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FROM TWO-DIMENSIONAL CALLIGRAPHY TO THREE-DIMENSIONAL ARTIFACTS: THE TRANSLATIONAL MECHANISM OF TRADITIONAL BRUSH FORMS IN CONTEMPORARY FUNCTIONAL ART

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ABSTRACT

The integration of traditional calligraphy into contemporary functional design frequently relies on visual imitation, limiting structural continuity and methodological clarity. To address this limitation, this study proposes and validates a systematic translational mechanism for transforming two-dimensional brush-based compositions into three-dimensional functional artifacts. Using Xu Beihong's calligraphic identity as a case study, the research develops a sequential framework consisting of morphological extraction, proportional abstraction, spatial reconstruction, and functional embedding. Within this framework, calligraphy is interpreted as a generative structural system characterized by stroke force, axial alignment, rhythmic sequencing, and void-solid relationships rather than as a symbolic graphic form. Five functional artifacts were designed and fabricated to operationalize the framework. Expert evaluation, including Index of Item-Objective Congruence (IOC) assessment, verified structural alignment between extracted compositional principles and spatial outcomes. A survey of 360 participants further demonstrated a positive association between structural recognition and aesthetic evaluation. The findings indicate that structural equivalence enables coherent cross-dimensional translation and establish a replicable methodological pathway for integrating planar artistic systems into volumetric functional design.

KEYWORDS: Calligraphic Translation; Morphological Analysis; Cross-Dimensional Transformation; Functional Art Design; Spatial Reconstruction; Structural Equivalence.

1. INTRODUCTION

Traditional Chinese calligraphy has long been regarded as a two-dimensional art form grounded in brushwork, rhythm, and structural balance. Its aesthetic system is constructed through line, stroke variation, spatial tension, and embodied gesture (Cao & Champadaeng, 2024). In recent decades, however, the expansion of design practice and contemporary craft has prompted renewed interest in translating traditional artistic languages into material and functional contexts (Li et al., 2025). This shift raises an important methodological question: how can the visual and structural essence of calligraphy be transformed into three-dimensional functional artifacts without reducing it to superficial decoration?

Existing studies on calligraphy largely focus on historical development, stylistic evolution, or cultural symbolism (Garima, 2024; Lyu, 2024). While some research explores the application of calligraphic elements in graphic design and visual communication (Li & Mayusoh, 2024), limited attention has been given to the morphological translation of calligraphic brush forms into spatial and functional objects. In particular, the mechanism by which two-dimensional brush structures are reconstructed into three-dimensional forms remains insufficiently theorized within contemporary functional art discourse.

This study aims to construct a translational mechanism that systematically converts traditional brush forms into three-dimensional functional artifacts. Rather than treating calligraphy as a symbolic motif, the research approaches it as a structural system composed of stroke dynamics, proportional relationships, and spatial configurations. Through morphological analysis, form abstraction, spatial reconstruction, and prototype experimentation, the study develops a design framework that bridges calligraphic aesthetics and functional object creation.

By articulating a mechanism-based model of form translation, this research contributes to contemporary discussions in functional art and design methodology in three ways. First, it redefines calligraphy as a generative structural language rather than a purely pictorial medium. Second, it proposes a replicable framework for translating two-dimensional artistic forms into three-dimensional artifacts. Third, it demonstrates how traditional brush aesthetics can be recontextualized within contemporary functional practice while preserving cultural depth and formal integrity.

Within this broader framework, the present study

focuses on the calligraphic identity of Xu Beihong as a case study through which the proposed translational mechanism is examined and implemented. Accordingly, the research pursues the following objectives:

RO1: To study and analyze Xu Beihong's calligraphic identity.

RO2: To create functional art inspired by Xu Beihong's calligraphic identity.

RO3: To evaluate how effectively the proposed translational mechanism supports the transformation of Xu Beihong-inspired brush forms into three-dimensional functional artifacts.

2. LITERATURE REVIEW

The integration of traditional cultural forms into contemporary design has become an important concern in recent decades, particularly within fields seeking to balance cultural continuity and modern functionality. Chinese calligraphy, as one of the most structurally sophisticated visual traditions, has attracted sustained scholarly attention. Research has extensively explored its stylistic evolution, expressive brush techniques, compositional rhythm, and aesthetic philosophy (Ma et al., 2025; Yu & Ghazali, 2023). Line quality, stroke variation, spatial balance, and the interplay between solidity and void have been widely recognized as defining features of calligraphic art (Song et al., 2025; Wang, 2025). Through such studies, calligraphy has been established as a complex visual system governed by proportional control, directional movement, and structural equilibrium.

Despite these substantial contributions, most investigations remain confined to the interpretation of calligraphy as a two-dimensional artistic medium (Li, 2021; Lin et al., 2025). Even when structural elements are analyzed, they are generally discussed within the boundaries of pictorial composition rather than as transferable principles capable of informing spatial construction. The internal logic of brushwork—its dynamic modulation of pressure, tempo, and directional flow—is rarely examined as a generative framework for three-dimensional form development. As a result, the morphological potential of calligraphy beyond the plane remains underexplored.

With the expansion of interdisciplinary design practices, calligraphy has increasingly entered contemporary design discourse. Designers frequently extract calligraphic strokes, character outlines, or symbolic meanings to enhance cultural identity in graphic design, branding, and product design (Wei & Zain, 2025). In cultural and creative

industries, calligraphic elements are often used to evoke tradition and authenticity. However, such applications commonly emphasize visual resemblance or symbolic association rather than structural reinterpretation (Zhao, 2024). Characters may be directly stylized, simplified, or applied as decorative motifs on product surfaces. While these strategies effectively reference cultural heritage, they do not necessarily engage with the intrinsic structural dynamics of brush-based form.

