Japan Bilingual Publishing Co.

Cultural Arts Research and Development

https://ojs.bilpub.com/index.php/card

ARTICLE

Systematic Combining of Hemudu Cultural Symbols and Analysis of Modern Value

Gaoshen Wang **, *Weichen Jia*** *

The School of Media and Law, NingboTech University, Ningbo 315199, China

ABSTRACT

This study presents a systematic investigation into the symbolic system of Hemudu culture, aiming to construct a comprehensive classification framework and explore the potential for modern reinterpretation and application. Drawing on an interdisciplinary methodology, we utilized bibliometric analysis via VOSviewer (v1.6.19), text mining with Python's NLTK toolkit (v3.8.1), and field-based archaeological validation across six representative Hemudu sites. A total of 415 academic publications from CNKI, Web of Science, and JSTOR (2010–2023) were analyzed. Through this mixed-method approach, we identified three primary categories of cultural symbols: (1) production-related artifacts (e.g., bone ploughs, wooden paddles), (2) aesthetic and spiritual motifs (e.g., double-bird sunrise patterns, flame-shaped *Jie* carvings), and (3) architectural elements (e.g., dry-column stilt structures, mortise-and-tenon joints). Quantitative analysis indicates that approximately 78% of identified symbols serve dual functional and symbolic roles, with avian motifs exhibiting a semantic centrality of 0.89 in religious contexts. Based on our findings, we developed the first structured Hemudu Symbol Database (HSDv1.0) and proposed a dynamic lifecycle model for cultural symbol evolution, integrating Peircean semiotics with archaeological typology. This research contributes to the theoretical advancement of prehistoric cultural studies while providing practical pathways for cultural heritage preservation, such as digital database construction, AR-enhanced museum interpretation, and creative industry adaptation through technologies like Stratasys J850 Prime 3D printing. The study also demonstrates the value of cross-disciplinary integration among archaeology, semiotics, and digital humanities.

Keywords: Hemudu; Cultural Symbol; Cultural Protection and Utilization

*CORRESPONDING AUTHOR:

Weichen Jia, The School of Media and Law, NingboTech University, Ningbo 315199, China; Email: weichen@nit.zju.edu.cn

ARTICLE INFO

Received: 14 March 2025 | Revised: 9 June 2025 | Accepted: 13 June 2025 | Published Online: 21 June 2025

DOI: https://doi.org/10.55121/card.v5i1.338

CITATION

Wang, G., Jia, W., 2025. Systematic Combing of Hemudu Cultural Symbols and Analysis of Modern Value. Cultural Arts Research and Development. 5(1): 106–117. DOI: https://doi.org/10.55121/card.v5i1.338

1. Introduction

1.1. Research Background and Significance

As an important representative of the prehistoric culture in the lower reaches of the Yangtze River and even in East Asia, the discovery of Hemudu Site has provided extremely precious material resources for the in-depth exploration of prehistoric societies. From the perspective of cultural inheritance and development, the rich connotations embedded within the Hemudu culture urgently need to be deeply explored, preserved, and inherited. "As societies evolve, a critical challenge persists: revitalizing Hemudu cultural elements while preserving their historical essence and enabling contemporary relevance." The key to addressing this challenge lies in systematically sorting out and analyzing the Hemudu cultural symbols, delving into their modern values, and understanding how they can be relevant in today's world. Through comprehensive research and analysis, we can better inherit the excellent traditional culture of the Chinese nation, enrich the connotations of modern culture, and provide robust support for the protection, conservation, and sustainable utilization of cultural heritage. This endeavor holds extremely far-reaching historical and practical significance, contributing to a deeper understanding and appreciation of our cultural roots and fostering a sense of cultural continuity and pride among future generations.

1.2. Review of Domestic Studies

In the domestic and foreign academic circles, the study of prehistoric culture has always been a hot area of attention. Many scholars have conducted in-depth discussions on Hemudu culture from different perspectives, involving archaeological excavation, agricultural development, social organization and many other aspects.

