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RESEARCH ARTICLE

Research on Digital Huishan Clay Figures

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Abstract

Huishan clay figures originated from the representative of Chinese clay figures and have a history of more than two programminghundred years. However, with the development of society and economy, the traditional handicraft of Huishan Clay Figure is gradually facing extinction. Nowadays, with the rapid development of information technology, digital technology has been applied to the study of intangible cultural heritage as a kind of efficient technical means, which plays an important role in the field of cultural inheritance and design innovation. This thesis will take Huishan clay figures as a research sample, and through the innovative design thinking process of carrying out computer-aided craft research, it will propose the strategy of digital craft to provide new ideas for realizing the inheritance and development of traditional craft in modern manufacturing, and lay the foundation for further integrating design and innovation, and developing highly personalized and customized new materials, new structures and new forms.

Keywords: Digital, Huishan clay figures, Traditional craft, Digital repository, Innovative design, Programming, Research

Introduce

Huishan clay figure is a representative of Chinese clay figures with a history of more than four hundred years. Its production process is unique, using clay as the main raw material, and through fine carving and hand-coloring, it shows a rich folklore and life scenes. As a representative of traditional crafts in Jiangnan region of China, Huishan clay figures are not only a kind of artwork, but also carry the memory of local history and culture.

However, with the advancement of modernization, traditional crafts are facing many challenges. The rapid development of industrialization and urbanization has gradually reduced the living space of traditional crafts, and the production skills of Huishan clay figures are at risk of being lost. In addition, changes in market demand and the drive for economic gain have gradually marginalized traditional handicrafts in modern society.

The rise of digital technology has provided new solutions for the inheritance and innovation of Huishan clay figures. Technologies such as computer- aided design, 3D modeling, 3D scanning, virtual reality (VR) and augmented reality (AR) not only enhance the design level of Huishan clay figures, but also expand their application and influence in modern society. The combination of these technologies not only preserves the essence of the traditional craft, but also promotes its development and innovation in the new era.

The objectives, Scope of Research, and expected benefits of this research are as follows:

Objectives

This research has three objectives:

1. Build a digital design application system: for the status quo of Huishan clay figures with single shape and limited inheritance of patterns, establish a digital model library of classic Huishan clay figures through 3D scanning technology, develop a clay figure shape generation tool based on parametric design, realize the modular reorganization of traditional patterns, and increase the number of variants of the clay figure shape compared with the traditional way of production, so as to provide reusable digital solutions for the diversified

development of Huishan clay figures. Provide reusable digital solutions for the development of Huishan clay figure diversity.

2. Form a cross-field integration methodology: take digital technology as a bridge, sort out the adaptation points between the traditional crafts of Huishan clay figures "kneading, shaping, printing and painting" and the modern industrial design process, form a standard for the digital transformation of the traditional crafts (including the digitization of the material parameters, and the specification for the visualization of the craft process), and make clear the specific application path of the digital tools in the modern transformation of the traditional handicrafts. Formation of standards for the digital transformation of traditional crafts (including specifications for the digitization of material parameters and the visualization of craft processes), and clarification of the specific application path of digital tools in the modern transformation of traditional crafts.

3. Explore the experimental paradigm of sustainable development: Aiming at the problems of succession gap and low production efficiency of Huishan clay figures, design the hybrid production mode of "digital modeling + 3D printing prototype + manual finishing", carry out small-scale production experiments, compare the differences in time cost and product yield between the traditional and digitally-assisted production, and refine a digital integration optimization scheme that can be promoted as an evidence base for the sustainable development of traditional handicrafts in the digital era. We will conduct small-scale production experiments to compare the differences in time cost and yield rate between traditional production and digitally-assisted production, so as to extract a digital integration and optimization plan that can be promoted and provide evidence for the sustainable development of traditional handicrafts in the digital era.

Scope of research

1. Object of research: The core object of this research is the Huishan Clay Figures from Wuxi, China, focusing on the classic figures of the 'rough goods' category. Special attention is paid to the digital representation and innovative design potential of Ah Fu. Comparative studies of 'fine goods' and other regional clay art are explicitly excluded.