When calligraphy is translated into three-dimensional objects, the process often relies on direct contour extrusion or literal volumetric replication. In such cases, the planar silhouette of a character is extended into space, producing objects that resemble the original script in outline but lack the dynamic qualities that define brushwork (Lin et al., 2025). The rhythmic modulation of line thickness, the tension between compression and expansion, and the spatial distribution of void are frequently flattened into static geometric volumes. Consequently, the transformation from two-dimensional calligraphic form to three-dimensional artifact risks becoming a superficial formal exercise rather than a meaningful structural reconstruction.

The broader field of design methodology offers analytical tools that could potentially address this issue. Morphological analysis, form abstraction, structural simplification, and spatial reconstruction are established processes in product design and functional art development (Dalpadulo et al., 2025). These methods enable designers to deconstruct complex visual forms into fundamental components and reorganize them into new spatial configurations. Through abstraction and reconstruction, two-dimensional graphics can be reinterpreted as volumetric objects while maintaining underlying structural relationships. However, the application of such methods to calligraphy-inspired design remains inconsistent and insufficiently systematized.

A central challenge lies in articulating a clear mechanism that connects brush-based structural principles with three-dimensional spatial logic. Calligraphic form is not merely defined by external contour but by the interaction of stroke direction, proportional modulation, rhythm, and void–solid balance (Yuan et al., 2025). Without a framework that translates these internal principles into spatial parameters, the design process risks privileging appearance over structure. This gap indicates the need for a methodological approach that begins with structural analysis of calligraphic identity and proceeds through abstraction, spatial reconfiguration, and functional integration.

Although previous studies have contributed valuable insights into calligraphic aesthetics and its contemporary applications (Shi, 2023; Xu & Shen, 2023), a systematic translational mechanism linking two-dimensional brush structures with three-dimensional functional artifacts remains underdeveloped. Addressing this gap requires moving beyond decorative adaptation toward structural reinterpretation. By establishing a process that extracts morphological principles from calligraphy and reconstructs them within spatial and functional contexts, design practice can more effectively integrate traditional brush aesthetics into contemporary functional art.

The present study responds to this methodological need by proposing a translational framework grounded in structural analysis, form abstraction, and spatial reconstruction. Using Xu Beihong's calligraphic identity as a case study, the research demonstrates how brush-based structural characteristics can be systematically transformed into three-dimensional functional artifacts. In doing so, it seeks to contribute a replicable design mechanism capable of bridging planar calligraphic structure and volumetric functional form.

3. METHOD

The present study develops a structured translational framework that systematically converts two-dimensional calligraphic structures into three-dimensional functional artifacts. Rather than approaching the transformation process as a stylistic adaptation, the methodology treats calligraphy as a generative structural system whose internal logic can be reconstructed within spatial and material contexts. The framework is conceived as a sequence of interrelated analytical and reconstructive operations, ensuring both conceptual rigor and procedural clarity. The overall organization of the proposed framework is summarized in Table 1. Table 1 presents the four-stage translational framework, specifying the analytical inputs, core methodological operations, and resulting outputs that structure the transformation from planar calligraphy to volumetric functional artifacts.

Table 1 The Translational Framework from Calligraphic Structure to Functional Artifact

Stage	Analytical Input	Core Operation	Methodological Output
Stage I	Xu Beihong's selected calligraphic characters	Structural and morphological analysis	Identified structural principles

Stage II	Extracted structural principles	Morphological abstraction and parameter conversion	Form-generating parameters
Stage III	Abstracted planar parameters	Spatial reconstruction and volumetric modeling	Three-dimensional structural systems
Stage IV	Spatial systems	Functional integration and prototyping	Functional art artifacts

3.1 Stage I: Structural Analysis of Calligraphic Identity

The first stage establishes the analytical foundation of the framework. Xu Beihong’s calligraphic works are examined as structural systems composed of interdependent elements rather than as textual or decorative forms. This analytical repositioning is essential because it shifts the focus from iconographic meaning to formal logic. The analysis investigates multiple structural dimensions simultaneously. Stroke directionality is examined to identify dominant compositional axes and movement trajectories. Variations in thickness are studied as indicators of pressure modulation and visual weight distribution. Angular transitions and curvature patterns are observed to determine how rigidity and fluidity coexist within the script. Additionally, the distribution of void and solid areas is evaluated to understand compositional breathing space and spatial rhythm.

This stage converts aesthetic perception into structured analytical categories. By doing so, it creates a transferable knowledge base that can inform later design decisions. The analytical output is not a reproduction of the characters themselves but a distilled set of morphological principles that define Xu Beihong’s calligraphic identity. Table 2 presents the principal structural characteristics identified during the analytical phase and indicates their relevance to spatial design translation.

Table 2 Extracted Structural Characteristics of Xu Beihong’s Calligraphic Identity

Structural Dimension	Morphological Description	Implication for Spatial Translation
Stroke Directionality	Dominant axial movement with controlled curvature	Establishment of structural alignment axes
Thickness Modulation	Gradual variation between compression and extension	Hierarchical proportion control
Angular Transitions	Dynamic interaction between rigid and fluid segments	Definition of articulation nodes
Void-Solid Distribution	Balanced spatial intervals within composition	Regulation of volumetric openness
Internal Equilibrium	Dynamic but stable compositional balance	Basis for three-dimensional stability

The outcome of Stage I is a structured morphological profile that serves as the conceptual backbone of the translational process.

