Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 7, 1249-1261
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i7.8877

Computational fusion of Chinese Gongbi figure painting elements in algorithmic ceramic design methodologies

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Abstract: This research explores the computational integration of traditional Chinese Gongbi figure painting elements with modern ceramic design methodologies. The goal is to preserve and reinterpret cultural heritage by algorithmically fusing Gongbi features—intricate brushwork, calligraphy, seals, and imagery—extracted via image processing techniques like edge detection and SIFT. These features are incorporated into ceramic design templates, which are optimized using the Dynamic Sailfish Optimizer (DSFO) for aesthetic coherence and functional adaptability in production. Digitized designs are securely archived using Advanced Encryption Standard (AES) encryption, ensuring integrity and confidentiality during storage and transmission. Secure access controls and blockchain-based protocols (smart contracts, cryptography) provide verifiable, decentralized, traceable, and non-repudiable access management, enabling controlled licensing and ethical reuse. Results demonstrate that the Gongbi-integrated designs successfully maintain traditional visual richness while being functionally viable. The AES system ensures robust digital rights protection, and user authentication achieves over 90% success. Evaluations show high satisfaction with the designs' aesthetic appeal, cultural accuracy, and production feasibility, confirming the method's effectiveness in bridging heritage and computational creativity.

Keywords: *Advanced encryption standard (AES), Ceramic design, Chinese gongbi painting, Dynamic sailfish optimizer (DSFO), Ink and calligraphy elements, Secure, Digital art archive.*

1. Introduction

Ideas of cultural heritage and craftsmanship have long impacted art and design, often propelled by advances in technology. Over the last few decades, a blending of digital innovation with traditional aesthetics has created new avenues for creative expression, specifically in the areas of visual arts and product design [1]. While computational tools evolved more broadly and became more complex, artists and designers explored algorithmic methods more and more to study, classify, and implement ancient forms of art in various modern contexts [2].

Chinese Gongbi painting, which was characterized by fine brushwork, scrupulous detail, and subtle imagery, particularly of human figures, stands out among traditional art forms [3]. The phrase "Gongbi," which translates to "meticulous," described an attribute that had been applied for more than a thousand years and was admired for its delicacy, accuracy, and profound cultural meaning. Gongbi painting conveys rich visual narratives imbued with symbolic and philosophical meanings, traditionally through scrolls, textiles, murals, and decorative arts [4]. Ceramics also played an important role in material culture and functioned both as useful objects and as media of expression for narrative. With the development of three-dimensional (3D) printing and algorithmic design, the world of ceramic art underwent a metamorphosis [5]. Designers were facilitated with tools like computer-aided design (CAD), parametric modeling, and generative algorithms to design complex, detailed, and innovative forms that would have otherwise been difficult to build manually [6]. This research explores how computational methods can be applied to integrate the aesthetic and symbolic aspects of Gongbi figure painting into contemporary ceramic design practices [7]. It transcended the fields of traditional Chinese

History: Received: 12 May 2025; Revised: 24 June 2025; Accepted: 27 June 2025; Published: 15 July 2025
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painting and algorithmic ceramic design. The algorithmic methods were designed to maintain the cultural heritage of Gongbi while reformulating it into new forms and digital platforms [8]. In addition to promoting artistic experimentation, the interdisciplinary incorporation also enabled cultural conservation by recontextualizing traditional art forms for contemporary audiences, either through public installations or interior design [9]. It facilitated conversation between tradition and contemporary, East, and West, as well as between manual production and digital technology. However, it was bounded by the subjective experience of Gongbi aesthetics, the difficulty of translating the complex brushwork into ceramic forms, and the technical constraints of digital fabrication, all of which were likely to affect the material existence and genuineness of traditional painting elements.

This research aims to comprehend and algorithmically incorporate it into the design of ceramic elements that are safe, functional, contemporary, and culturally significant. The significant contributions are as follows:

(1) Innovative Integration: To balance cultural tradition and modern digital art, a new computational model was developed that blends traditional Chinese Gongbi figure painting themes with algorithmic ceramic design processes.

(2) Advanced Optimization: Ceramic design templates were optimized using the Dynamic Sailfish Optimiser (DSFO) to make them both aesthetically pleasing and producible.

(3) Secure Digital Preservation: To preserve, arrange, and ethically license the produced ceramic designs, a secure digital art archive was established using blockchain-based smart contracts and AES encryption.