2. Technology Application: The core digital technologies used include 3D scanning (for data acquisition), specific 3D modeling software (3DMAX for model construction and parametric design), and FDM and SLA 3D printing technologies (for prototyping and production validation). Other digital technologies such as VR/AR, AIGC, blockchain, etc. are not involved in this study, and parametric design mainly serves morphology generation rather than material or dynamics simulation.

3. Research Content and Segments: The research covers sample digital acquisition, model library construction, development of parametric design methods, evaluation of 3D printing prototyping, and initial practice of hybrid production model integrating digital design and manual finishing. The core research content lies in the support of digitization for modeling diversity, and the performance evaluation of 3D printing in the prototyping session. It explicitly does not delve into the historical and cultural sociology of Huishan clay figures, does not explore marketing strategies and business models, and does not involve non-core process aspects such as firing glazes.

Expected benefits

This research has two expected benefits:

Academic contributions

I. Proposing and Validating an Innovative Methodology: The parametric design process for Huishan clay figures developed and practically validated in this research will provide a replicable and scalable methodological reference for the digital innovative design of intangible cultural heritage. The methodology demonstrates how digital technology can be utilized to parse the rules of traditional aesthetics and efficiently generate diverse solutions, enriching the library of technical methods at the intersection of digital humanities and design.

II. Output Empirical Evaluation Results: The quantitative and qualitative comparative data obtained through systematic experiments on the performance of FDM/SLA 3D printing technology in the production of Huishan clay figure prototypes (precision, efficiency, cost, and the degree of artistic effect reproduction) will provide valuable empirical evidence for research in

related fields and fill the gap in the data for the evaluation of the specific technologies in the digitalized manufacturing of traditional handicrafts.

III. Exploring a New Model of Integration: The "Digital Design- 3D Printing- Handmade Finishing" hybrid production and collaboration framework proposed and initially practiced in this study provides a concrete case for understanding the symbiotic relationship between digital technology and traditional andicrafts in contemporary contexts, and contributes an actionable paradigm of the integration path for other traditional crafts projects facing similar challenges to learn from. The framework provides a concrete example for understanding the symbiotic relationship between digital technology and traditional crafts in the contemporary context, and contributes an actionable paradigm for the integration path for other traditional crafts projects facing similar challenges.

Figure 1 Huishan clay figure
Source: Photographed by the author from the Chinese clay figure museum

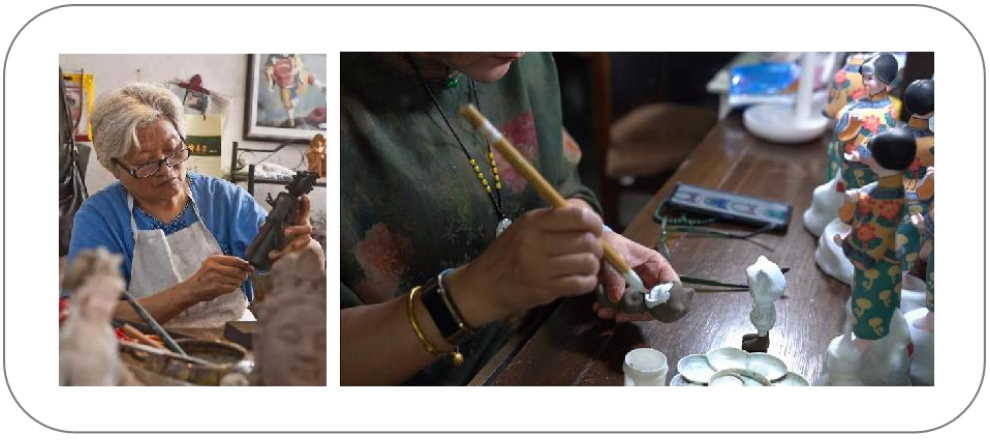

Figure 1 Huishan clay figure inheritors
Source: Photographed by the author from the studio

Practical contributions

I. Empowering Inheritors and Designers: The parametric design tool can directly serve the Huishan Clay Inheritors and modern designers, significantly improving the design efficiency of new products and the ability to explore the diversity of forms, and reducing the cost of trial and error in innovation.