3.2 Stage II: Morphological Abstraction

Building upon the analytical findings, Stage II translates identified structural principles into abstract design parameters. This phase is crucial because direct reproduction of calligraphic forms would result in literal mimicry rather than structural reinterpretation. Abstraction ensures that the transformation process preserves internal logic while freeing the design from textual dependency. Stroke trajectories are simplified into directional vectors that represent primary compositional forces. Thickness modulation is converted into scalable proportional modules. Intersection points are interpreted as structural nodes capable of supporting volumetric articulation. Meanwhile, void-solid relationships are translated into adjustable spatial intervals that regulate density and openness.

The abstraction process therefore functions as a conceptual filter. It reduces complex calligraphic configurations into a manageable system of form-generating parameters without eliminating dynamic relationships. The result is a generative morphological matrix capable of guiding spatial reconstruction. Table 3 demonstrates how specific calligraphic features are converted into abstract parameters and clarifies the logic underlying each transformation.

Table 3 Morphological Abstraction from Calligraphic Structure

Calligraphic Feature	Abstracted Parameter	Conversion Principle
Directional stroke flow	Primary structural vector	Simplification of movement trajectory
Pressure-based thickness variation	Proportional module ratio	Transformation of visual weight into scale hierarchy
Stroke intersections	Structural articulation node	Interpretation as spatial joint
Compositional void	Spatial interval regulator	Control of mass-to-void relationship

3.3 Stage III: Spatial Reconstruction

Stage III performs the dimensional transformation from planar abstraction to volumetric form. Rather than extruding character outlines, the framework reconstructs spatial systems by reinterpreting abstract parameters as structural components within three-dimensional space. Directional vectors become spatial alignment axes that organize mass distribution. Proportional modules inform

volumetric scaling and hierarchy. Structural nodes evolve into load-bearing articulation points. Spatial interval regulators guide the carving of cavities and openings that preserve dynamic balance.

This process requires iterative spatial testing to ensure that reconstructed forms maintain equilibrium and structural coherence. The transformation from planar composition to volumetric organization is therefore not linear but dialectical: each spatial decision is evaluated against the original structural principles extracted in Stage I. Table 4 summarizes the relationship between planar abstraction and volumetric reconstruction strategies.

Table 4 Spatial Reconstruction Parameters

Planar Parameter	Spatial Implementation Strategy	Three-Dimensional Outcome
Structural vector	Axis-based spatial alignment	Formal coherence
Proportional module	Hierarchical volume scaling	Visual balance
Articulation node	Load-distribution joint	Structural stability
Spatial interval	Controlled void carving	Dynamic openness

The output of Stage III is a set of stable three-dimensional structural systems that embody calligraphic logic without literal imitation.

3.4 Stage IV: Functional Integration and Prototyping

The final stage integrates functional requirements into reconstructed spatial systems. As the research operates within the domain of contemporary functional art, the artifacts must balance aesthetic integrity and practical usability. Functional considerations—including stability, ergonomic interaction, structural durability, and material feasibility—are incorporated as constraints within the spatial system rather than imposed externally. Adjustments are made to ensure that functional adaptation does not undermine structural coherence derived from calligraphic principles.

Physical prototyping plays a crucial evaluative role. It allows the verification of balance, load distribution, and usability while preserving formal continuity. The integration process thus ensures that the final artifact embodies both calligraphic identity and functional viability. Table 5 outlines the functional integration criteria applied during the prototyping stage.

Table 5 Functional Integration Criteria

Spatial Configuration	Functional Requirement	Adaptation Strategy
Base structure	Stability	Reinforced support geometry

Vertical articulation	Load distribution	Controlled thickening
Open spatial elements	Ergonomic interaction	Proportional adjustment
Material system	Durability and manufacturability	Material refinement

Through these four interconnected stages, the translational framework transforms calligraphic identity into a structured design methodology. By formalizing the analytical and reconstructive operations, the study converts intuitive artistic inspiration into a systematic and replicable mechanism applicable to contemporary functional art practice.

4. CASE IMPLEMENTATION

To demonstrate how the proposed translational mechanism operates in practice, this section presents an in-depth implementation analysis based on selected functional artifacts developed in this study. Rather than treating the works as isolated design outputs, the focus here is to illustrate how the analytical framework outlined in the methodology—morphological extraction, abstraction, spatial reconstruction, and functional integration—was systematically applied.

Two representative cases are discussed in detail: the “De” (德) Incense Holder and the “Ma” (馬) Pen Holder. These two characters were selected because they embody structurally distinct calligraphic conditions: one emphasizes axial stability and compositional balance, while the other expresses dynamic expansion and rhythmic repetition. Through these cases, the practical operability of the translational mechanism is validated.

4.1 Case I: “De” (德) - Structural Stability and Vertical Translation

4.1.1 Calligraphic Structural Characteristics

In Xu Beihong’s rendering of the character “De” (德), the composition exhibits a clearly defined vertical axis supported by balanced left-right structural distribution. The upper components demonstrate compact spatial density, while the lower radical forms a stabilized closure. Stroke modulation alternates between thick and thin, creating internal tension while maintaining compositional equilibrium.

Three transferable structural principles were identified:

Axial dominance - A central vertical force anchors the structure.

Proportional layering - Upper and lower

components create hierarchical balance.

Void–solid contrast – Internal negative spaces generate visual breathing room.

These characteristics provided the morphological foundation for spatial reinterpretation.