The investigation is structured into several key components. The first component is a conceptual framework for integrating Gongbi painting with ceramic art. This is followed by a description of the dataset and a technical framework that incorporates AES and DSFO encryption. Subsequently, the experimental findings, user satisfaction analysis, encountered challenges, and prospects for intelligent cultural preservation are discussed.

2. Literature Review

Hu, et al. [10] created interactive ceramic display virtual environments using Virtual Reality Modeling Language (VRML)-based modeling tools such as Three-Dimensional Studio Max (3DS MAX) and VRML editors. Level of Detail (LOD) nodes were implemented, with system stability demonstrated by response times under four seconds and error rates below 0.51%. However, the potential intricacy of visual depiction was identified as a limitation. The findings suggested that virtual ceramic design interaction required highly sophisticated computer modeling techniques.

Tang [11] employed deep learning and 3D virtual reconstruction to automate the creation of ceramic models for examining the aesthetics of literati Yaji and identifying ceramic image elements through neural networks. The model demonstrated high accuracy in identifying similarities and updating dynamic parameters. Limitations included restricted generalizability and the complexity of 3D modeling. Enhancing model flexibility and achieving real-time design precision remain ongoing challenges.

A separate investigation classified Gongbi painting features using an Improved Self-Organizing Algorithm (ISOA)-optimized Adaptive Recurrent Neural Network (ARNN) and employed Histogram of Oriented Gradients (HOG) for edge-texture extraction by Huang [12]. The model achieved 96.1% accuracy, 93.7% precision, 94.3% recall, and a 94.0% F1 score. Preprocessing techniques and Z-score normalization improved input quality. Nevertheless, high computational cost and reliance on manually curated features were notable drawbacks, underlining the difficulty of preserving artistic detail in digital media.

The ANYXI classifier was utilized by Costa, et al. [13] to categorize artistic styles such as Baroque, Impressionism, and Post-Impressionism using expert-driven classifications and human-interpretable color characteristics. ANYXI showed high interpretability and accuracy through comparative validation and a human survey. However, subjectivity in expert classification and reliance on color-based features

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 7: 1249-1261, 2025
DOI: 10.55214/25768484.v9i7.8877

were recognized as limitations. The study emphasized that classification models in art must balance accuracy with explainability.

Guo [14] focused on teaching Gongbi figure painting, traditional Chinese elements were incorporated to explore emotional and cultural depth. A qualitative analysis of pedagogical strategies revealed increased cultural awareness and student engagement. However, the absence of statistical validation and quantitative indicators, along with the use of subjective methodology, were identified as limitations. The absence of computational modeling of traditional art integration was also noted.

A multimodal discourse analysis combining media, semiotic, quantitative, and qualitative techniques was applied by Qi, et al. [15] to ten Chinese picture books. Findings regarding historical scrolls revealed alignment with conventional beliefs through pictorial-narrative structures. Limitations included subjective judgments and a small sample size. Statistical tests were not reported, highlighting a research gap in the computational modeling of culturally embedded visual narratives in children's literature.

A novel style transfer approach incorporating local affine transformation and watershed segmentation was proposed by Zhao and Ke [16] to improve ceramic painting design. The technique preserved artistic integrity and form consistency. Despite improvements in visual coherence, the study lacked thorough statistical validation. Limitations included missing performance metrics and limited generalizability, demonstrating the necessity for systematic and intelligent design strategies that honor cultural aesthetics in ceramic art.

The objective is to preserve cultural heritage while fostering creativity by integrating traditional Chinese Gongbi figure painting techniques into contemporary algorithmic ceramic design processes. Current models were not perfect: their limitations included model generalizability and real-time precision for Tang [11] accurate ceramic model generation through image analysis by deep learning, and their limitations in computational cost and dependence on hand-crafted features. The earliest reports indicated that virtual ceramic modeling required highly sophisticated modeling techniques but was hampered by issues in capturing detailed visual features by Hu, et al. [10]. These limitations posed significant challenges in integrating computational ceramic design with the delicate artistic features of Gongbi painting. To address these limitations, the proposed model combined advanced image processing methods with optimization algorithms, enhancing practical flexibility and visual authenticity in ceramic production while maintaining the artistic and cultural integrity of Gongbi paintings.

