CR = 0.000241. The resulting priority vector was approximately Symbolic Clarity 0.288, Contextual Fitness 0.229, Craft & Maintainability 0.188, Identification 0.158, and Narrative Capacity 0.137. The exact criterion weights derived from the AHP group decision-making and the criterion-level scores of the two brooch design alternatives are presented in Table 2, which forms the core data matrix for transparent and reproducible AHP–TOPSIS replication in this study.

Table 2
Reconstructed validation matrix used for transparent AHP–TOPSIS replication of the two brooch alternatives; exact weights are shown to three decimals for reproducibility, while the rounded values reported in the prose sum to 1.00.

Criterion	Exact Weight	Brooch A	Brooch B
Symbolic Clarity	0.288	4.3	3.6
Contextual Fitness	0.229	3.9	4.2
Craft & Maintainability	0.188	4.1	4.0
Identification	0.158	4.1	3.9
Narrative Capacity	0.137	4.4	3.5

TOPSIS was implemented under the standard benefit-criteria formulation using Euclidean vector normalization at the criterion level. After normalization and weight multiplication, positive and negative ideal solutions were computed criterion-wise. The closeness coefficient for each alternative was then obtained by dividing the distance to the negative ideal by the sum of distances to the positive and negative ideals. Monte Carlo robustness testing perturbed the baseline weight vector using Gaussian noise proportional to ten percent of each criterion weight, followed by renormalization to unit sum. This ten-percent setting was chosen as a moderate uncertainty envelope: it allows meaningful local variation in expert-derived priorities without overturning the published ordering too aggressively. Unlike Dirichlet resampling, which redraws an entirely new simplex of weights, the present Gaussian perturbation preserves the neighborhood of the observed expert consensus and is therefore better suited to sensitivity testing around an already interpreted group solution.

In procedural form, the replication logic was as follows: aggregate the AHP matrix by geometric mean; compute the normalized priority vector; normalize the alternative-score matrix; derive weighted scores and ideal solutions; compute TOPSIS distances and closeness coefficients; perturb the weight vector repeatedly; and record rank frequencies and confidence intervals. This pseudocode-level statement makes the computational path inspectable even before the full code archive is deposited.

4. Results

4.1 Brooch Comparison

Brooch A, defined as a Butterfly Mother composition with filigree-informed layering, outperforms Brooch B, defined as a more abstract dragon-crest form with smoother finishing. Under standard TOPSIS, Brooch A attains Ci = 0.777, whereas Brooch B attains Ci = 0.223. The difference is substantial rather than marginal. A radar comparison of the criterion performance profiles for Brooch A and Brooch B is shown in Fig. 6, which visually presents the differential advantages of the two design alternatives across the five core evaluation dimensions. Figure 7 shows the conceptual renderings of the two brooch design alternatives, intuitively contrasting the semantic density of Brooch A with layered repairable filigree logic and the contextual simplification of Brooch B with abstract smooth finishing. Brooch A benefits from higher Symbolic Clarity, Identification, and Narrative Capacity, while Brooch B performs relatively better only in Contextual Fitness. The result supports the paper’s central claim that abstraction can improve everyday adaptability but may do so by sacrificing mythic explicitness and semantic density. Figure 8 provides a high-fidelity concept rendering of Brooch A in an actual wearing scenario, which verifies that the design can simultaneously achieve high semantic density and good fit with contemporary usage contexts.

4.2 User Heterogeneity and Interpretive Reach

The user survey remains important because it demonstrates that semantic preference is not uniform across audiences. Respondents with stronger local familiarity are more likely to value dense narrative references and motif identification, while more external audiences place stronger emphasis on immediate symbolic legibility and contextual fit. Preliminary subgroup reading therefore indicates a consistent directional pattern: higher-familiarity respondents favored narrative density and stronger motif recognizability, whereas lower-familiarity respondents prioritized immediate clarity and adaptation to contemporary use. This distinction is methodologically important: the framework does not claim that one universal public exists, but rather makes visible how heritage significance and design reception intersect. Detailed subgroup means, effect sizes (Cohen's d for continuous measures, Cramér's V for categorical associations), and χ^2 association tests stratified by age group, gender, region, and familiarity level are reported in Supplementary Table S1. Of particular interest is the contrast between respondents from Guizhou province (the primary locus of Miao silver craft) and those from other regions, as this geographic comparison most directly tests whether proximity to living craft traditions shapes semantic preference; the corresponding χ^2 tests and effect-size estimates for this local-versus-external contrast

are highlighted in Supplementary Table S1 to enable readers to inspect how interpretive differences vary across locality and familiarity strata rather than relying on narrative summary alone.

4.3 Monte Carlo Robustness

Robustness analysis confirms that the ranking is exceptionally stable. Across 10,000 Monte Carlo iterations, Brooch A remains top ranked in 100.0% of simulations. The simulated mean closeness is 0.777 for Brooch A (95% CI [0.733, 0.819]) and 0.223 for Brooch B (95% CI [0.181, 0.267]). Additional sensitivity checks at 5%, 10%, and 15% proportional Gaussian perturbation all preserve the same rank order, with Brooch A remaining first in 100.0%, 100.0%, and 100.0% of runs respectively. To probe the collapse boundary requested by the reviewer, an extreme 25% proportional Gaussian perturbation was added as a stress test. Even under this enlarged uncertainty envelope, Brooch A remains first in 100.0% of 10,000 runs, with mean Ci = 0.777 (95% CI [0.662, 0.879]) versus 0.223 for Brooch B (95% CI [0.121, 0.338]). The wider intervals show variance inflation at the edge of plausible expert disagreement, but no rank reversal or systemic collapse is observed within this stress envelope. Accordingly, the present decision structure appears to fail gracefully through uncertainty broadening rather than abruptly losing semantic discrimination. The distribution of TOPSIS closeness coefficients for the two design alternatives across 10,000 Monte Carlo weight perturbation iterations is visualized in Fig. 9, which intuitively demonstrates the exceptional stability of the ranking result obtained by the proposed framework.