4.1.2 Morphological Abstraction

The abstraction phase did not rely on direct contour extrusion or literal replication of the calligraphic outline. Instead, the character “De” was systematically decomposed to reveal its internal structural logic and compositional hierarchy. The purpose of this stage was to reinterpret the character as a system of spatial forces rather than as a graphic symbol. This required shifting the analytical focus from visual resemblance to structural equivalence.

The process began with structural decomposition. The character was segmented into primary, secondary, and connective stroke groups according to visual weight distribution and directional force. The dominant vertical stroke was identified as the principal axis of stability, functioning as the structural spine of the character. Rather than being treated as a graphic line, it was interpreted as a vector of force capable of becoming a vertical load-bearing element in three-dimensional space. Horizontal strokes were examined in relation to their stabilizing or extending roles within the composition. The lower radical, characterized by closure and grounding, was analyzed as a unit contributing to compositional balance and base equilibrium. This analytical shift – from reading strokes as calligraphic gestures to understanding them as structural components – laid the foundation for volumetric translation.

Following decomposition, proportional simplification was undertaken. Xu Beihong’s brushwork includes subtle variations in ink density, stroke tapering, and expressive modulation. While these nuances contribute to the aesthetic richness of the calligraphy, they are not directly transferable into volumetric design. Therefore, ornamental brush details were selectively removed while preserving relational proportions between components. Tapered stroke endings were clarified into stable geometric terminations, and complex overlapping intersections were simplified to avoid structural ambiguity. Care was taken to maintain the proportional relationship between the upper and lower sections of the character. The vertical-to-horizontal ratio and internal spacing were measured and retained to ensure that compositional balance would survive spatial transformation. The objective at this stage was not to maintain literal resemblance, but to preserve hierarchical relationships between elements.

The final step of abstraction involved spatial hierarchy reconfiguration. The dense upper portion of the character, originally expressed through clustered strokes, was interpreted as a zone of concentrated mass. This density was translated into a compact volumetric block capable of providing structural weight and visual anchoring. In contrast, the lower radical was reinterpreted as a supportive base system. Its planar spread was subtly expanded to enhance stability while maintaining proportional integrity. Negative spaces between strokes were also evaluated. Rather than eliminating these voids, selected internal gaps were preserved and translated into carved spatial cavities, allowing light penetration and maintaining rhythmic balance. In this way, the interplay between solidity and void in the original calligraphy was reconstructed as a relationship between mass and space.

Through this layered abstraction process, the character gradually shifted from a linguistic sign to a spatial schema. Lines were reconceived as planes, planes were transformed into volumes, and voids were reinterpreted as functional spatial intervals. The abstraction did not aim to preserve immediate recognizability of the character, but to retain its structural logic. Axial dominance was transformed into vertical stability, proportional layering became mass distribution, and void–solid contrast evolved into volumetric rhythm. By the end of this phase, the calligraphic form had been reconstituted as a coherent three-dimensional structural framework, ready for digital modeling and functional integration.

4.1.3 Spatial Reconstruction

Following morphological abstraction, the project entered the stage of spatial reconstruction, in which the clarified structural schema was translated into a three-dimensional configuration. At this stage, the task was no longer analytical but constructive: the planar relationships extracted from the calligraphic form had to be reorganized into a stable volumetric system capable of accommodating functional requirements.

The first operation involved establishing a vertical load-bearing structure derived from the dominant axial stroke. In the original calligraphy, this vertical element functions as the visual anchor of the composition, stabilizing surrounding strokes. In spatial reconstruction, it was transformed into the primary supporting column of the incense holder. Its thickness was adjusted to ensure structural integrity while maintaining proportional consistency with the abstracted schema. This vertical element became the

core around which other volumetric components were organized. Secondary horizontal strokes were reinterpreted as transitional planes and supporting surfaces. In two-dimensional calligraphy, these strokes create rhythm and directional extension. In three-dimensional translation, they were expanded into shallow planar volumes capable of bearing light functional load. Their orientation and relative elevation were carefully adjusted during digital modeling to preserve compositional balance while avoiding structural weakness. Rather than functioning as decorative appendages, these planes contributed to the overall structural coherence of the object. Internal void relationships also underwent reinterpretation. The negative spaces that originally served as breathing intervals between strokes were preserved and translated into carved spatial cavities. These cavities were not arbitrary decorative cut-outs; instead, they were strategically positioned to maintain visual rhythm while reducing unnecessary material mass. The carved voids reinforced the contrast between solidity and emptiness that characterizes Xu Beihong's calligraphic composition, allowing the volumetric object to retain spatial tension similar to the planar original. Functional integration was embedded within this reconstructed structure rather than added externally. The incense channel was positioned along the established vertical axis to ensure that function followed compositional logic. By aligning the incense pathway with the structural spine, the design maintained internal coherence between symbolic origin and practical application. During digital modeling and rendering, structural simulations revealed slight imbalance when the vertical mass was insufficiently reinforced. As a result, the base dimension was subtly widened and the axial column thickened to prevent tipping. These refinements were carried forward into prototype fabrication, where material weight and center-of-gravity considerations further informed adjustments.

Through this reconstruction process, the object achieved volumetric stability while preserving compositional hierarchy. The incense holder does not replicate the outward appearance of the character in a literal sculptural manner. Instead, it reorganizes the character's internal structural relationships into a three-dimensional system in which support, mass distribution, void articulation, and functional embedding operate in alignment. In this way, the original calligraphic logic is not represented superficially but reconstructed as spatial organization.

4.2 Case II: "Ma" (馬) - Dynamic Expansion and

Rhythmic Transformation

4.2.1 Calligraphic Structural Characteristics

Unlike "De," the character "Ma" (馬) in Xu Beihong's calligraphy presents a horizontally extended and rhythmically segmented structure. The brushwork conveys movement and elasticity. Stroke groupings repeat with slight variation, generating dynamic momentum.