II. Guiding decision-making on technology application: A detailed assessment report on 3D printing technology (potential and limitations) will provide a decision-making basis for specific technology selection, cost-effectiveness, and application scenarios for Huishan clay workshops, studios, or related enterprises when considering the introduction of digital fabrication

technology for prototyping or small-volume customized production.

III. Contributing to the living inheritance of intangible heritage: The overall research results (model library, design methodology, manufacturing evaluation, collaboration mode) will provide practical technical paths and solutions for the protection, inheritance and innovative development of Huishan clay figures, a national intangible cultural heritage, in the digital era, enhance its ability to adapt to the modern market and cultural environment, and promote its sustainable inheritance. At the same time, the model explored in this study can also provide valuable reference experience for other traditional handicraft programs facing similar dilemmas.

Literature review

Current status of international research on the integration and development of digital technology and traditional handicrafts

Over the past decade, international research on the integration of digital technologies with traditional crafts has yielded significant results. These studies cover the impact of digital technologies on the design, production, marketing and cultural values of handicrafts.

Computer-aided design (CAD) technologies have been shown to enhance the flexibility and sophistication of traditional craft designs, enhancing design accuracy and production efficiency through digital tools. Sharma. (2016). Digitalization of Motifs Based on Indian folk Paintings through CAD and their Adaptation on Apparels using Digital Printing Technique. *Research Journal of Family, Community and Consumer Sciences* : The art of folk painting in India is traditionally time-consuming and labor-intensive to draw by hand, but with the help of CAD technology the initial idea can be transformed into a visual representation of the fabric within a few minutes, realizing the fusion of the two types of folk paintings in a design that enhances the expressive power of the design. Concepcion et al., (2023), this study examines the impact of the use of computer-aided design (CAD) software in handloom weaving design by a social enterprise at the Cebu Institute of Technology (CIT) Aldgao Campus on the livelihood of local weavers and the preservation of the traditional handloom weaving industry in Aldgao.

Artificial Intelligence (AI), on the other hand, shows great potential for automatic design generation and production process optimization. Eskak and Salma (2020), this research is an overview of the application of AI in the crafts sector, and the findings show that AI is very useful for the crafts industry, including: effective and efficient production management, productivity optimization, human error minimization, and personalized marketing and customer service capabilities. Ratalewska (2024), this research analyzes the use of AI technologies in the design and product development of SMEs in the creative industries, identifying the main benefits that these technologies bring, the barriers and challenges faced by the companies analyzed.

Interdisciplinary research and collaboration further promotes the deeper integration of digital technologies with traditional crafts, driving innovation and applications. Lagares et al. (2018), the research outlines the parallels between this collective, collaborative and complex design work and the multidisciplinary, interdisciplinary and transdisciplinary approach. Nørgaard (2024), the research analyzes how to promote the innovative development of traditional crafts through cross-sectoral collaboration, including case studies and sharing of successful experiences.

The impact of digital technologies on traditional crafts is becoming more and more significant globally. Traditional crafts have undergone a process of transformation in the modernization process from relying exclusively on manual work to gradually integrating advanced digital technologies. This transformation has not only improved productivity, but also injected new innovative vitality into traditional crafts.

Current status of research on the development of digital technology and traditional handicrafts in China

In recent years, the development of the integration of digital technology and traditional handicrafts in China has become an important area of research. Zhang (2022), this study analyzes the modern inheritance of traditional handicrafts, and needs to carry out dialectical cognition and reflection based on the symbiotic mechanism constructed by digital media and the modern

inheritance of traditional handicrafts, so as to re-comprehend the logic of value and cultural connotation of the modern inheritance of traditional handicrafts in the era of digital media in the context of communication science. Li and Zhang (2019), this study interprets the excellent cases of digital media technology application, with a view to providing a reference for the innovation of traditional handicrafts communication methods. Luo and Zheng (2024), this study integrates artificial intelligence technology with the regenerative design of Yi embroidery, deeply analyzes the influence of artificial intelligence on the embroidery creation method and pattern generation, and explores the regenerative design and creation of Yi embroidery in the digital era.