5. Comparison with Related AHP–TOPSIS Heritage Studies

Positioning the framework against adjacent AHP–TOPSIS heritage studies helps clarify its specific contribution. Existing work on handicraft intangible cultural heritage creative products has used narrative design, Kansei engineering, and TOPSIS to support theme selection. Exhibition-space studies have combined expert consultation with viewer responses to optimize display strategies. Conservation-oriented studies have used AHP–TOPSIS to compare heritage preservation pathways at the urban scale. These studies confirm the value of the method family, but most operate at the levels of topic selection, exhibition optimization, or governance strategy rather than motif-level semantic transfer. A systematic horizontal comparison between the proposed framework and representative AHP–TOPSIS heritage studies in recent years is detailed in Table 3, highlighting the unique contributions of this study in methodological design and research focus.

The present study differs in four ways. First, it introduces semiotic anchoring before quantification. Second, it combines expert and user evidence explicitly. Third, it uses contextual reweighting instead of rebuilding the hierarchy for every new scenario. Fourth, it adds Monte Carlo robustness and an AI-oriented semantic data logic. The result is a framework that is not only decision-analytic but also data-protocol oriented.

Table 3
Comparison between the present framework and related AHP–TOPSIS heritage studies.

Study	Object	Method	Decision Focus	Contrast with Present Study
This study	Miao silver ornament motifs	Kansei + AHP + TOPSIS + dual evidence + Monte Carlo	Semantic coherence in design translation	Motif ontology, dual evidence, contextual reweighting, and semantics-first AI protocol
Heliyon 2024	Handicraft ICH creative products	Narrative design + Kansei + TOPSIS	Narrative theme selection	Strong narrative modeling, but weaker semantic ontology and robustness auditing
Kang et al. 2025	Miao wax-printing design	Diffusion model + fuzzy TOPSIS	AI-assisted motif generation	Advances Miao-related AI design, but relies more on style-production optimization than explicit myth-relation ontology
Li weaving exhibition study	ICH exhibition space	Expert consultation + user survey + AHP + TOPSIS	Exhibition optimization	Less explicit myth-to-motif mapping and no semantics-first AI layer
Historic port conservation study	Built heritage conservation	AHP + TOPSIS	Conservation strategy comparison	Governance scale rather than motif-level transfer

Table 4
Visual summary of methodological differences between the present study and related heritage evaluation research.

Study	Object	Method	Decision focus	Relevance to this paper
This study	Miao silver ornaments	Kansei + AHP + TOPSIS + dual evidence	Semantic coherence in contemporary design	Adds contextual reweighting, auditable framework
Li et al. 2024	Huangmei cross-stitch creative products	Narrative text model + Kansei + factor analysis	Narrative theme selection	Strong on narrative theme construction
Yu & Xie 2025	Li ethnic weaving exhibition space	AHP + TOPSIS + expert consultation	Exhibition strategy optimization	Good dual-source evaluation, but less emphasis on semantic coherence
Akter et al. 2025	Historic port conservation	AHP + TOPSIS	Adaptive reuse/conservation strategy	Strong heritage governance frame, no focus on craft semantics

To further clarify the methodological positioning of this study, a supplementary visual summary of the core differences between the proposed framework and related heritage evaluation research is provided in Table 4, covering research objects, method combinations, and decision-making focus.

6. Discussion: Toward a Semantics-First AI Protocol

The broader significance of the framework lies in its ability to convert culturally dense heritage interpretation into structured, inspectable ground-truth. Recent AI work on Miao embroidery has already demonstrated that labeled datasets, motif prompts such as butterfly and dragon, LoRA fine-tuning, expert review, and artisan feedback can improve style fidelity and production feasibility. However, such systems still rely primarily on visual-semantic tags and production-oriented evaluation. The present study extends this logic by proposing that cultural AI should be conditioned not only on motif words but also on relational meaning.

In practical terms, the framework can inform three AI pathways. First, for diffusion-model conditioning, the criterion weights and motif ontology can be transformed into structured prompt templates or control vectors so that a model is guided not merely toward “Miao style” but toward relationships such as butterfly–bird–egg–ancestor continuity. Second, for reinforcement learning from human feedback or related reward-model pipelines, the five criteria and resulting Ci values can function as interpretable reward dimensions rather than opaque preference scores. Third, for retrieval-augmented prompting, the ontology can be used to retrieve culturally relevant narrative fragments, craft constraints, and motif co-occurrence rules before generation occurs. In each case, the aim is to move from style imitation to relation-aware generation. Concretely, the proposed semantic loss $L_{sem} = \Sigma_k w_k(1 - s_k(x))$ can be introduced as a weighted auxiliary term alongside the standard denoising objective during diffusion-model fine-tuning, while the reward function $R(x) = \Sigma_k w_k r_k(x)$ can serve as an auxiliary reward signal within RLHF pipelines, thereby penalizing semantically weak outputs without overriding the base model's generative capacity. Both formulations are designed to be additive and tunable, so that practitioners can adjust the relative influence of cultural-semantic constraints during training or inference. These mechanisms allow flexible integration while preserving the generative model's core capabilities and cultural pluralism.