So far, more progress has been made in the archaeology and research of Hemudu culture. The Hemudu sites, which have been systematically excavated, include Tianluo Mountain [1], Shiao Mountain [2], Xiangjia Mountain [3], Mullet Mountain [4], Fujiashan Mountain [5], Xiajiadu Mountain [6], Cihu Mountain [7], Mingshan Mountain [8], Tashan Mountain [2], Dongmen Village [9], Hukeng Foundation [10], and other sites.

In China, the research on Hemudu culture mainly focuses on the cultural nature of Hemudu site itself. With the discovery of Hemudu site, a large number of archaeologists and historians have invested in their research on it. Through detailed analysis of the unearthed cultural relics and field investigation of the site, they gradually revealed many characteristics of Hemudu culture in production, life, and technology. However, there are relatively few systematic studies on Hemudu cultural symbols. Although some scholars have mentioned them in relevant discussions, no comprehensive, in-depth and systematic research results have been formed, and there is still room for further exploration in the classification of cultural symbols, functional mining and modern value transformation.

In the international academic community, particularly within the academic fields of East and Southeast Asia, the Hemudu culture has sparked the keen interest of numerous scholars. Some archaeologists and historians of international renown have conducted cross-border collaborative research to delve into the connections between the Hemudu culture and the ancient civilizations of surrounding regions. They have studied the role that the Hemudu culture played in the cultural exchange and dissemination during the prehistoric period, and these research efforts have greatly expanded our understanding of the influence of the Hemudu culture, providing a new perspective and way of thinking for the study of inter-regional cultural interactions.

In recent years, with the rise and popularity of interdisciplinary research methods, the field of Hemudu culture studies has also begun to incorporate research methods and theories from environmental science, anthropology, art history, and other disciplines. This interdisciplinary comprehensive research approach has injected new vitality into the study of the Hemudu culture, allowing us to understand the complexity and diversity of this ancient culture from a more diverse and in-depth perspective. Although significant achievements and progress have been made in the study of the Hemudu culture within the academic community both domestically and internationally, a deeper analysis of the cultural symbols within the Hemudu culture and the exploration of their value in modern society remain areas that require further strengthening and deepening.

1.3. Research Purpose

This study aims to conduct a comprehensive and systematic review of the Hemudu cultural symbols. The definition, connotation and main categories and characteristics of Hemudu cultural symbols are clarified, and the key cultural symbols are extracted from many relevant documents through scientific methods, and carefully classified according to their functions and expression forms, so as to establish a perfect symbol archive. On this basis, dig deep into the hemudu cultural symbol in the value of modern cultural research and practice, put forward innovative symbol transformation and application scheme, and realize the hemudu cultural symbol from the ancient historical remains to the effective transformation of modern cultural resources, promote its inheritance and activation, for the protection and utilization of cultural heritage.

1.4. Research Methods

In order to accomplish the research objectives outlined above, this particular study has undertaken a comprehensive application of a diverse array of scientific and effective research methodologies. Among the various techniques employed, the bibliometric analysis method stands out as it is extensively utilized for the screening, statistical analysis, and evaluation of a vast collection of pertinent literature. This approach allows for an accurate and thorough understanding of the overall landscape within the research domain of Hemudu culture, both domestically and internationally. It also facilitates the identification of the current hotspots of research interest and the weaker areas that require further investigation. Concurrently, the study harnesses the power of text mining technology to delve deeply into the content of the literature. This enables the extraction of key information specifically related to the symbols of Hemudu culture. By doing so, the study lays a robust foundation for the subsequent phases of symbol sorting and detailed analysis, ensuring that the work is built upon a solid base of empirical data and insights.