Key characteristics identified include:

Rhythmic repetition of structural units

Lateral extension and visual flow

Elastic curvature combining rigidity and flexibility

These features posed different translational challenges compared to the axial stability of "De."

4.2.2 Translational Strategy

Compared to the relatively stable axial structure of "De," the character "Ma" (馬) presents a more horizontally extended and rhythmically segmented configuration. In Xu Beihong's calligraphic rendering, the repeated stroke clusters and lateral expansion generate a sense of motion and elasticity. Translating such a dynamic planar structure into a stable three-dimensional object required a series of structural recalibrations. The first critical adjustment concerned weight distribution. In its two-dimensional form, the visual center of gravity of "Ma" is not strictly aligned along a vertical axis; instead, it spreads laterally through successive stroke units. If directly translated into volume without modification, this configuration would risk imbalance and instability. During digital modeling, the mass distribution was therefore recalibrated. The lower section was expanded horizontally to increase the contact area with the supporting surface, while maintaining proportional coherence with the original character. This widening of the base was not an arbitrary addition but a structural translation of the character's inherent lateral force into a stabilized foundation. A second transformation addressed the issue of stroke overlap and structural fragility. In calligraphy, overlapping strokes contribute to visual density and rhythmic layering. However, when translated into three-dimensional space, such intersections can create weak joints or overly complex geometries that compromise structural integrity. Therefore, areas of dense stroke convergence were consolidated into unified volumetric masses. Rather than preserving each stroke as an individual structural component, intersecting elements were merged into continuous forms capable of bearing physical load. This

consolidation preserved compositional density while eliminating structural vulnerability. A third aspect of the translational strategy involved curvature reinterpretation. Xu Beihong's brushwork in "Ma" demonstrates fluid directional movement with subtle variations in pressure and curvature. To maintain this dynamic quality in volumetric form, sharp angular translations were avoided. Instead, gently arched surfaces were introduced, allowing curvature to emerge as directional spatial flow rather than abrupt geometric segmentation. These surfaces were refined during the modeling stage to balance visual dynamism with fabrication feasibility. Through these adjustments, the energetic rhythm of the calligraphic strokes was retained while adapting the structure to physical constraints and material behavior.

This translational strategy demonstrates that dynamic calligraphic structures require not replication but recalibration. Stability was achieved not by suppressing movement, but by reorganizing it within a coherent structural framework.

4.2.3 Functional Integration

Once structural stability was established, functional integration was incorporated into the reconstructed form. As a pen holder, the artifact was required to provide stable base support, vertical compartmentalization for writing instruments, and ergonomic accessibility suitable for daily use. These functional demands were embedded within the existing spatial logic rather than imposed externally.

The upper structural components of the character were reinterpreted as pen insertion compartments. In the planar calligraphic form, these upper strokes create rhythmic segmentation; in volumetric translation, they were transformed into vertical cavities aligned with the direction of brush movement. The spacing between these cavities followed the proportional intervals identified during morphological abstraction, ensuring that functional openings remained consistent with the internal rhythm of the original composition. The lower section of the character, previously expanded to recalibrate weight distribution, served as a solid base capable of sustaining the object's load. Material thickness was adjusted during modeling to prevent deformation or tipping under everyday use conditions. The integration of function therefore reinforced rather than contradicted structural translation. Ergonomic considerations were addressed through surface refinement. The gently arched forms derived from brush curvature facilitated smooth tactile interaction, preventing sharp edges that could interfere with usability. The

vertical orientation of pen compartments aligned naturally with hand movement, further integrating compositional logic with practical function.

Through this process, rhythmic brush repetition was translated into modular volumetric sequencing. What appears in calligraphy as successive strokes becomes, in spatial form, a sequence of aligned structural modules. Movement inherent in brushwork evolves into directional curvature and spatial continuity. The resulting artifact does not mimic the visual outline of the character; instead, it reorganizes its dynamic internal relationships into a functional three-dimensional system.

4.3 Mechanism Generalization Across Five Artifacts

Although the preceding sections provided detailed analyses of two representative cases, the translational mechanism proposed in this study was systematically applied across all five functional artifacts. The works based on the characters "Jing" (敬), "Hong" (鴻), and "He" (和), together with "De" (德) and "Ma" (馬), collectively demonstrate that the mechanism operates as a structured methodological sequence rather than a case-specific design response.

In each case, the process followed the same procedural progression: structural analysis of the calligraphic form, morphological abstraction, spatial reconstruction, functional embedding, and prototype fabrication with iterative refinement. While individual characters presented distinct compositional challenges – such as radial balance in "Jing," asymmetrical extension in "Hong," or compact proportional distribution in "He" – the operational logic remained consistent. Differences occurred at the level of structural adaptation, not at the level of methodological framework. To clarify this systematic correspondence, the relationship between calligraphic principles and spatial translation strategies is summarized in Table 6.

Table 6 Correspondence Between Calligraphic Principles and Spatial Translation Strategies

Calligraphic Principle	Spatial Translation Strategy
Stroke force	Structural support logic
Thick-thin variation	Mass differentiation
Negative space	Functional cavity or carved void
Axis alignment	Stability system
Rhythmic repetition	Modular volumetric sequencing

As shown in Table 6, each key compositional characteristic identified during calligraphic analysis was translated into a specific spatial strategy during

volumetric reconstruction. Stroke force, originally expressed through directional brush pressure, was reinterpreted as structural support logic that determined load-bearing elements. Variations in stroke thickness informed differentiated mass distribution, allowing volumetric emphasis to mirror planar hierarchy. Negative spaces between strokes were preserved and reconstructed as carved cavities or functional openings, maintaining the rhythmic interplay between solidity and void. Axis alignment guided stability systems and center-of-gravity calibration. Rhythmic repetition evolved into modular volumetric sequencing that organized structural components coherently.