At the same time, a semantics-first protocol must avoid a new form of rigidity. If an AI system is trained to optimize only the highest Ci profile, it may freeze a living tradition into one evaluative orthodoxy. Heritage is dynamic, internally diverse, and negotiated across regions, lineages, and historical moments. The purpose of the present framework is therefore not to impose a single authorized design solution, but to make the trade-offs visible and auditable. In AI terms, semantic coherence should operate as a constraint and dialogue mechanism, not as a machine for cultural standardization. This is especially important for craft ethics: outputs should be audited not only for motif resemblance but also for whether they preserve repairable layered construction, leave space for maker signatures, and remain compatible with lifetime maintenance promises as living cultural obligations rather than optional branding details.

7. Limitations and Future Work

Several limitations remain. First, the present motif ontology is intentionally lightweight. It is designed to support transparent evaluation, not to exhaust the full complexity of Miao cosmology. Second, although this revision substantially improves transparency, some numerical components in the validation module remain reconstructed for demonstration purposes until the underlying expert scoring sheets, pairwise matrices, and respondent-level survey files are publicly archived. Third, the visual materials introduced here are concept visuals and explanatory schematics rather than documentary photographs of field artifacts. Direct collaboration with Miao silversmiths remains an essential next step: future prototype development should be conducted in partnership with practicing artisans to ensure material authenticity, ethical craft continuity, and the preservation of maker-signed maintenance obligations as living cultural commitments.

Future work should therefore proceed on four fronts. One direction is archival: anonymized expert matrices, raw survey files, code, and figure-generation scripts should be deposited in a repository such as OSF, Zenodo, or Figshare. A second direction is empirical: physical prototype studies, eye-tracking, willingness-to-pay tests, and comparative user studies can examine how different publics actually perceive narrative density and craft legitimacy. These empirical extensions should explicitly test whether maker signatures, repair commitments, and lifetime maintenance promises are legible to users as cultural-ethical value markers rather than merely as luxury-service signals. A third direction is computational: computer vision and knowledge-graph methods could be used to detect and extend motif co-occurrence rules automatically, while generation systems could incorporate ontology-guided retrieval and constraint learning to maintain cultural flexibility without sacrificing semantic accountability. More explicitly, the AHP priority vector can be converted into trainable generative objectives by defining criterion-specific scoring heads or expert-labeled evaluators for Symbolic Clarity, Contextual Fitness, Craft & Maintainability, Identification, and Narrative Capacity, and then weighting them directly by the learned priorities. In a diffusion pipeline, this yields a semantic loss of the form $L_{sem} = \Sigma_k w_k(1 - s_k(x))$, where w_k is the AHP weight and $s_k(x)$ is the normalized criterion score predicted for a generated design x; this term can be combined with denoising loss so that semantically weak generations are penalized during training or fine-tuning. In a reward-model or RLHF-style pipeline, the same structure becomes $R(x) = \Sigma_k w_k r_k(x)$, where $r_k(x)$ is obtained from expert ratings, user preference models, or pairwise ranking networks, allowing TOPSIS-style closeness or criterion-wise rewards to guide sampling, reranking, or policy optimization. A fourth direction is participatory updating: the lightweight motif ontology should be iteratively refined through recurring expert review, artisan consultation, and community feedback so that the protocol remains responsive to living heritage rather than freezing one historical snapshot. The same strategy would also support cautious transfer to other minority and cross-cultural heritage domains, provided that criterion elicitation, motif mapping, and contextual validation are re-established locally rather than imported wholesale.

8. Conclusion

This study proposes a transparent and auditable AHP–TOPSIS framework for translating Miao silver ornament patterns into contemporary design while preserving semantic coherence. By combining semiotic anchoring, dual evidence, contextual reweighting, and Monte Carlo robustness testing, the framework shows that cultural motifs are not interchangeable decorations but structured carriers of cosmology, ritual meaning, material practice, and communal memory. The current revision further clarifies myth-to-criterion mapping, adds an extreme 25% perturbation stress test, strengthens craft ethics around maker signatures and lifetime maintenance promises, and specifies how the framework can support relation-aware AI generation through explicit weighted loss and reward pathways. Taken together, these additions substantially improve the paper's reproducibility, interpretive precision, and relevance to both heritage governance and culturally responsible AI design.

Declarations

Ethics statement: The expert panel study and user survey were conducted in accordance with institutional ethical guidelines and the principles of informed consent, anonymity, confidentiality, and voluntary participation. All expert panelists and survey respondents were adults and provided informed consent before participation. No vulnerable populations were involved. Expert identities and respondent-level survey records were anonymized before analysis and reporting. Participants were informed that they could withdraw at any time without consequence. The study protocol was reviewed and approved by the Ethics Review Committee of Zhongkai University of Agriculture and Engineering (Approval No. ZK202621102, approved on April 13, 2026). We confirm that all research was performed in accordance with the relevant guidelines and regulations, including the principles of voluntary participation, confidentiality, safety, and compensation.

Author Contributions: F.Y. provided core academic leadership—establishing the research framework, defining the path for interdisciplinary theoretical integration, and ensuring methodological rigor; J.L. and Y.Y. conceived the study and wrote the main manuscript text; W.Y. developed the methodology and co-wrote the original draft; W.Y. and H.W. implemented the software, curated the data and together with Y.Y. conducted validation; G.H. performed formal analysis; Y.Y. and F.Y. provided resources and secured funding; J.L. produced the visualizations; F.Y. refined the research framework and assisted with manuscript editing. All authors reviewed and approved the final manuscript.