3. Methodology

To preserve and revitalize traditional Chinese Gongbi painting using computational ceramic design. The most prominent visual traits, such as delicate brushwork, calligraphy, seals, and imagery, are employed to distinguish edge detection and SIFT. These are algorithmically merged into ceramic design templates, which are then optimized for aesthetics and implemented via the DSFO. The final designs are securely encrypted using AES and governed by smart contracts to ensure restricted access, traceability, and digital rights protection. Figure 1 depicts the overall flow for Chinese Gongbi Figure Painting Elements in Algorithmic Ceramic Design Methodologies.

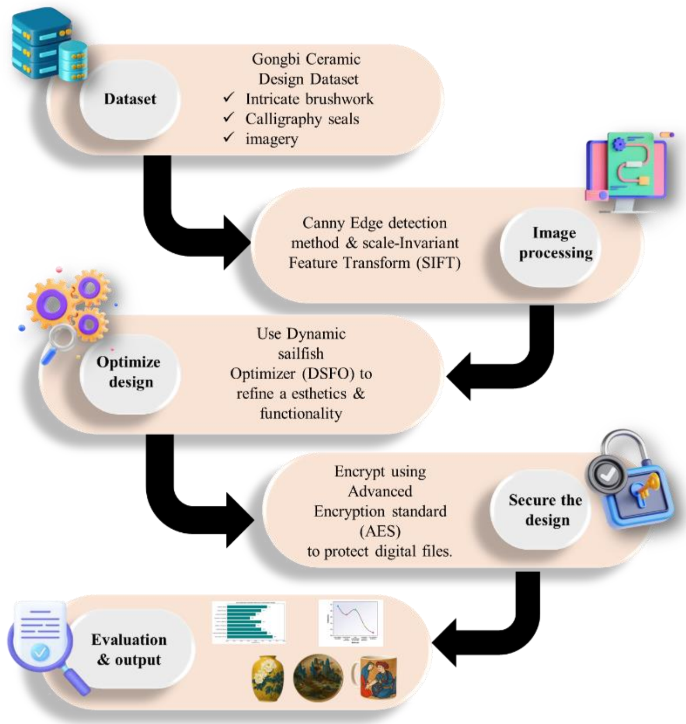

Figure 1.
Overall flow for Chinese Gongbi Figure Painting Elements.

3.1. Dataset

To integrate traditional Gongbi painting into algorithmic ceramic design, this dataset provides computerized aspects such as calligraphy, brushwork, seals, and illustration sample images shown in Figure 2. These are retrieved using sophisticated image processing techniques, allowing for computationally generated ceramic designs that retain art tradition while being used in modern design.

Figure 2.
Sample Dataset Images.
Source: https://www.kaggle.com/datasets/programmer3/gongbi-ceramic-design-dataset/data

3.2. Edge Detection of Traditional Art Using Canny Method

Edge detection is used as a preprocessing technique to extract key visual elements from Gongbi paintings, such as contours and brushwork. To reliably formulate recommendations that adhere to the same cultural and aesthetic visual properties as traditional Gongbi aspects in algorithmic ceramic design, the Canny Operator was used due to its ability to detect precise, fine edges with the least amount of noise. Canny defined several criteria for edge detection and suggested the best way to achieve

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 7: 1249-1261, 2025
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it. Canny identified the following basic issues that an edge detector should address, which are particularly significant for the finer details of brushstrokes and delicate line work observed in Gongbi art:

Good Detection (Low Error Rate): To ensure that no visible portions of the Gongbi paintings are missed, the edge detector must react correctly only to real edges. It is crucial to maintain the cultural and artistic relevance of the aspects that were taken out. The definition of the detection criterion is as follows in Equation (1):

$$S\,N\,R = \frac{\left|\int_{-x}^{x} H\,(-w)\,e\,(w)\,cw\right|}{m_0\sqrt{\int_{-x}^{x} e^2\,(w)cw}} \tag{1}$$

Where the filter is denoted by e, the edge signal by $H,$ and the root-mean-squared (RMS) response to noise $m(w)$ alone is represented by the denominator.

Good Spatial Localisation: The edge pixels found will be as near to the actual edges of the Gongbi images as feasible, guaranteeing precise geometries in the ceramic patterns that are produced. The following Equation (2) is the localization criteria:

$$localization = \frac{1}{\sqrt{F[W_0^2]}} = \frac{\left|\int_{-x}^{x} H'\,(-w)\,e'(w)\,cw\right|}{m_0\sqrt{\int_{-x}^{x} e'^2\,(w)cw}} \tag{2}$$

The reciprocal of the RMS distance between the identified and real edge positions is used to calculate accuracy.