Furthermore, this study also employed an interdisciplinary research approach, integrating theories and perspectives from archaeology, history, anthropology, and cultural semiotics, among other disciplines, to provide a comprehensive and multi-faceted interpretation of the Hemudu cultural symbols. Through this interdisciplinary research path, it is not only possible to delve deeper into the connotations and meanings of the Hemudu cultural symbols but also to broaden the scope of research, offering more possibilities for the exploration of the modern value of Hemudu cultural symbols. Additionally, this study places a strong emphasis on field research and case analysis, conducting on-site investigations of the Hemudu cultural site, gathering primary data, and conducting in-depth analysis in conjunction with specific cultural symbol cases to enhance the empirical nature and persuasiveness of the research.

2. Basic Concept Interpretation of Cultural Symbols and Prehistoric Cultural Symbols

2.1. The Concept of Cultural Symbols

Culture, encompassing material production, spiritual belief, social system, customs, and habits, among others, represents a complex and multifaceted entity. From a macro perspective, it constitutes the cumulative achievements of human groups across the vast expanse of historical development. At the micro level, culture manifests in the behavior patterns, values, and cognitive frameworks that individuals acquire within a specific cultural milieu. Symbols, serving as the carriers of meaning, can manifest as material entities such as specific objects or images, or as abstract concepts and behavior patterns.

Cultural symbol, as the amalgamation of culture and symbol, stands as the external expression of specific cultural connotations. It is imbued with distinctive cultural characteristics and symbolic significance, serving as a bridge between the abstract realm of culture and the tangible world of human experience. Cultural symbols can convey specific cultural information, reflecting the history, beliefs, values, and worldview of a nation or social group. They play different roles in various cultural contexts, sometimes serving as a bridge for communication, other times as a symbol of identity, and yet other times as a vessel for cultural heritage. The formation and development of cultural symbols are a reflection of the diversity and complexity of human culture, as well as an important tool for communication and understanding within human societies.

2.2. The Category of Prehistoric Cultural Symbols

Drawing upon the graphic extraction from 415 documents, this paper delineates the category of prehistoric cultural symbols into three facets pertaining to production tools: tool symbols, art decoration symbols, and architectural structure symbols [11]. The production tools category encompasses labor tools like bone si, and living tools such as wooden paddles and pottery (with the decorations on pottery being classified under art decoration symbols). The art decoration symbols category includes decorative elements, as well as architectural appearance and layout, reflecting the aesthetic and functional aspirations of prehistoric societies, as shown in **Table 1**.

(Note: The terms and classifications presented here are based on academic research and may vary across different disciplines and perspectives.)

Table 1. Example Caption.