References

1. ICOMOS The Nara document on authenticity[EB/OL]. 1994[2026-04-06]. Available: https://www.icomos.org/charters/nara-e.pdf
2. Minzu University of China Museum of Ethnic Cultures Miao intangible cultural heritage—silversmithing[EB/OL]. Google Arts & Culture[2026-04-06]. Available: https://artsandculture.google.com/story/miao-intangible-cultural-heritage-%E2%80%94%E2%80%94-silversmithing-nationalities-museum-central-university-for-nationalities-

%E4%B8%AD%E5%A4%AE%E6 %B0%9 1%E6%97%8F%E5%A4%A7%E5%AD%A6%E6 %B0%91%E6%97%8F%E5%8D%9A%E7%89% A9%E9%A6%86/4AUx3hToBca5LQ?hl=en

3. Li R, Chen L, Guo S, Wu Y, Ye D, Liu J (2026) Digitalization of She Silver: Integrating Traditional Silver Carving Craftsmanship with Modern Technology. Empowering Educational Innovation Through Design: Volume Two: Best Practices from University Students. Springer Nature Singapore, Singapore, pp 253–267
4. China Intangible Cultural Heritage Network · China Intangible Cultural Heritage Digital Museum, Wang Qinghe WX Body Memory and Practice: The Formation Mechanism of Cultural Genes of Miao Embroidery in the Middle and Upper Reaches of the Qingshui River [EB/OL]. [2026-04-06]. Available: https://www.ihchina.cn/Article/Index/detail?id=28021
5. Bender M (2006) Butterfly Mother: Miao (Hmong) creation epics from Guizhou, China[M]. Indianapolis: Hackett Publishing, Available: https://hackettpublishing.com/butterfly-mother
6. Nagamachi M (1995) Kansei engineering: a new ergonomic consumer-oriented technology for product development[J]. Int J Ind Ergon 15(1):3–11. 10.1016/0169-8141(94)00063-5
7. Saaty TL (2008) Decision making with the analytic hierarchy process[J]. Int J Serv Sci 1(1):83–98. 10.1504/IJSSCI.2008.017590
8. Hwang CL, Yoon K (1981) Multiple attribute decision making: methods and applications[M]. Berlin: Springer, Available: https://link.springer.com/book/10.1007/978-3-642-48318-9
9. Akter F, Wang S, Wang R et al (2025) Historic port conservation multi-criteria evaluation based on AHP-TOPSIS: cases from the UK, Spain and China[J]. Humanities and Social Sciences Communications, 12:1920. 10.1057/s41599-025-06071-5
10. Hou L, Li W, Yang M, Liu R, Liu W, Wang Y (2025) Sustainable design of museum bronze cultural-creative products through an integrated Kano-AHP-TOPSIS approach[J]. Discover Sustain 6:1212. 10.1007/s43621-025-02130-8
11. Kang X, You W, Xie H (2025) An innovative and sustainable design of intangible Miao wax printing patterns in combination of diffusion model and fuzzy TOPSIS[J]. Humanit Social Sci Commun 12:1365. 10.1057/s41599-025-05724-9
12. Jiang JB, Cai X, Yin HM (2025) Research on the local reconstruction of intangible cultural heritage in ethnic tourism villages: a case of Miao silver ornaments in Xijiang Miao Village[J]. SAGE Open 15(1). 10.1177/21582440251322573
13. Tibaut A, Guerra de Oliveira S (2022) A framework for the evaluation of the cultural heritage information ontology[J]. Appl Sci 12(2):795. 10.3390/app12020795
14. Li W, Xie Q, Ao J, Lin H, Ji S, Yang M, Sun J (2025) Systematic review: a scientometric analysis of the status, trends and challenges in the application of digital technology to cultural heritage conservation (2019–2024)[J]. npj Herit Sci 13:91. 10.1038/s40494-025-01636-8
15. Yu Q, Tao X, Wang J (2025) Sustainable design on intangible cultural heritage: Miao embroidery pattern generation and application based on diffusion models[J]. Sustainability 17(17):7657. 10.3390/su17177657