Good Response Rate: To prevent confusion when processing lines and strokes in Gongbi art during interpretation, the edge detector should aim to avoid having repeated replies to one edge. The mapping of characteristics for integration into a design is made easier by a single edge, which offers a clear depiction free of duplication. Although the first criterion naturally addresses this one, it is emphasized here to prevent duplication. The first two criteria can be trivially maximized by setting $e(w) = H(-w)$. The Gongbi art of the original image is seen in Figure 3. To obtain precise structural outlines without sacrificing design detail, canny edge detection is employed. The Canny operator anticipated that Gongbi's visual features would be accurately and faithfully articulated and recorded for both practical and aesthetic purposes in computational ceramic design.

Figure 3.
Extracting Gongbi Art Features for Ceramic Design Using Canny Edge Detection.

DOI: 10.55214/25768484.v9i7.8877

3.3. Scale-Invariant Feature Transform (SIFT) for Gongbi Feature Extraction

SIFT is used to extract distinctive visual features of traditional Chinese Gongbi figure paintings. SIFT is invariant to image operations like rotation, scale, and brightness adjustments, it is ideal for this application. This ensures that creative components produced digitally and inserted into ceramic design templates are consistent. The program limits the consistency of image transformations and identifies important geometric features that distinguish Gongbi figure artworks. To optimize matching and the transfer of ornamental features into ceramic design models, the method uses SIFT for Gongbi image segmentation. The process includes:

- Acquiring the desired Gongbi image.
- Utilizing the Difference of Gaussian (DoG) function, the scale-space extrema are calculated.
- Locating important locations to eliminate features with poor contrast or shaky edges.
- Orienting objects according to local gradients in images.
- Using gradient orientations and magnitudes to generate descriptions for every important site.

For any key point (w, z), the estimation of local extrema is provided by Equations (3) to (5).

$$C(w,z,\sigma) = \big(H(w,z,\sigma) - H\,(w,z,\sigma)\big) * J(w,z) = K(w,z,t\sigma) - K(w,z,\sigma) \quad (3)$$

$$K(w,z,\sigma) = H\,(w,z,\sigma) * J(w,z) \quad (4)$$

$$H\,(w,z,\sigma) = \frac{1}{2\pi\sigma^2} f^{-(w^2+z^e)/_2} \quad (5)$$

The Gaussian-smoothed image at scale σ is represented by $K(w,z,\sigma)$, where σ is the scale parameter. Key point interpolation is performed using the Taylor series expansion of the DoG scale-space function $C\,(w,z,\sigma)$ to improve accuracy in Equation (6):

$$C(w) = C + \frac{\lambda C^S}{\lambda w} w + \frac{1}{2} w^S \frac{\lambda^2 C}{\lambda w} w \quad (6)$$

Each key point's gradient magnitude $n(w,z)$ and orientation $\theta(w,z)$ are calculated using Equations (7) and (8):

$$n(w,z) = \sqrt{(K(w+1,z-K(w-1,z))^2 + (K(w,z+1) - (K(w,z-1))} \quad (7)$$

$$\theta\,(w,z) = tan^{-1}\left(\frac{(K(w,z+1) - (K(w,z-1)}{(K(w+1,z) - (K(w-1,z)}\right) \quad (8)$$

By connecting traditional aesthetic domains with innovative manufacturing techniques, the descriptors enable the reliable transfer of Gongbi visual themes into digitally optimized ceramic patterns. Key points necessary for maintaining artistic integrity are identified by SIFT feature extraction. With the use of these computational techniques, stylistic aspects and patterns can be systematically extracted as shown in Figure 4. The extracted characteristics will preserve the visual aesthetic's depth and conform to the functional design restrictions discussed throughout the assignment's optimization phase.

Figure 4.
Using SIFT Techniques to Extract Gongbi Art Features for Ceramic Design.

3.4. Improving Gongbi-Style Ceramic Design with Smart Optimization Using Sailfish Algorithm

To adaptably adjust the global and local search capabilities required to include intricate Gongbi elements into algorithmic ceramic designs, the Dynamic SailFish Optimizer (DSFO) was enhanced with an adaptable nonlinear iterative component. The placement of individuals within the sailfish population is automatically altered by this element. As the number of repetitions increases, the velocity term preserves the artistic delicacy required for Gongbi-style translation in design by ensuring rapid search in the early stages and essential convergence in the latter stages. Equation (9) displays the mathematical model:

$$w_j^s = 1 + sin\left(\frac{\pi \times (2 \times S_{max} + s)}{2 \times S_{max}}\right) \tag{9}$$