China has made significant progress in integrating digital technologies with traditional crafts, but this process has also faced challenges such as the disconnect between technology and the transmission of traditional skills and the digital divide. Overall, digital technology brings opportunities for the development of traditional crafts, but issues still need to be addressed to achieve full integration and sustainable development.

Table 1 The process of making traditional Huishan clay figures.

No.	Process steps		Step-by-step analysis
1	design drawings		The artist needs to design the whole composition on paper first, so as to facilitate the modelling and kneading.
2	pinch molded clay pots	knead a prototype	The structure is shaped for the first time, making it easy to keep adjusting it at a later stage.
		pinch molded clay pots	It takes 5 shaping passes to set the shape and facilitate the maturation of the look.
3	trimming and mould turning	Trimming of Clay Blanks	The clay blanks are required to be smooth, not deformed, and able to be placed stably.
		Mould turning	Facilitates mass production.
4	coloured painted-on designs	underpainting	The overall topping is white for easy colouring.
		scribble (graffiti)	Carry out colour blocking, requiring uniform colour and a smooth surface.
		draw designs	The detailing is fine and beautiful.
		face painting	The facial treatment of the figures requires a great deal of craftsmanship.

Research on the development status of digital technology for Huishan clay figures

Zhang and Zhu (2019), this study explores the application value and realization of three-dimensional digital image acquisition and interactive display means in the protection and dissemination of intangible cultural heritage in physical form and analyzes the status quo of the protection and dissemination of Huishan clay figures, and proposes a solution of three-dimensional digitization means for the problems existing therein. Shi (2022), this paper analyzes the digital "revitalization" of Huishan mudmen in various ways, shows the visual experience brought by the intervention of 3D virtual technology in traditional non-heritage, deduces the design of Huishan mudmen emoticons and IP image peripheral products, and discusses the possibility and inevitability of "revitalization" of traditional non-heritage Huishan mudmen in the digital era. exploring the possibility and inevitability of "revitalization" of traditional non-heritage Huishan clay figures in the digital era.

Digital technology is gradually integrated into the protection and promotion of Huishan mudman, the current research on digital Huishan mudman only stays at the theoretical level, in practice or lack of certain data, to improve the quality of craftsmanship, innovative product design, and enhance the competitiveness of the market will be the key direction of its development.

Experimental design

Traditional Huishan clay figures

Huishan's kneading and moulding techniques have been continuously explored, practiced and innovated by generations of craftsmen in the long history, relying on the traditional master-disciple model for the inheritance and development of the techniques. The specific production steps are shown in Table 1.

The design process of traditional Huishan clay figures has long relied on the production method of traditional handicraft manufacturing and the "one to one" form of transferring embodied knowledge from master to apprentice, which is highly time-consuming and labor-intensive. At the same time, some of the kneading skills are at risk of being lost due to the interruption of knowledge transmission. Therefore, the introduction of digital technology into Huishan clay figures will bring about multiple changes.

The realization of digital technology in the design of Huishan clay figures

Under the rapid development of society, the integration of digital technology and traditional handcraft has become the development trend of non-heritage culture. Through the preliminary research on digitization and Huishan clay figures respectively, using digital technology to open up the innovation potential in the design process of Huishan clay figures can be realized in the following ways: Table 2.

Digital design of Hishan clay figures

There are many types of Huishan clay figures, mainly divided into "coarse goods" and "fine goods". The "coarse goods" are mainly based on festive and auspicious folklore images, the most classic image is called "Ah Fu", which adopts the molding process and is highly efficient in mass production. The shape is exaggerated and full, and the color is strong and contrasting, focusing on conveying the meaning of praying for good fortune through the naive form, which is a popular work for the mass market. "Fine goods", also known as "hand-pinched opera text", with opera characters, historical stories as the theme, hand-pinched molding. The craft is fine and complex, focusing on the character demeanor, clothing details of the carving, face can be as fine as the eyebrows, clothing lines smooth and layered, elegant and subtle colors, the pursuit of artistic expression and cultural connotation of the fusion, belongs to the collection of high-quality goods.