16. Gîrbacia F (2024) An analysis of research trends for using artificial intelligence in cultural heritage[J]. Electronics 13(18):3738. 10.3390/electronics13183738
17. Li M, Wang L, Li L (2024) Research on narrative design of handicraft intangible cultural heritage creative products based on AHP-TOPSIS method[J]. Heliyon 10(12):e33027. 10.1016/j.heliyon.2024.e33027
18. Huang Y, Pan Y (2021) Discovery and extraction of cultural traits in intangible cultural heritages based on Kansei engineering: taking Zhuang brocade weaving techniques as an example[J]. Appl Sci 11(23):11403. 10.3390/app112311403
19. Han D, Cong L (2023) Miao traditional patterns: the origins and design transformation[J]. Visual Stud 38(3–4):425–432. 10.1080/1472586X.2021.1940261
20. Desul S, Mahapatra RK, Patra RK, Sethy M, Pandey N (2025) Semantic technology for cultural heritage: a bibliometric-based review[J]. Global Knowl Memory Communication 74(5–6):1356–1380. 10.1108/GKMC-04-2023-0125
21. Paolanti M, Frontoni E, Pierdicca R (2026) Towards trustworthy AI in cultural heritage[J]. npj Herit Sci 14:131. 10.1038/s40494-026-02403-z
22. Skublewska-Paszkowska M, Milosz M, Powroznik P, Lukasik E (2022) 3D technologies for intangible cultural heritage preservation—literature review for selected databases[J]. Herit Sci 10:3. 10.1186/s40494-021-00633-x
23. Nikolakopoulou V, Koutsabasis P (2025) The making of participatory and co-design for digital experiences in cultural heritage: a review[J]. CoDesign 21(4):876–902. 10.1080/15710882.2025.2511791
24. Ren K, Lam JFI (2026) Knowledge graph-driven digital preservation of intangible cultural heritage: a cross-cultural comparative study of Chinese and Western implementation paradigms[J]. Humanit Social Sci Commun 13:147. 10.1057/s41599-025-06186-9
25. Sangamuang S, Ariya P, Intawong K, Khanchai S, Puritat K (2025) Integrating generative AI and the metaverse for cultural heritage: a case study on the preservation of Lamphun brocade fabric[J]. Humanities and Social Sciences Communications, 12:1974. 10.1057/s41599-025-06237-1
26. Fu Y, Shi K, Xi L (2025) Artificial intelligence and machine learning in the preservation and innovation of intangible cultural heritage: ethical considerations and design frameworks[J]. Digit Scholarsh Humanit 40(2):487–508. 10.1093/llc/fqaf034
27. Cheng H, Sun X, Xie J, Liu BJ, Xia L, Luo SJ, Tian X, Qiu X, Li W, Li Y (2024) Constructing and validating the museum product creativity measurement (MPCM): dimensions for creativity assessment of souvenir products in Chinese urban historical museums[J]. Humanit Social Sci Commun 11:280. 10.1057/s41599-024-02780-5
28. Hong C, Liu Y, Yu Q, Yang C (2026) A Kansei-inspired product design approach for the Liao Dynasty Pagoda: bridging cultural heritage and physiological signals[J]. J Eng Des 37(1):94–123. 10.1080/09544828.2025.2474376

29. Hu W, Li M, Chi X, Wang X, Khan AU (2024) Intangible cultural heritage research in China from the perspective of intellectual property rights based on bibliometrics and knowledge mapping[J]. Humanit Social Sci Commun 11:825. 10.1057/s41599-024-03314-9
30. Wang M, Lau N (2023) NFT digital twins: a digitalization strategy to preserve and sustain Miao silver craftsmanship in the metaverse era[J]. Heritage 6(2):1921–1941. 10.3390/heritage6020103

Figures

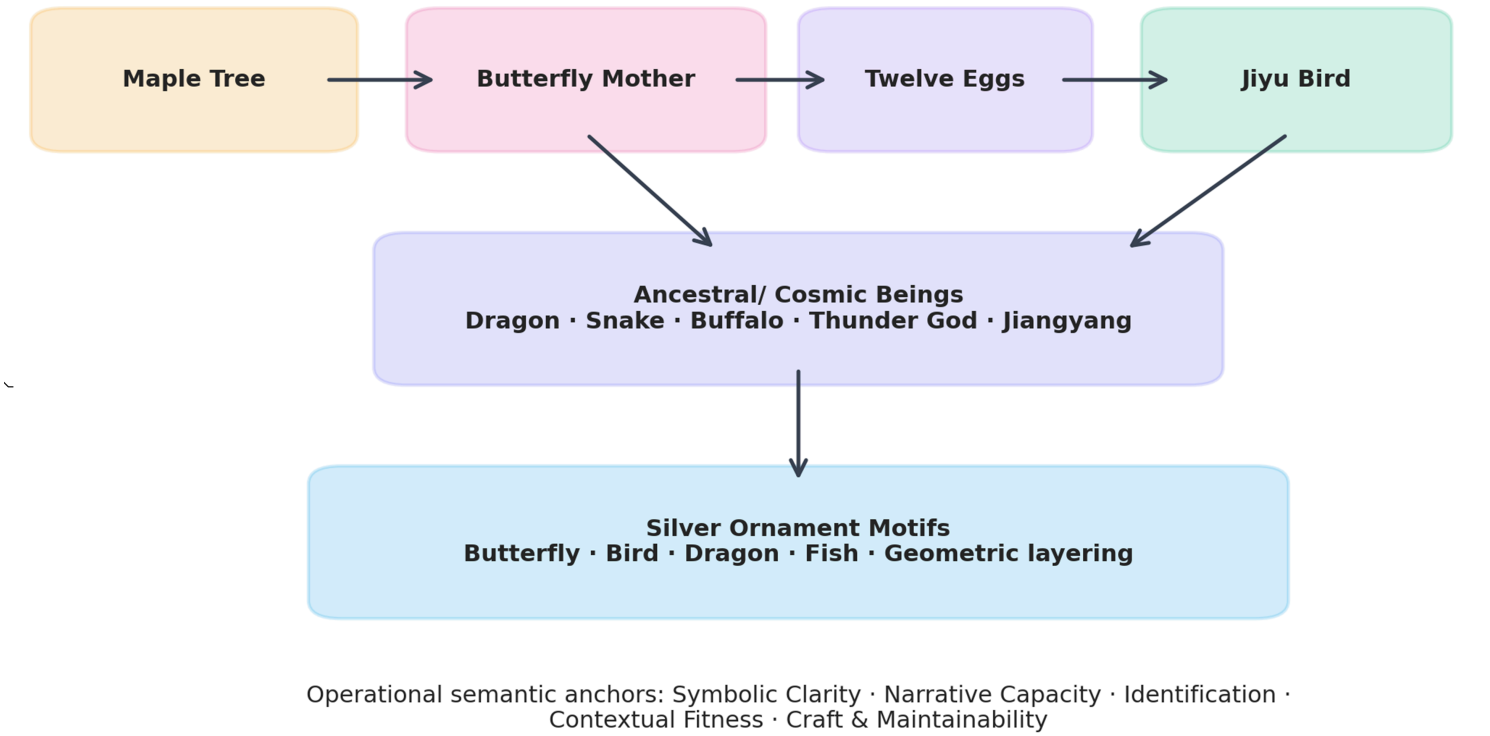


Figure 1

Myth-to-motif semantic pathway used to anchor the evaluation framework (conceptual schematic, not a field artifact).