This technique improves local accuracy and prevents premature convergence, both of which are essential for capturing the subtleties of Gongbi features. Speed adjustment has diminishing influence as iterations go on, promoting convergence towards aesthetically pleasing optimals. The following are the updated location formulae for sardines and sailfish: Equations (10), and (11) show the revised position update equation for the j^{th} sailfish and sardine following the iteration of $s+1$ after incorporating w_j^s.

$$W_{newSF_j}^{s+1} = w_j^s \times W_{eliteSF_j}^s - \lambda_j \times \left(q \times \left(\frac{W_{eliteSF_j + W_{injuredS_j}^s}^s}{2}\right) - W_{oldSF_j}^s\right) \tag{10}$$

$$W_{newS_j}^s = q \times (w_j^s \times W_{eliteSF_j}^s - W_{oldSF_j}^s + BO) \tag{11}$$

The Le'vy flying technique was used to enhance search space variation, which is essential for stylistic richness in Gongbi features. This ensures greater aesthetic exploration and introduces controlled randomness into the optimizer, as simulated by Equations (12) and (13):

ISSN: 2576-8484
Vol. 9, No. 7: 1249-1261, 2025
DOI: 10.55214/25768484.v9i7.8877

$$Le'vy(w) = 0.01 \times \frac{O_{1\times\sigma}}{|O_2|^{\frac{1}{\beta}}} \tag{12}$$

Where O_1, O_2 are two random integers with a range of values between 0 and 1; β is a constant with a value of 1.5; σ is computed as follows:

$$\sigma = \left[\frac{\Gamma(1+\beta) \times \sin\frac{\pi\beta}{2}}{\Gamma\frac{(1+\beta)}{2} \times \beta \times 2^{\left[\frac{\beta-1}{2}\right]}}\right] \tag{13}$$

Where $\Gamma(\mathrm{w}) = (\mathrm{w}-1)!$ Sardines and sailfish positions are now updated as follows in Equations (14) and (15):

$$W^{s+1}_{newSF_j} = W^{s}_{newSF_j} + Le'vy(c) \times W^{s}_{newSF_j} \tag{14}$$

$$W^{s+1}_{newS_j} = W^{s}_{newS_j} + Le'vy(c) \times W^{s}_{newS_j} \tag{15}$$

Although the SailFish Optimiser (SFO) can accurately simulate real sailfish hunting behavior, it is prone to premature convergence and local optima traps when confronted with complex adaption patterns. To address these limitations while maintaining population variety, a different mutation technique is proposed. This method boosts exploration ability by constantly producing new variants, allowing Gongbi-inspired ceramic designs to grow in an adaptable manner. The mutation helps the optimizer avoid a local standstill and promotes improved convergence to more aesthetically and functionally superior ceramic design ideas in Equation (16).

$$N^{j,s} = w^{l_1,s} + T \times \left(w^{l_2,s} - w^{l_3,s}\right) \tag{16}$$

Where, $w^{l_2,s} - w^{l_3,s}$ the difference vector is $l_1 \neq l_1 \neq l_1$, the scaling factor is $T \in [0.1, 0.9]$, and the mutation vector is it, $N^{j,s}$ at the j^{th} place in the iteration of s. A crossover and selection procedure guarantees that only the most aesthetically and functionally appropriate designs aligned with Gongbi visual characteristics are kept for final production in Equations (17) and (18).

$$v^{j,s} = \begin{cases} N_i^{j,s}, & if\ i = i_0\ and\ rand(0,1) \leq oDQ \\ \quad w^{j,s}, & else \end{cases} \tag{17}$$

$$w^{j,s+1} = \begin{cases} v^{j,s}, & if\ e\left(v^{j,s}\right) < e\left(w^{j,s}\right) \\ \quad w^{j,s}, & else \end{cases} \tag{18}$$

The crossover variable is denoted by $v^{j,s}$, the dimension index is $i0$, and the crossover probability is denoted as $oBQ \in [0,1]$. The DSFO uses this improved optimization technique to enable the effective and precise inclusion of Gongbi painting elements, such as delicate brushstrokes and heritage motifs, into ceramic model templates. The algorithm's adaptive nature maximizes artistic authenticity while remaining practical, therefore meeting the primary purpose of safeguarding the cultural past through computational innovation.