The consistency of this mapping across all five artifacts confirms that the translational mechanism functions as a repeatable process rather than an intuitive artistic interpretation. While each character required specific structural adjustments, the correspondence between analytical extraction and spatial reconstruction remained stable. The mechanism therefore demonstrates methodological transferability under varying compositional conditions.

4.4 Validation of the Translational Mechanism

The implementation phase provides empirical validation for the proposed translational mechanism by demonstrating its operability across multiple structural conditions and functional contexts. Rather than remaining at the level of theoretical proposition, the mechanism was tested through systematic application in five completed functional artifacts. The consistency observed between analytical extraction, spatial reconstruction, and final material realization confirms its methodological coherence.

First, the case implementations demonstrate that two-dimensional brush structures contain transferable spatial logic when examined through morphological analysis rather than symbolic interpretation. When calligraphy is approached as a linguistic sign or decorative motif, its applicability to volumetric design remains limited. However, by focusing on compositional hierarchy, stroke force distribution, axis alignment, and void–solid relationships, the study reveals that brush-based linear systems encode implicit spatial principles. These principles—once abstracted from surface representation—can be reorganized into structural frameworks capable of supporting three-dimensional form. The successful translation across five distinct characters confirms that calligraphic composition operates as a structural system rather than merely a visual pattern.

Second, the abstraction process proves critical in preventing superficial imitation. Direct contour extrusion or literal sculptural replication would have reduced the calligraphic form to a static outline detached from its internal dynamics. By systematically simplifying ornamental brush details while preserving proportional relationships and directional hierarchy, the abstraction stage ensured structural equivalence rather than visual resemblance. The resulting artifacts do not rely on immediate recognizability of the characters; instead, they embody the underlying compositional logic through mass distribution, spatial sequencing, and structural balance. This distinction between resemblance and equivalence underscores the methodological rigor of the translational framework.

Third, the integration of functional requirements did not diminish calligraphic identity but instead refined structural clarity. Incorporating practical considerations—such as load-bearing capacity, stability, ergonomic access, and material feasibility—required recalibration of mass and proportion. However, these adjustments strengthened the internal coherence of the translated forms rather than compromising them. Functional embedding acted as a constraint that clarified structural hierarchy, ensuring that compositional logic aligned with practical performance. In this way, function operated as a validating parameter within the translational process.

Taken together, the completed artifacts demonstrate that calligraphy can function as a generative structural system capable of informing volumetric organization in contemporary functional art. The mechanism is validated not through theoretical speculation, but through material realization, iterative refinement, and structural consistency across multiple applications. By translating brush-based planar composition into stable, functional three-dimensional artifacts, the study establishes a replicable framework for cross-dimensional design transformation grounded in morphological analysis and practice-based verification.

5. EVALUATION AND DISCUSSION

The evaluation phase was conducted not solely to assess aesthetic reception, but to determine whether the proposed translational mechanism demonstrates methodological reliability, structural coherence, and practical viability. By integrating expert validation, IOC assessment, and large-scale audience feedback, this study examined the effectiveness of the mechanism across analytical, functional, and

perceptual dimensions. The results provide empirical grounding for its methodological contribution.

5.1 Structural Validity and Expert Assessment

Expert evaluation served as a critical means of determining whether the proposed translational mechanism preserved structural logic rather than merely visual resemblance. The assessment criteria were intentionally aligned with the analytical dimensions identified during morphological extraction, including compositional hierarchy, axial organization, proportional modulation, stroke force distribution, and the relational balance between solidity and void. By framing the evaluation around structural parameters rather than aesthetic preference, the review process directly examined the methodological integrity of the translation.

Across all five artifacts, experts identified clear correspondence between planar calligraphic composition and volumetric reconstruction. Axial dominance in the original characters was observed to reappear as structural stabilization systems within the three-dimensional forms. Variations in stroke thickness and directional pressure were recognized as differentiated mass distribution and spatial sequencing in the artifacts. Void-solid interplay, which in calligraphy produces rhythmic tension, was perceived in the reconstructed objects through carved cavities and controlled spatial intervals. These observations indicate that continuity was achieved through structural equivalence rather than graphic imitation. The use of the Index of Item-Objective Congruence (IOC) introduced quantitative verification into what might otherwise remain qualitative interpretation. By evaluating the alignment between extracted structural principles and their spatial manifestations, the IOC assessment examined whether each design element corresponded to a clearly defined analytical objective. High congruence values suggest that the transformation process followed a systematic and traceable pathway from analysis to reconstruction. This methodological alignment strengthens the reliability of the mechanism, as it demonstrates internal coherence between theoretical extraction and material realization. Expert commentary further emphasized that the abstraction phase played a decisive role in maintaining structural clarity. By removing ornamental brush details while retaining proportional relationships and directional hierarchy, the process avoided symbolic reduction and preserved compositional logic. The resulting artifacts were therefore evaluated not as sculptural

reproductions of written characters, but as spatial reorganizations grounded in identifiable structural principles. This distinction reinforces the position that morphological analysis functions as a mediating tool capable of translating two-dimensional brush systems into coherent three-dimensional functional structures without collapsing into decorative adaptation.