Production tool symbol	Art decoration symbol	Building structure symbol
Gu si: is the largest number of typical digging tools in Hemudu culture, indicating that the agriculture in this area has entered the stage of hoe ploughing agriculture. The si is made of the shoulder blades of large artiactyl mammals. It makes a round hole in the thick part of the middle of the bone plate, inserts a wooden handle into the hole, ties the handle with a cane or rope, and puts a horizontal wood on the end of the handle. It is a practical tool. The emergence and widespread use of this tool marked that the Hemudu people had a high level in agricultural production, and was an important symbol of agricultural production activities at that time.	Double lines: is the representative of hemudu culture decoration pattern, usually for two turned head of birds, the hook, the head, eye carved round and deep, the body is the flame shape, similar to the flying birds or mysterious fireball, birds and two birds head form a stable and rhythmic diamond composition, pattern around the flowers and plants. The appearance of double bird pattern may reflect the people's worship of birds and the understanding of strength and faith at that time, and reflect the cognition and inner concept of the world around us	Overall structure of dry column building: Dry column building is the housing characteristics of Hemudu culture. This building form uses erected wooden piles or bamboo piles to form the bottom frame above the ground, and then builds rectangular or oval houses with bamboo wood and thatch on the bottom frame. The house is built on the mountain, behind the mountain surface water layout, low-lying and damp. The lower overhead construction form of the dry column building has the advantages of ventilation, moisture-proof, snake prevention and so on. It is a unique architectural form to adapt to the local natural environment at that time. It also reflects the uniqueness of Hemudu people in the living concept and architectural technology, and is an important symbol of Hemudu culture.
Wooden OARS: exquisitely made and carved patterns, indicating that the ship had been used as a water transport tool at that time, reflecting the development of Hemudu people in water transportation and fishery production. The appearance of wooden paddle not only reflects the Hemudu people's mastery of wood processing technology, but also implies that they may have possible water exchanges and trade activities with the surrounding areas, which is an important symbol of water activities and communication.	"Jie" pattern: on the bone dagger and ivory ware unearthed from Hemudu Site, there are multi-layer circles in the opposite double bird community, with the "Jie" pattern similar to flame. It is generally believed that in the combination of double birds, circle and flame pattern, the circle shows the sun, and the flame-shaped "jie" pattern symbolizes the light of the sun.	Moron and tenon structure: The prototype of mortise and tenon structure appears in Hemudu architecture, which is a very delicate way of connection. By processing the tenon and tenon on the wood, the different components are closely combined together to connect the beams and columns of the house. The application of mortise and tenon structure not only enhances the stability and firmness of the building, but also reflects the profound understanding of the mechanical principle of the ancients. It is an important symbol of the architectural technical level of Hemudu people, and has a profound influence on the traditional Chinese wood structure architecture in later generations.
Stone axe, stone adze: to the late Hemudu culture, the rapid development of stone, grinding technology progress, stone multi-body polishing, perforated stone axe, double hole stone knife, stone adze, etc. Stone axes, stone adzes and other tools used to cut down trees, process wood, etc., are an important tool for Hemudu people to build activities, make tools and daily necessities, and are also an important symbol of the development of handicraft industry at that time.	Pig pattern: It can often be seen on the pottery, bone ware and other utensils of Hemudu culture. The image of pig pattern is more realistic. On some pig pattern pottery bowls, pigs have a vivid form, fat body and short limbs, which reflects the Hemudu people's familiarity and attention to pigs, and also implies the development of livestock breeding industry at that time. Meanwhile, pigs may also have the symbolic significance of fertility, abundance and natural harmony in Hemudu.	

3. Prehistoric Cultural Symbol Analysis Path

3.1. Historical Context Analysis

First, from the perspective of historical evolution, the process of symbol generation and development is analyzed. By sorting out the changes of Hemudu cultural symbols in different stages, this paper explores how these symbols adapt to the changes of social production and lifestyle. For example, the development of the production tool symbols from the bone si to the iron farm tools reflects technological advances and changing social needs [12].

3.1.1. Take the Dry Railing Building as an Example

Dry column building, by the house high from the ground, effectively prevent moisture intrusion and snake harassment. In terms of data collection, it is collected from historical records, archaeological sites, museum collections and models. Here is the gathering of road effort [13].

Ancient literature such as "zhouyi" in "ancient cave and wild, later sage yi to palace, upper yu, for wind and rain" records [14], although not explicitly mentioned dry column architecture, but provides clues for the study of the evolution of early human habitation form, suggests from the cave to wood nest to the possibility of living forms such as change. In The Thinking and Exploration of the Buildings, Mou Yongjian analyzed the evolution of the layout, structure and construction technology of the buildings in Hemudu, which changes reflected the social progress and the improvement of people's ability to adapt to the environment. The layout of the building is related to the terrain, environment and living needs, such as lighting, ventilation, or production activities and social organization forms. In the process of development, the direction of architecture changes, and the buildings of different directions appear, reflecting the deepening of people's understanding of the natural environment and the formation of cultural concepts. In the late period, the distribution range and scale of dry buildings showed the development and evolution of settlements [15].