3.5. Advanced Encryption Standard (AES) for Secure Digital Art Archiving

To preserve and protect digital ceramic creations inspired by Gongbi, use the AES to save digital artifacts in a safe and secure art archive. The Data Encryption Standard (DES) was superseded by AES, a symmetric block cybers issued.

Digital ceramic design files that incorporate traditional Gongbi painting were encrypted and protected using AES. Abbreviated as AES-128, AES-192, and AES-256, respectively, the AES algorithm accepts blocks of 128 bits of data and supports a key of 128, 192, or 256 bits in length. The key length determines how many cycles the AES algorithm runs; AES-128 has 10 rounds, AES-192 has 12, and AES-256 has 14.AES encryption safeguards digital ceramic designs by encrypting the data in numerous rounds, each employing certain transformations to complete the encryption of the design files, ensuring that they are correctly encrypted and secure. Here is what happens during these rounds:

- Substitute Bytes: A complex lookup table known as an S-box replaces each byte of data with another. This approach makes it exceedingly difficult to anticipate or invert the encryption, hence protecting the design's secrets.
- ShiftRows: Data matrix rows are rotated or shifted to the left to varied degrees. This reordering spreads the information throughout the data block, making patterns harder to uncover and improving security.
- MixColumns: Data columns are integrated using mathematical operations inside a unique number system ($GF(2^8)$). It again randomizes the data, preventing even attackers from simply identifying the basic design data.
- AddRoundKey: A piece of the encryption key is added to the data via bitwise XOR (a digital "toggle"). This technique securely connects the encrypted data to the secret key, allowing only valid users to decipher the designs.

These four steps are done several times (depending on the key length) to create a very safe encryption. The final round completes the encryption in three stages, omitting the MixColumns function. The digital design library is well protected by AES, which prevents unwanted access and ensures data integrity throughout transmission and storage. By using cryptographic protocols and smart contracts to enable controlled licensing, traceability, and non-repudiation, this encryption policy supports the protection, preservation, and responsible sharing of Gongbi-inspired algorithmic ceramic designs within safe digital storage.

4. Results and Discussion

Using the implementation in Python 3.10, the framework effectively extracts Gongbi characteristics, optimizes ceramic designs using DSFO, and protects digital archives with smart contracts and AES encryption. Each of these improves design quality and preserves intellectual property.

4.1. Findings and Evaluation of the Gongbi-Inspired Algorithmic Ceramic Design System

Digitally produced ceramic designs inspired by Gongbi are more effectively protected by the AES encryption metrics in Figure 5. A 96.8% data integrity verification rate demonstrated correct and undamaged storage. Strong access control was demonstrated by the 95.4% success rate in preventing unwanted access and the 96.2% success rate in user authentication. The computation-friendly nature of the security procedures is guaranteed by the 93.7% encryption overhead efficiency and the 92.5% CPU usage efficiency. These results support the goal of transmitting and saving culturally rich digital designs safely while maintaining excellent practical performance for real ceramic production processes.