Based on the research results of the current development of Huishan clay figures, the use of digital technology can make Huishan clay figure design and production with the times of inheritance and innovation. The current application of digital technology in the field of Huishan clay figures can be divided into the following main stages: data collection establishment; cultural elements extraction and summarization; digital design program: creative prompts vocabulary construction (prompts), conceptual sketches processing, digital modeling, details modification and adjustment, and the final program finishing and output. Let's take the most recognizable classic image of Huishan clay figure "Ah Fu" as an example, because "Ah Fu" carries deep regional cultural connotations. With a fixed shape (round and fat body, smiling face and traditional dress) and a clear meaning (praying for blessings and good fortune), it is a concentrated manifestation of the "shape" and "meaning" of Huishan clay figures. Taking such an image, which carries the public's general perception, as a sample, clearly demonstrates the ability of digital design to strike a balance between "preserving the traditional charm" and "realizing innovative variants" - the need to dismantle the facial proportions, the traditional costume, and the symbolism of the clay figure. The need to dismantle core elements such as facial proportions and clothing patterns in order to create a digital module without destroying its iconic features is a constraint that validates the rigor of the digital program.

Suggestion

Through the above experiments, we can get the advantages that digital technology brins to the design and production of Huishan clay figures. However, these are still not enough, the digital transformation of non-heritage cultural creative design is more necessary to build a comprehensive, multi-level, diversified and multi-channel synergistic innovation ecosystem integrating digital technology.

Table 2 The way digital technology is implemented in the design process

Technology Type	Pathway	Design Process				
		Design Research	**Design Proposal**	**Design Production**	**Design Promotion**	**Design Marketing**
Text Generation	Chatgpt ERNIE Bot	Insight demand trend studies;Product positioning with user	Supporting problem analysis and data processing	Auxiliary style positioning	Personalized copywriting placement	Marketing copywriting
Image & Model Generation	Midjourney Stable Diffusion 3DMax 3DPrinting	Style acquisition & training	Prototype testing & iteration	Styrofoam treatment material adjustment	Promotional material generation	Marketing Poster Generation
Digital Human Generation	Meta AI Llama2 Heygen	Simulate user feedback	Presentation of design proposals	Product demonstration & Function explanation	Customer Service& Interactive Consultation	Intelligent explaining
Multimodal Composite Technology	Copilot Poe	Personalized demand collection	Rapid conceptualization programme	CMF design reference & parametric aids	Personalized campaign cross-platformadaptation	Crowd-sourcing& Personalized Recommendation