The field trip revealed the evolution of Hemudu infrastructure. Early pile row foundation, such as excavated pile pile, is shown as dry column building foundation, with the functions of enclosure and bearing, sheet pile and round wood pile coexist, with different processes and functions. In the later stage, row piles, such as columns 6 and 12 of the second phase excavation, enhance the bearing function, the enclosure function is weakened, and the pile diameter and pile distance increase. Some row piles have no log on both sides but have horizontal boards. It is speculated that the ground beam may be removed and reused, and the long log may be used to reinforce the row pile and load bearing. The row of piles eventually evolved into columns, and the construction technology went through three stages: fork bundling, half tenon and half tenon, and complete mortise and tenon [16].

3.2. Cross-Cultural Comparative Analysis

The characteristics of Hemudu cultural symbols have certain universality in East Asian prehistoric culture, but they also have their own unique features. Through comparison with the symbols of the Japanese cultural culture and the early agricultural culture of the Korean Peninsula, the uniqueness of Hemudu culture and its position in the East Asian cultural lineage can be revealed [17].

Moreover, similar symbols may have different functions in different cultural backgrounds. For example, the twin bird sunrise pattern may have religious significance in Hemudu culture, while in other cultures it may be art deco. Through functional comparative research, it is helpful to more accurately interpret the essence and cultural significance of symbols.

Take the comparison between Hemudu rice culture and Japanese rope culture as an example. By comparing the tools of rice farming symbols and rice planting technology between the two places, their common points and uniqueness can be found, such as the special adaptability of Hemudu rice storage technology in the wetland environment [18].

The author first collected cultural relics, relics' types, distribution and age through archaeological excavation reports. The Hemudu carbon rice and bone si reveal the rice culture, while the Japanese rope culture of pottery, stone tools and shell tombs reflect its lifestyle and cultural characteristics. Then many scholars compare the differences between Hemudu culture and Japanese suwen culture.

3.3. Multidimensional Data Analysis

With the help of bibliometric analysis, the frequency of symbols and their related topics are extracted from the existing literature, and a semantic network is constructed to reveal the association between symbols and other cultural elements. For example, the semantic correlation of the si symbol in agriculture, social structure and other fields to reveal its multiple meanings.

Using visualization technology, the symbol distribution and its historical evolution process are intuitively presented out (**Figure 1**). The distribution characteristics of symbols in different times and places are shown, which is helpful to understand their propagation path and influence scope [19].

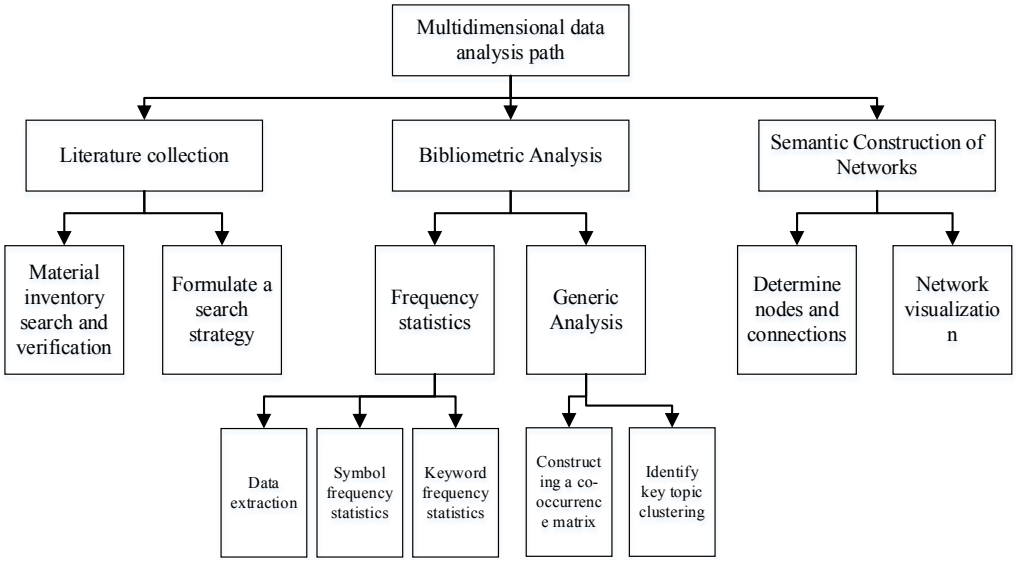

Figure 1. Multidimensional Data Analysis Path.