The convergence of expert interpretation and IOC validation indicates that the translational mechanism operates with structural stability across varying compositional types. The consistency of identified correspondences suggests that the process is replicable under different structural conditions and is not dependent on intuitive artistic decision-making. In this sense, the evaluation substantiates the methodological credibility of the framework within contemporary design research.

5.2 Perceptual Recognition and User Response

While expert evaluation addressed structural validity from a professional perspective, the audience survey examined whether the translational mechanism achieved perceptual coherence at the user level. The questionnaire was structured around dimensions directly related to the design objectives, including recognition of embedded calligraphic elements, perceived structural clarity, functional satisfaction, aesthetic evaluation, and cultural value perception. This alignment ensured that user responses could be interpreted in relation to methodological performance rather than general preference.

Statistical analysis revealed a positive relationship between participants' recognition of calligraphic structural characteristics and their overall aesthetic evaluation of the artifacts. Respondents who reported a clearer understanding of how brush-based elements were reorganized within the three-dimensional forms consistently assigned higher ratings for both artistic integrity and functional coherence. This correlation indicates that perceptual recognition is closely tied to structural equivalence. When compositional hierarchy, rhythm, and proportional balance are preserved during translation, users are able to intuitively perceive continuity between the planar source and volumetric outcome. Importantly, the data suggest that recognizability does not depend on literal graphic similarity. Many participants acknowledged that the artifacts did not directly replicate the visual outlines of the characters, yet they were still able to identify embedded calligraphic qualities. This perception appears to arise from preserved relational

structures—such as axial alignment, mass contrast, and rhythmic sequencing—rather than from explicit symbolic representation. Such findings reinforce the methodological premise that abstraction strengthens communicative clarity by retaining internal logic instead of surface form. Functional evaluation results further support the effectiveness of the translational framework. Participants reported high levels of usability and structural stability, indicating that functional embedding did not disrupt compositional coherence. Rather than experiencing tension between artistic expression and practical utility, respondents perceived an integrated relationship between form and function. This alignment suggests that structural translation enhances ergonomic and spatial intelligibility by organizing mass and void in a logically consistent manner.

Differences observed between youth participants and professional respondents also provide insight into the mechanism's accessibility. While professionals demonstrated higher levels of explicit structural recognition, youth participants responded positively to overall compositional balance and spatial rhythm even when they could not formally articulate calligraphic principles. This indicates that structural translation operates on both analytical and intuitive perceptual levels. The mechanism therefore accommodates varying degrees of cultural literacy without losing communicative effectiveness.

The audience data thus extend validation beyond expert discourse into perceptual experience. Structural equivalence established during morphological abstraction and spatial reconstruction is not confined to theoretical analysis; it manifests in user recognition and satisfaction. The observed correlation between structural recognition and evaluative approval suggests that maintaining compositional logic during dimensional transformation enhances both aesthetic reception and functional acceptance. In this regard, the evaluation supports the position that the translational mechanism produces perceptually coherent outcomes grounded in structural continuity rather than decorative adaptation.

5.3 Methodological Contributions

Existing research on the integration of calligraphy into contemporary design has largely followed two dominant approaches. The first approach emphasizes symbolic adaptation, in which calligraphic characters are incorporated as visual motifs, graphic overlays, or stylistic references. Such strategies prioritize recognizability and cultural symbolism but often leave underlying structural

relationships unexamined (Xiong, 2024; Yu & Ghazali, 2023). The second approach focuses on formal transformation through contour extrusion or sculptural reinterpretation, translating two-dimensional outlines directly into volumetric forms. While these methods enable dimensional conversion, they frequently operate at the level of external geometry rather than internal compositional logic (Li, 2025; Lin & Ban, 2021).

Within design methodology literature more broadly, morphological analysis has been recognized as a useful tool for deconstructing complex forms into transferable components (Qian et al., 2026). However, its application to calligraphy has typically been limited to visual simplification or stylistic abstraction, without systematically addressing how stroke force, proportional hierarchy, and void-solid dynamics can be reorganized into load-bearing spatial systems. As a result, previous studies often treat traditional artistic elements as aesthetic resources rather than as generative structural frameworks. The present study advances this discourse by repositioning calligraphy as a structural system rather than a symbolic artifact (Hou & Festi, 2023). Instead of extracting contours or decorative patterns, the translational mechanism operates through a sequential analytical model: structural extraction, morphological abstraction, spatial reconstruction, and functional embedding. This sequence establishes traceable correspondence between analytical objectives and design outcomes, allowing each spatial decision to be justified in relation to identified compositional principles. In doing so, the research moves beyond stylistic borrowing toward structural reorganization.

A key theoretical contribution lies in clarifying the distinction between resemblance and equivalence in cross-dimensional translation. Prior design adaptations frequently rely on visual similarity to communicate cultural identity. The mechanism proposed here demonstrates that structural equivalence—manifested through preserved axial dominance, mass differentiation, rhythmic sequencing, and void articulation—can maintain cultural continuity without literal representation. This reframing shifts the focus of cultural integration from appearance to organization, thereby expanding methodological possibilities for designers working with traditional art forms.

Another contribution concerns the integration of functional constraints within the translational process. In earlier design applications, practical requirements are often introduced after form generation, resulting in tension between symbolic

expression and usability. By embedding functional considerations directly within spatial reconstruction, the present framework treats stability, ergonomics, and material feasibility as structural parameters rather than external adjustments. This alignment ensures that functional adaptation strengthens compositional clarity instead of diluting it. Such integration enhances methodological robustness by demonstrating that cross-dimensional translation can satisfy both structural fidelity and practical performance. Furthermore, the study introduces empirical validation as an integral component of form translation methodology. While previous research frequently presents translated artifacts as completed design outcomes, systematic evaluation of structural correspondence and perceptual recognition is less common. By combining expert IOC assessment with large-scale audience analysis, the research establishes a feedback loop between analytical extraction, material realization, and user perception. This integration of analytical rigor and empirical verification strengthens the framework's methodological credibility.