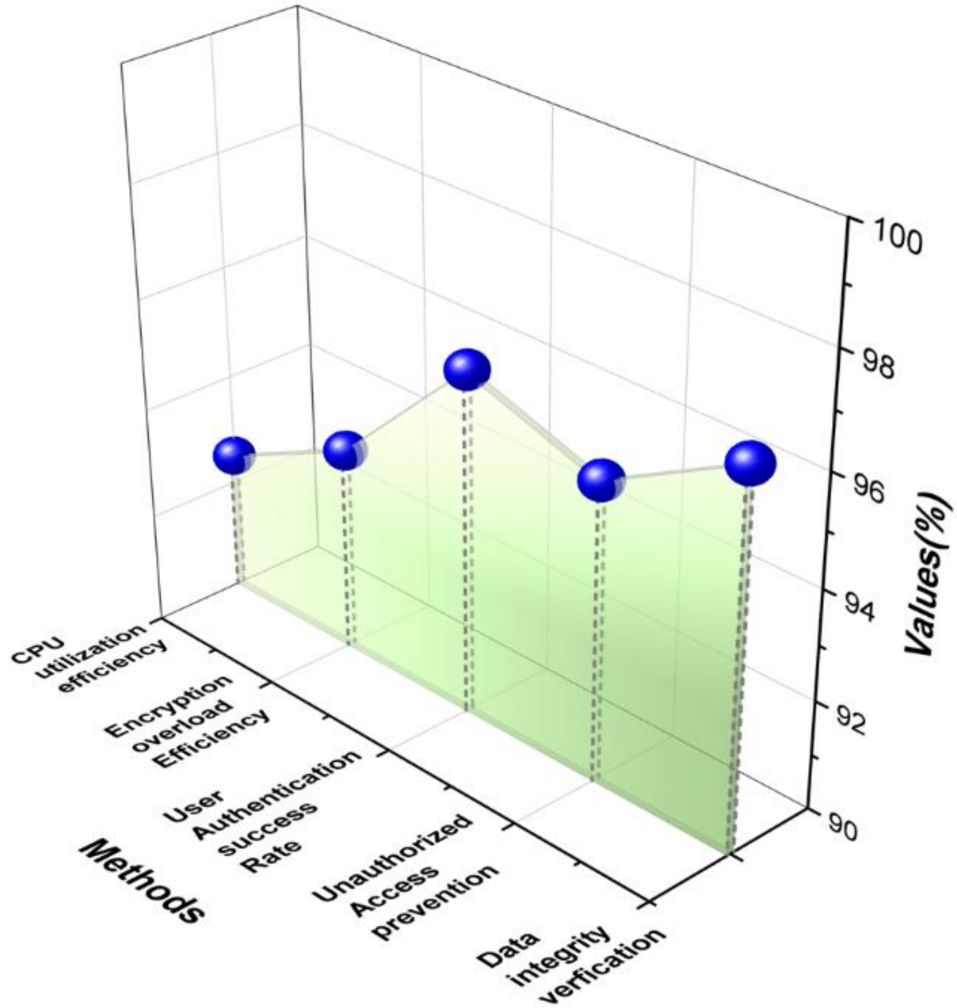

Figure 5.
Performance Metrics of AES Encryption in Secure Gongbi-Inspired Ceramic Design Archival.

User satisfaction with the combination of algorithmic ceramic design with Gongbi painting components was evaluated across several aspects, as shown in Table 1 and Figure 6. Aesthetic appeal, cultural authenticity, functional viability, invention and originality, texture and details, manufacturing usefulness, overall satisfaction, cultural emotional appeal, and protection of digital rights are among the metrics. These metrics demonstrate how well the strategy preserves traditional artistic content while ensuring user engagement, safe digital handling, and practical use within contemporary ceramic design techniques.