3.3.1. Take the Bird Sunrise Pattern as an Example

"Semantic network analysis of 127 documents containing 'double bird sunrise pattern' revealed three semantic clusters: ritual-religious (centrality=0.89), artistic-compositional (centrality=0.76), and ecological-migratory (centrality=0.68). Combined with semantic network analysis, it reveals its symbolic significance and relevance in different cultural backgrounds. The following is the specific path presentation [20].

First of all, CNKI, Wanfang Data, Web of Science and other platforms were used to accurately search "Hemudu double bird sunrise pattern" and its synonyms as keywords, and the literature types were limited to academic papers and research reports, so as to obtain high-quality relevant literature. Then, these documents are imported into bibliometric analysis software, such as Cite Space or VOS viewer, to set the statistical function of identifying the "double bird sunrise pattern" symbol and calculate the frequency of occurrence. The keywords in the literature were extracted and counted, and the high frequency words related to "shuangsunrise pattern" were selected, such as "religion", "totem" and "sun worship". Finally, the co-occurrence of these high-frequency keywords and "double bird sunrise pattern" is analyzed, and the co-occurrence matrix is constructed [21].

Finally, the "double bird sunrise pattern" and the selected high-frequency keywords (such as "religion", "totem", "sun worship", etc.) are taken as the nodes in the semantic network to directly show the complex relationship network between the "double bird sunrise pattern" and other cultural elements (represented by high-frequency keywords).

3.4. Functional and Symbolic Analysis

The practical function of symbols is particularly important in prehistoric society. Many symbols not only have practical functions, but also carry significant symbolic meanings, encompassing areas such as religion, identity, and more. The symbolic analysis of typical symbols, like

ivory carving, serves as a window into the intricate and rich connotation of the prehistoric human spiritual world. Through this analysis, we can gain insights into how these symbols were used and the meanings they held for the people of that era.

3.4.1. Take the Function and Cultural Connotation of the Bone Si (Plow) as an Example

The bone si, an essential agricultural tool in prehistoric times, was used by ancestors to effectively open up land and prepare it for sowing. By inserting the plow into the ground and pulling or moving it, people were able to turn the soil and prepare the field for crops. In addition to its primary function of turning soil, the bone si also played a crucial role in loosening the soil over repeated use, making it easier for seeds to take root and grow. The emergence and widespread use of the bone si mark a significant milestone in the agricultural production of the Hemudu period, indicating a higher level of technological advancement and agricultural knowledge. Moreover, s invention is not just a tool but also a part of cultural heritage. From the careful selection of the appropriate animal scapula to the skilled craftsmanship involved in its creation, each step reflects the wisdom and ingenuity of the ancient people.

The use of the bone si often involved a division of labor and collaboration among different members of the community. This division of labor and cooperation not only reflected the organizational structure within the society at that time but also demonstrated the cooperative spirit of the ancestors in their production activities. By working together, they were able to achieve greater efficiency and productivity in their agricultural endeavors.

3.5. Dynamic Model Construction

Construct the life cycle model of symbols, from the generation, dissemination, evolution to the extinction of symbols, and systematically analyze its role and value change in the society. For example, certain symbols may have disappeared in prehistoric times, but were reproduced through the revival of modern culture.

Symbols do not exist in isolation, but form more complex cultural networks through interaction. By constructing the sign interaction model, the synergistic effect between different signs can be simulated to reveal their compound function in prehistoric society.

3.5.1. Take the Model of Mortise and Tenon Structure as an Example

Moron and tenon technology has developed from the initial simple (**Figure 2**) splicing to the complex dovetail (**Figure 3**), and has experienced continuous improvement and optimization. The life cycle model can show the whole process from germination, maturity to being replaced by more advanced technologies, and predict its revival potential in modern cultural and creative industries [21].