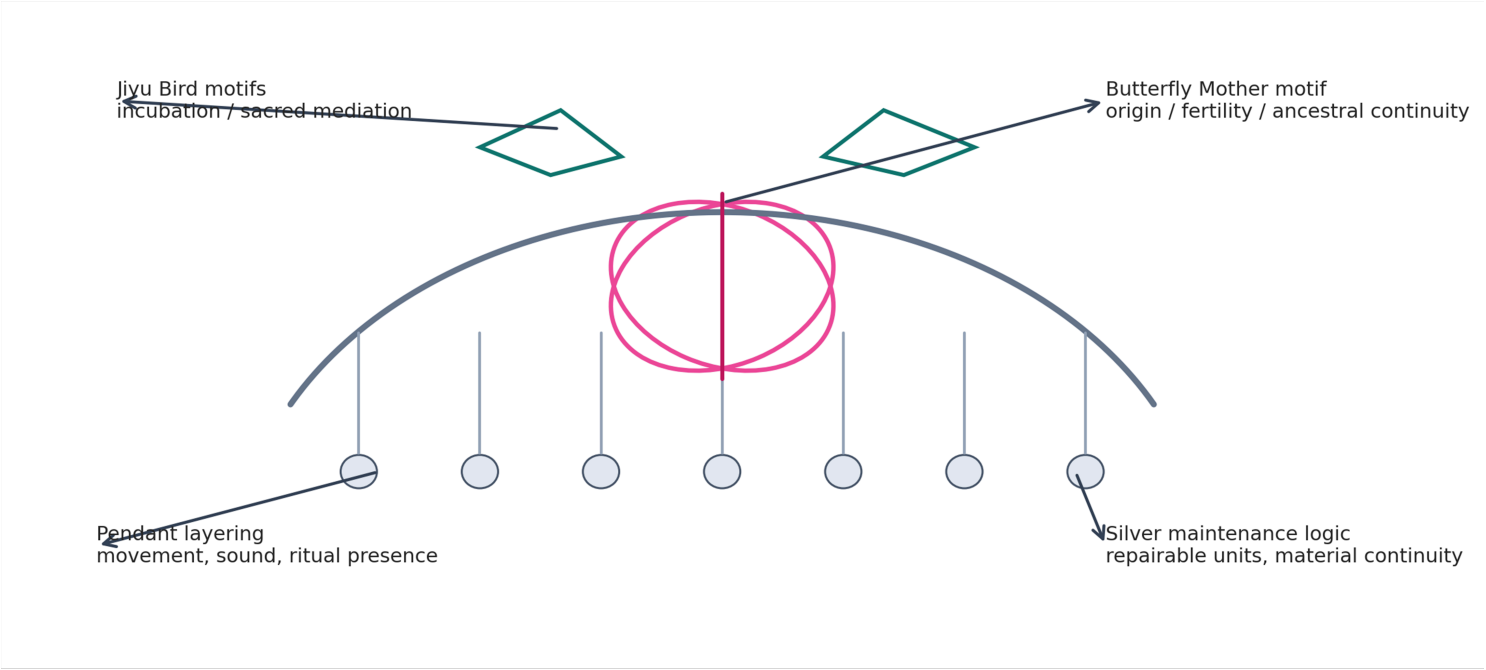


Figure 2

Schematic reference for the butterfly–bird–layered ornament logic in traditional Miao silver visual culture (conceptual schematic, not a documentary photograph of field artifacts).