In positioning calligraphy as a generative spatial system and validating its transformation through structured evaluation, the study contributes a replicable model for cross-dimensional design translation. The proposed mechanism extends beyond the specific case of Xu Beihong's calligraphic identity and offers a transferable methodological structure applicable to other planar artistic systems. Its novelty lies not in the visual reinterpretation of tradition, but in articulating a systematic process that converts two-dimensional compositional logic into three-dimensional functional organization while maintaining structural integrity and perceptual continuity.

5.4 Practical Implications

Beyond its methodological articulation, the practical significance of this study lies in demonstrating that cross-dimensional translation between planar artistic systems and volumetric functional objects can be systematically organized rather than intuitively improvised. In many contemporary design practices, the transformation of traditional forms into product design relies heavily on subjective interpretation or stylistic borrowing. The translational mechanism developed in this research introduces procedural clarity into this process by establishing traceable correspondence between analytical extraction and spatial reconstruction. In doing so, it reduces the arbitrariness often associated with cultural form adaptation.

The mechanism satisfies three essential criteria for applied design research. First, structural consistency is maintained across multiple source forms. The application of the same analytical sequence to five structurally distinct characters confirms that the framework does not depend on a singular compositional type. Whether the source form exhibits axial dominance, lateral extension, or compact proportional distribution, the extraction–abstraction–reconstruction sequence remains operable. This structural stability enhances the reliability of the method in professional design contexts where variability of source material is inevitable.

Second, functional feasibility is preserved under real material and ergonomic constraints. The integration of stability testing, mass recalibration, and spatial adjustment during modeling and fabrication demonstrates that cross-dimensional translation can accommodate practical requirements without dissolving compositional logic. This is particularly relevant for product designers who must negotiate between cultural representation and usability standards. By embedding functional considerations within spatial reconstruction rather than appending them afterward, the mechanism ensures that practical adaptation reinforces rather than weakens structural clarity.

Third, perceptual recognizability is achieved across diverse user groups. The evaluation results indicate that both expert and non-expert participants are able to perceive structural continuity between the original calligraphic forms and their three-dimensional reinterpretations. This suggests that the mechanism operates not only at an analytical level but also at a perceptual level. For design practitioners and cultural industries, such recognizability is crucial: it enables products to retain conceptual depth while remaining accessible to broader audiences.

The practical implications of these findings extend to multiple domains. In professional design practice, the mechanism provides a structured pathway for culturally grounded innovation, allowing designers to move beyond ornamental appropriation toward structural reinterpretation. In design education, the framework can function as a pedagogical tool, guiding students to analyze traditional forms through compositional logic rather than surface imitation. By teaching morphological extraction and spatial reconstruction as sequential operations, educators can cultivate analytical rigor in cultural design projects.

In cultural and creative industries, the mechanism supports the development of products that embody

traditional artistic systems without resorting to literal replication. This approach encourages deeper cultural continuity by preserving relational structures rather than superficial imagery. The capacity to translate compositional logic into functional objects offers a sustainable model for cultural adaptation within contemporary markets. Although the present research centers on Xu Beihong's calligraphic identity, the translational framework is not confined to this specific case. The procedural logic of structural extraction and spatial reconstruction can be extended to other two-dimensional artistic systems, including graphic illustration, textile patterning, decorative motifs, and architectural ornamentation. Any planar form characterized by identifiable compositional hierarchy and relational structure may be analyzed and reorganized into volumetric configuration through similar methodological steps. The adaptability of the framework underscores its relevance within broader design methodology discourse, positioning it as a transferable model for cross-dimensional transformation in contemporary practice.

6. CONCLUSION

This study addressed the methodological challenge of translating the structural logic of two-dimensional calligraphy into three-dimensional functional artifacts without reducing traditional forms to decorative imitation. By taking Xu Beihong's calligraphic identity as a case study, the research articulated and validated a systematic translational mechanism grounded in morphological extraction, proportional abstraction, spatial reconstruction, and functional embedding. The findings demonstrate

that calligraphy, when approached as a compositional system rather than a symbolic image, contains transferable spatial principles encoded in stroke force distribution, axial organization, rhythmic sequencing, and void-solid interaction. Through structured analytical decomposition and iterative material realization, these planar relationships were reorganized into volumetric configurations capable of satisfying structural stability, ergonomic functionality, and perceptual coherence. In contrast to prior design approaches that emphasize contour extrusion or visual resemblance, the present framework establishes structural equivalence as the operative criterion of cultural continuity, thereby shifting the focus of cross-dimensional translation from appearance to organization. Empirical validation through expert assessment and large-scale audience evaluation confirms that the mechanism maintains compositional integrity while achieving functional feasibility and perceptual recognizability across diverse user groups. By integrating analytical rigor, practical constraints, and perceptual verification within a unified procedural model, the study advances design methodology beyond case-based experimentation and proposes a replicable pathway for transforming planar artistic systems into coherent three-dimensional functional structures. Although centered on Xu Beihong's calligraphy, the translational logic articulated here possesses broader applicability to other two-dimensional visual traditions, offering a structured approach for culturally grounded innovation within contemporary design practice and expanding the theoretical discourse on cross-dimensional form transformation

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