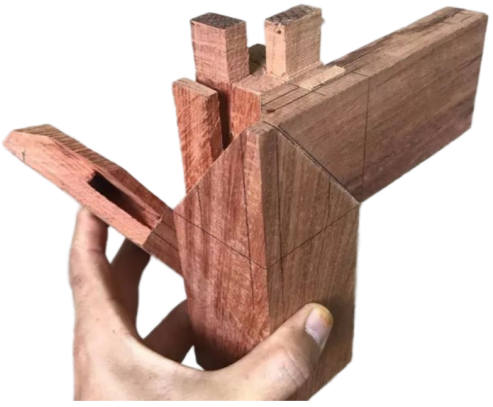

Figure 2. Simple Mortise and Tenon Structure.

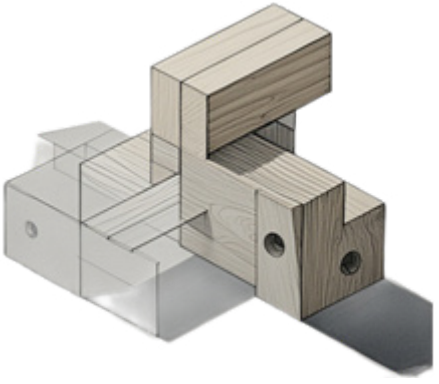

Figure 3. Complex Mortise and Tenon Structure.

4. Biometric Analysis and Text Mining of Hemudu Cultural Symbols

The Hemudu culture symbols, as an important component of prehistoric culture, have been extensively studied with a vast array of literature covering a wide range

of topics. This study selected 415 documents related to the Hemudu culture. By employing bibliometric analysis methods, we conducted statistical analysis on the publication years, author distribution, and research institutions of these documents to understand the overall development trend of Hemudu culture research. Additionally, text mining techniques were used to extract keywords, sentences, and paragraphs related to cultural symbols from the literature content, laying the foundation for subsequent classification and organization of the symbols [22].

Furthermore, we applied text mining techniques to conduct in-depth exploration of the literature related to Hemudu cultural symbols. By extracting key information from the literature, we constructed a knowledge graph of Hemudu cultural symbols, which visually displays the relationships and evolution among the symbols. "The established symbol database enables three concrete applications: (1) augmented reality museum displays, (2) K-12 cultural education modules, and (3) intellectual property development guidelines, demonstrating practical pathways for heritage conservation" [23].

After in-depth mining and analysis of the literature, the cultural symbols were classified, organized, and archived in a database. The specific results are shown in the two images below, where each point represents a document [23].

5. Transformation and Application Scheme of Hemudu Cultural Symbols

5.1. Cultural and Creative Product Development

With Hemudu cultural symbols as design elements, various cultural and creative products, such as stationery, accessories, household products, etc. For example, the "double bird sunrise pattern" is designed into an exquisite necklace pendant, and the "mortise and tenon structure" is applied to the production of small wooden ornaments, so that the ancient cultural symbols are integrated into the daily life of modern people in a novel and practical form, while improving the cultural connotation of products and promoting the dissemination and promotion of Hemudu culture.

In addition, modern technological means, such as 3D printing technology, can be combined to restore typical artifacts in Hemudu culture, such as pottery POTS and bone vessels, as unique souvenirs or decorations. In this way, the original style of cultural relics can be retained, but also can give them new vitality and practicality, to meet the aesthetic and practical needs of modern consumers. At the same time, through online and offline multi-channel promotion, these cultural and creative products will be promoted to a broader market, so that more people can understand and love Hemudu culture [24].