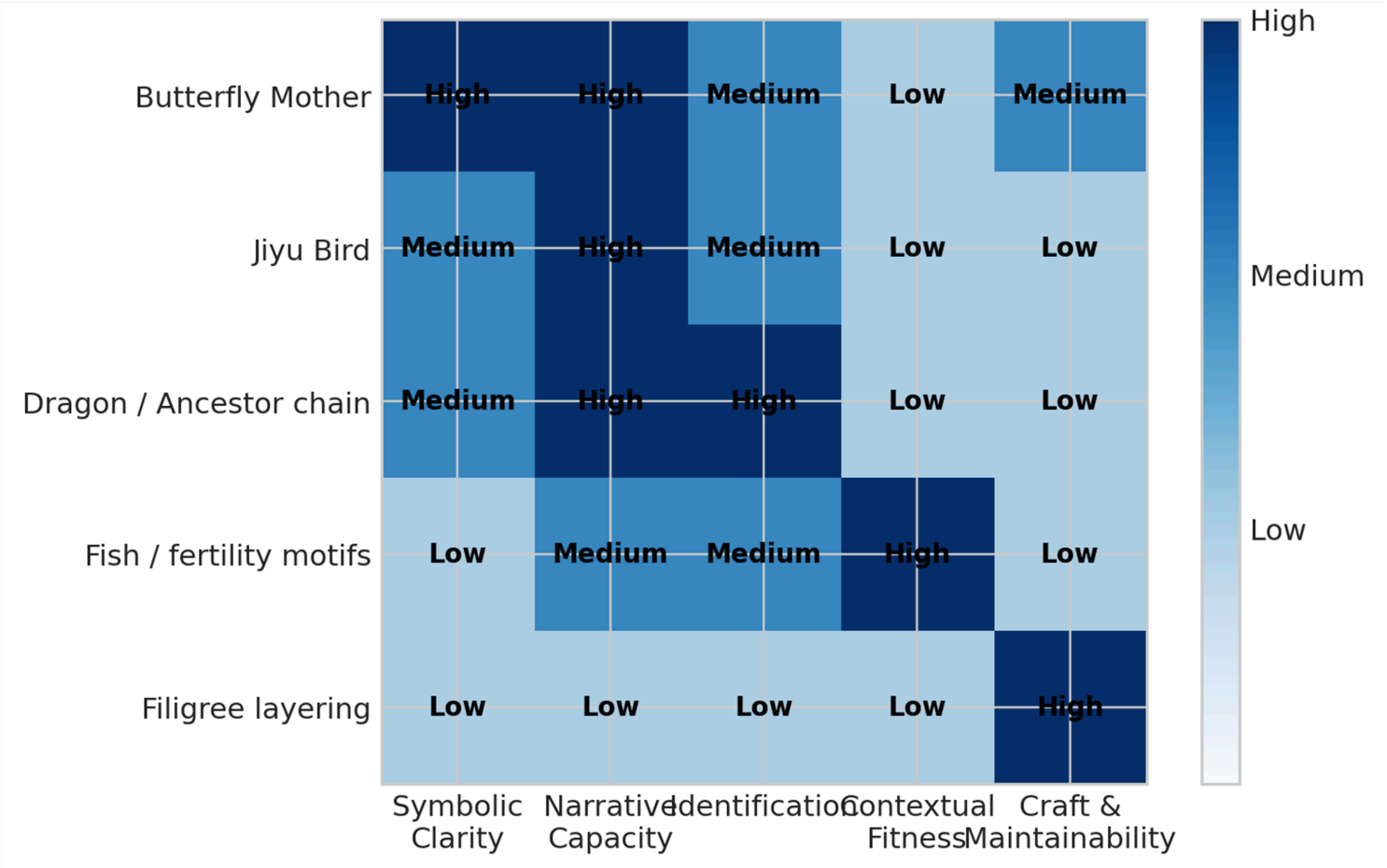


Figure 3

Heatmap representation of the myth-to-criterion mapping intensity matrix, prepared with a color-blind-friendly contrast scheme for publication use. All color contrasts meet WCAG 2.1 AA guidelines for accessibility. This figure is a conceptual visualization derived from the authors' analytical framework and should be submitted at a minimum resolution of 300 dpi for print reproduction.



Figure 4

Miao Silver Filigree Craftsmanship Process:From Raw Material to Layered Filigree



Figure 5

Empirical Evidence of the Responsibility Index'in Miao Silverware:(a)The hand-chiselled signature of a traditionalsilversmith family,serving as a contract symbol for purity certification and life-long maintenance obligations;(b)A typical case ofmodular repair,demonstrating the technological disassembly and ethical continuity of the lavered filigree structure.