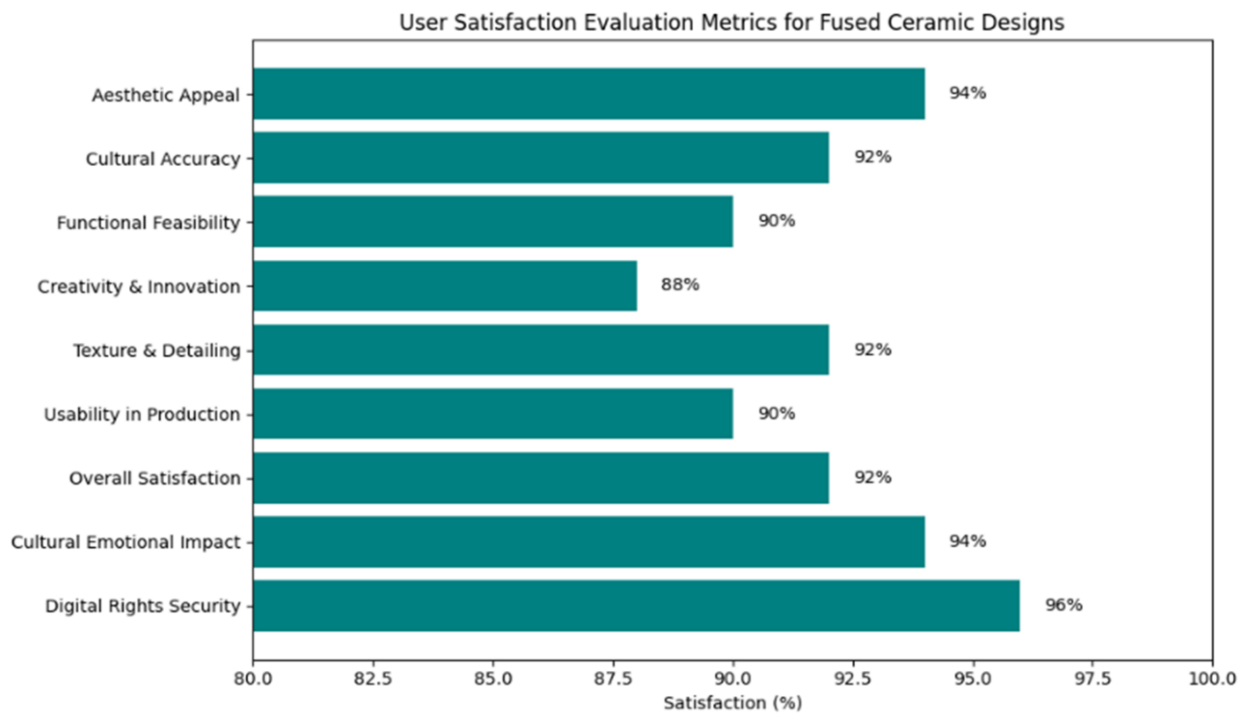

Figure 6.
Evaluation of User Satisfaction in Algorithmic Gongbi-Ceramic Design Integration.

Table 1.
User Satisfaction Metrics for Algorithmic Gongbi-Inspired Ceramic Design Integration.

Metric	**Satisfaction (%)**
Aesthetic Appeal	94
Cultural Accuracy	92
Functional Feasibility	90
Creativity & Innovation	88
Texture & Detailing	92
Usability in Production	90
Overall Satisfaction	92
Cultural Emotional Impact	94
Digital Rights Security	96

Unique dataset images were incorporated into functional ceramic creations by drawing inspiration from Chinese Gongbi miniature paintings, as shown in Figure 7. Using computational methods, key creative components like calligraphy, brushstrokes, and symbolic motifs are encoded and applied to ceramic items like mugs and vases. This preserves cultural legacy and makes it relevant to the contemporary world. AES encryption is used to securely save these finished designs for ethical digital dissemination and preservation, authenticity, and traceability.

Figure 7.
Transforming Traditional Art Datasets into Functional Ceramic Designs.

5. Discussion

To computationally fuse traditional Gongbi painting elements into algorithmic ceramic design, this research addresses key challenges in preserving cultural richness while enabling practical production. Huang [12] was severely limited by the high computational cost and dependence on hand-crafted features, which limited scalability and automation for the extraction of artistic details. Although Zhao and Ke [16] acknowledged the need to integrate cultural aesthetics into intelligent design, their technique lacked comprehensive optimization, which reduced its dependability and generalizability across a range of ceramic artworks.

The present work uses automated feature extraction by Canny edge detection and SIFT to preserve high-detail and accurate Gongbi feature capture. Furthermore, the application of the DSFO optimizes ceramic templates in a way that is both aesthetically pleasing and functionally responsive. Digital rights protection flaws in previous research were fixed by using AES encryption to guarantee the safe archiving of designs. The user satisfaction survey demonstrates a high level of acceptance of the designs' cultural accuracy and manufacturing viability, addressing gaps left by previous approaches regarding both artistic integrity and practicality. Additionally, it suggests a digital pipeline that integrates traditional visual characteristics into parametric ceramic modeling, allowing for automated analysis and real-time design iteration. The system's scalability in collaborative design and licensing for future creative contexts is ensured by the secured archives and intelligent access procedures.

6. Conclusion

This work demonstrates how traditional Chinese Gongbi figure painting motifs can be successfully integrated into modern algorithmic ceramic design in a novel way that preserves cultural continuity while fostering computational innovation. It creates design templates that are imbued with classical beauty by using techniques like the Canny edge detection method and SIFT to extract significant visual characteristics like intricate brushwork, calligraphy, seals, and images. The DSFO optimizes these templates to increase flexibility and consistency in ceramic manufacture in the real world. Additionally, AES encryption promotes ethical reuse and protects against intellectual property infringement by enabling the safe storage and distribution of digital designs. The user authentication success rate of 96.2% and an aesthetic appeal score of 94% support both the security and visual impact of the designs. Overall, the technique creates ceramic items that are aesthetically pleasing, culturally genuine, and functionally feasible while striking a balance between innovation and tradition. The limited availability of high-quality, labeled Gongbi painting datasets limits this work, and it may be difficult to generalize design outputs across various ceramic styles and production methods. Future studies might look at AI-based real-time user-controlled ceramic design systems that let designers combine 3D-printed ceramics with Gongbi painting components in an interactive way. Large cultural databases and generative models may be used to improve innovation, personalization, and cultural preservation. This opens up possibilities for digital museums based on virtual reality and for the distribution of deeply cultured algorithmic ceramic art through Non-Fungible Tokens (NFTs).

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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