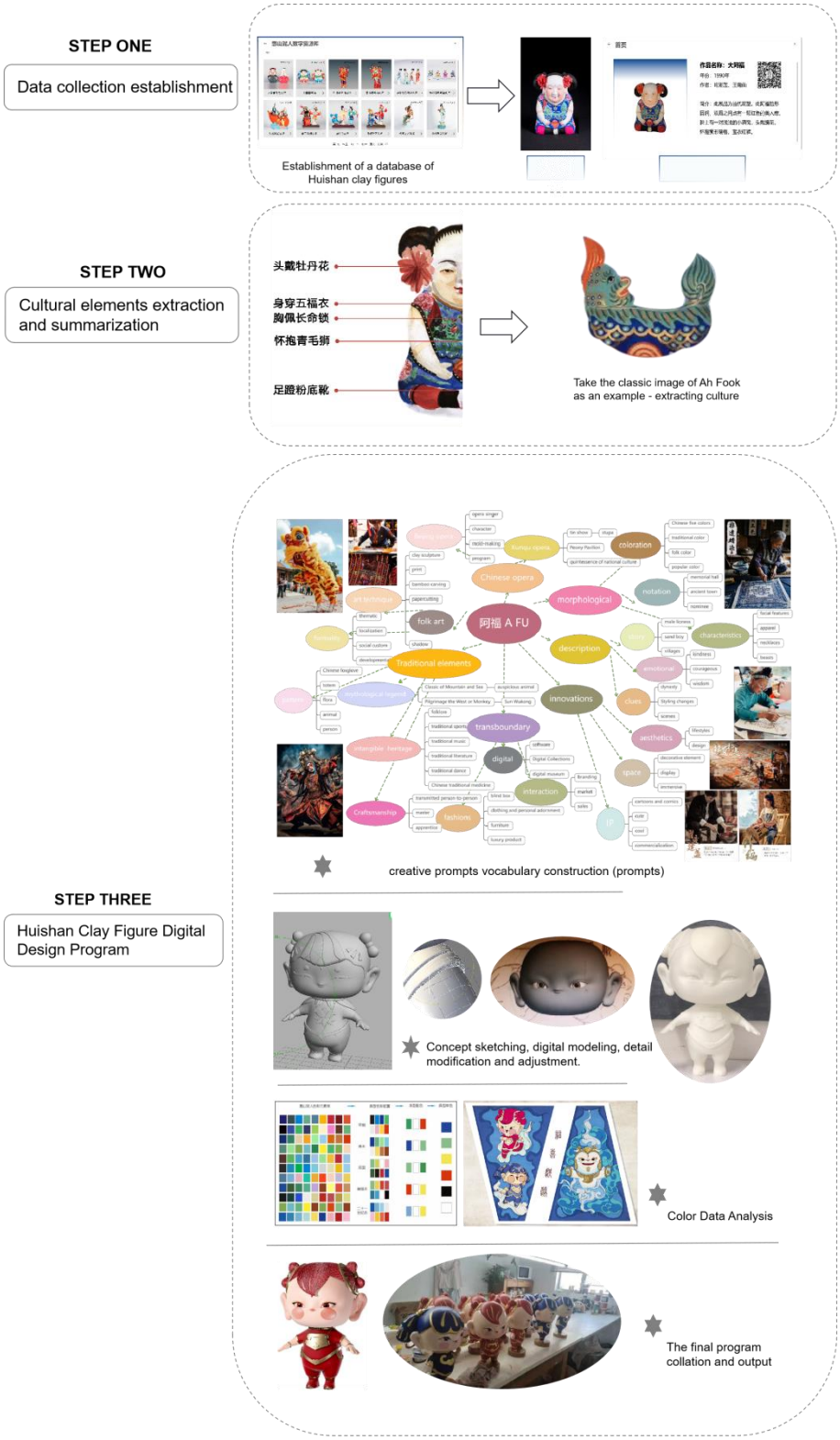

Figure 3 Demonstration of the digital design process of "Afu".

Source: Author's drawing

Conclusion

Compared with the design and production of traditional Huishan clay figures, we can visualize that digital technology brings more convenience and efficiency. On the one hand, it can assist designers and craftsmen to improve their design and innovation ability, and pass on and promote their profound artistic cultivation and exquisite handcraft skills; on the other hand, it can reduce the difficulty of traditional art, and provide a new impetus for the inheritance and development of traditional art. This study aims at the design method of digitized Huishan clay figures, proposes a digital design program, and takes the classic image of Huishan clay figure "Ah Fu" as an example, verifies the feasibility of the method, and provides a new idea for the design and production of traditional Huishan clay figures.

In summary, this study not only provides a reusable digital design method for Huishan clay figures, but also builds a practical paradigm for traditional handicrafts to "keep the right and innovate" in the digital era - - not only breaking through the efficiency bottleneck of traditional design through digital technology, but also avoiding technological alienation by taking the essence of the craft as the anchor point, which provides a reference path for other regional traditional handicrafts to modernize and transform. This provides a theoretical and practical reference path for the modernization and transformation of other regional traditional handicrafts.

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CRediT author statement

Author A: Conceptualization,Methodology, Data Curation,Writing - Original Draft, Project Administration.

Author B: Writing - Review & Editing, Supervision.

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