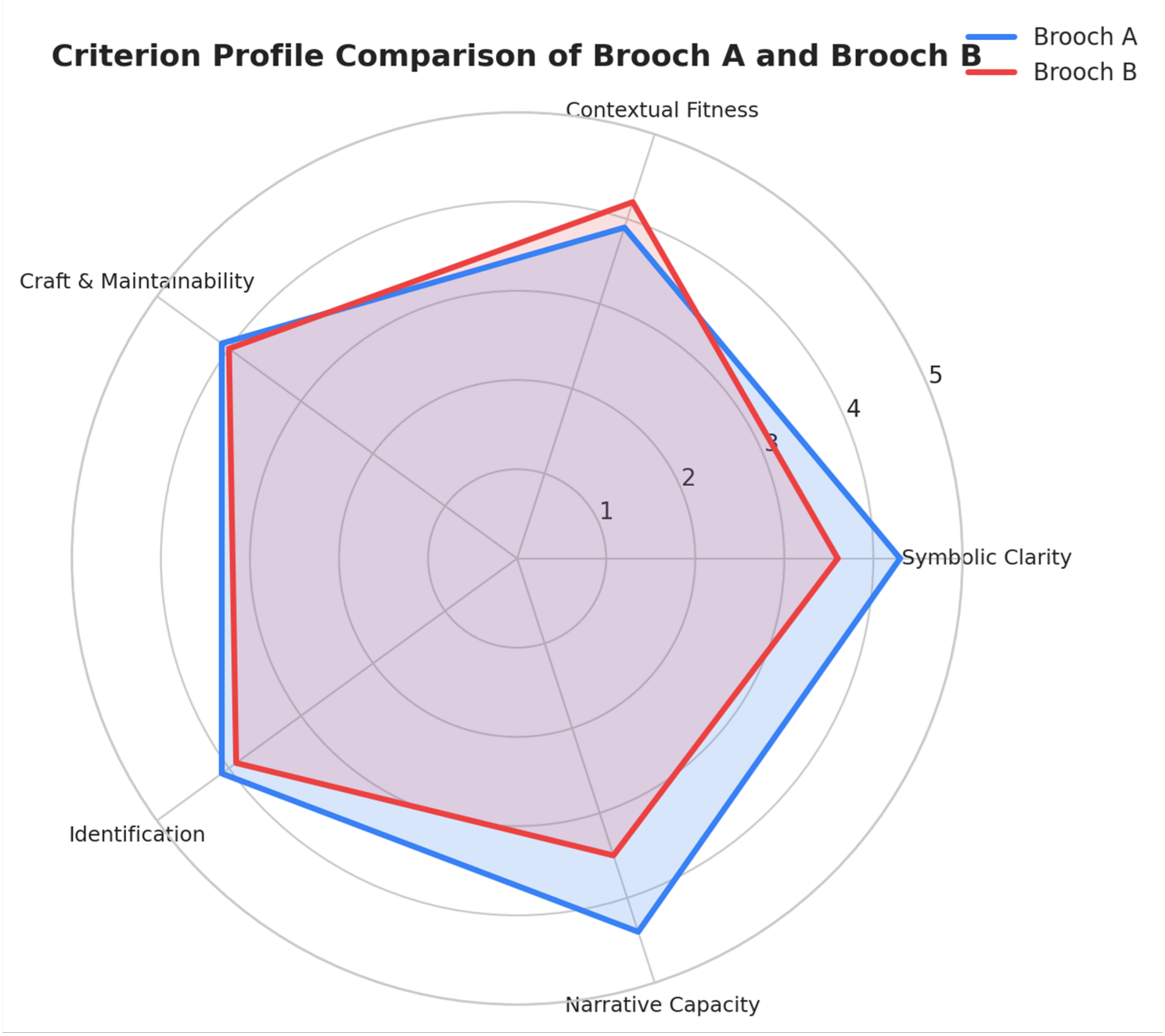


Figure 6

Radar comparison of criterion profiles for Brooch A and Brooch B, prepared with a color-blind-friendly contrast scheme for publication use. Distinct line styles (solid vs. dashed) supplement color coding to ensure legibility under monochrome printing and for readers with color-vision deficiencies; the figure should be submitted at a minimum resolution of 300 dpi.



Figure 7

Conceptual renderings illustrating semantic density (Brooch A: filigree-informed Butterfly Mother with layered texture, explicitly supporting Craft & Maintainability through layered repairable logic) versus contextual simplification (Brooch B: abstract dragon crest with smooth finish). Note: These images are conceptual renderings (not field artifacts or documentary photographs) produced for evaluative illustration only and comply with journal image-integrity requirements; final prototypes would require direct collaboration with Miao silversmiths to ensure material authenticity and ethical craft continuity.



Figure 8

A high-fidelity concept rendering of Brooch A in a wearing situation, demonstrating the combination of semantic density and contemporary contextual fit.

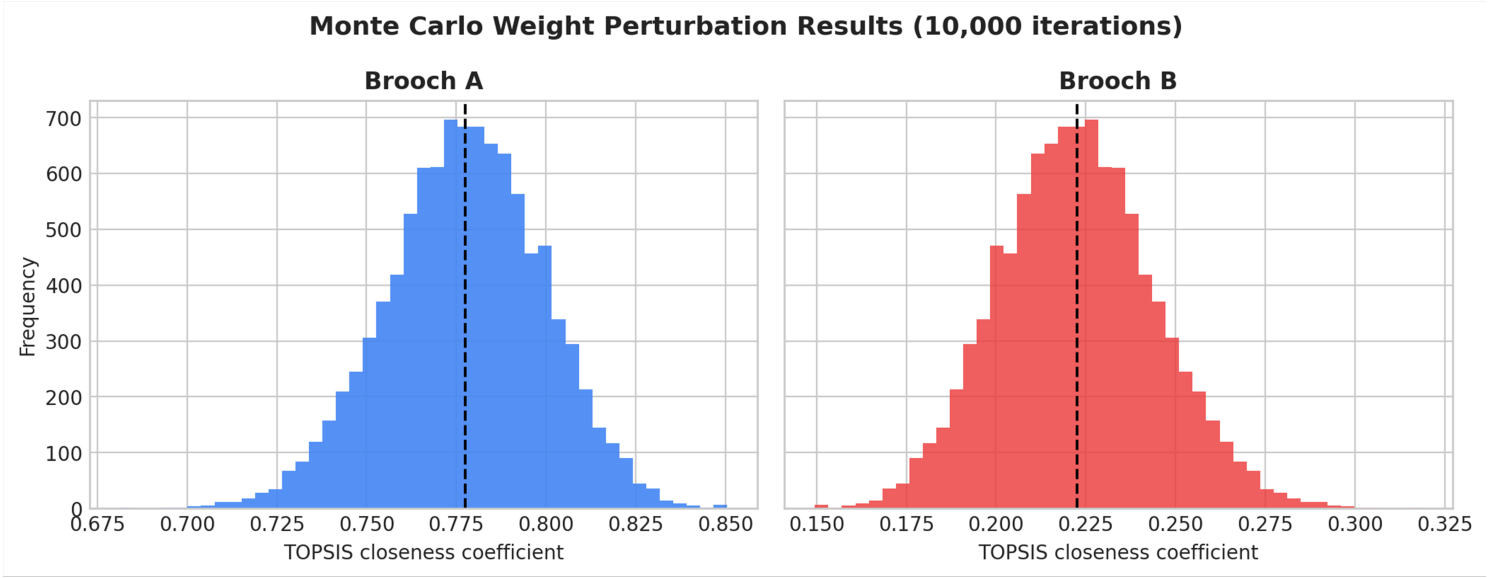


Figure 9

Monte Carlo distributions of TOPSIS closeness coefficients under perturbed weight vectors.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryDataAHPTOPSISMiaoSilver.xlsx