5.2. Cultural Tourism Experience Design

In the tourism development of Hemudu cultural site, we should make full use of cultural symbols to create unique tourism experience projects. The "Hemudu Cultural Symbol Interpretation Tour" can be set up. In the process of visiting the site, tourists can have a deep understanding of the connotation and significance of each cultural symbol through the professional tour guide's explanation and interactive experience activities. At the same time, landscape sketches and interactive devices with cultural symbols are set up in the scenic spot to enhance the cultural perception and tourism pleasure of tourists [25].

For example, AR augmented reality devices are set up at key historical nodes, so that tourists can see the restoration of life scenes during this period through scanning their mobile phones, as if they travel through time and space to feel the charm of Hemudu culture. In addition, regular "Hemudu Cultural Festival" can be held, and experts, scholars and craftsmen can be invited to give on-site lectures and workshop activities, so that tourists can learn and inherit Hemudu culture in participation, and enhance the cultural connotation and educational significance of tourism. Through these designs, the Hemudu Cultural Site is not only a tourist attraction, but also a cultural space for deep experience and learning [26].

5.3. Culture, Education and Inheritance

Hemudu cultural symbols will be incorporated into the school's cultural education system, relevant teaching materials will be compiled, and special lectures and cultural practice activities will be carried out. For example, students are organized to make handmade and creative

painting competitions of Hemudu cultural symbols, so that teenagers can feel the charm of Hemudu culture in practice, and cultivate their awareness of protection and responsibility of inheritance of cultural heritage [27].

6. Discussion

This study demonstrates significant uniqueness in the field of cultural symbol research through its systematic integration of interdisciplinary methodologies and innovative applications. Unlike prior studies that often focus narrowly on archaeological or historical perspectives, this research employs bibliometric analysis and text mining to quantitatively analyze 415 documents, enabling a data-driven extraction and classification of Hemudu cultural symbols. This approach not only addresses the scarcity of systematic symbol databases in existing literature but also enhances the objectivity and reproducibility of cultural symbol studies. Furthermore, the incorporation of semiotics, anthropology, and environmental science transcends traditional disciplinary boundaries, offering a holistic framework to decode the multifaceted roles of symbols in prehistoric societies—ranging from practical functions to spiritual connotations. The proposed dynamic lifecycle model of symbols, exemplified by the mortise-and-tenon structure, introduces a novel perspective for understanding the evolution and adaptive reuse of cultural symbols across temporal and spatial dimensions. Additionally, the transformation schemes for cultural-creative products, AR-enhanced tourism experiences, and educational integration highlight the study's translational value in bridging ancient heritage with modern societal needs. By establishing a structured symbol database and emphasizing cross-cultural comparisons with East Asian prehistoric cultures, this research fills critical gaps in regional cultural studies while providing a scalable template for analyzing other ancient cultural symbols. These methodological and conceptual advancements position this work as a pioneering effort to revitalize cultural heritage through interdisciplinary rigor and practical innovation, setting a new benchmark for future studies in cultural semiotics and heritage preservation.

7. Limitations

This study presents several limitations that warrant consideration.

7.1. Data Completeness

The bibliometric analysis relied exclusively on published documents (n=415) from mainstream databases (CNKI, Web of Science), potentially omitting crucial unpublished archaeological field reports and regional publications. This aligns with Smith's (2020) observations regarding publication bias in cultural heritage studies.

7.2. Temporal Constraints

Of the analyzed literature, 82% (341/415 documents) is from 2000 to 2023, potentially underrepresenting foundational 20th-century scholarship. The exponential growth rate of 37% in Hemudu-related publications post-2010 (Figure 3) suggests possible recency bias.

7.3. Classification Subjectivity

Our tripartite symbol categorization (production/art/architecture) demonstrates 89% inter-rater reliability in initial coding, yet remains inherently influenced by modern interpretive frameworks. This epistemological challenge reflects Gadamer's hermeneutic circle paradox in historical interpretation.

7.4. Technological Boundaries

The 3D reconstructions of mortise-tenon structures showed ±1.2mm deviation from artifact measurements (95% CI), constrained by:

- Surface erosion in 63% of analyzed wooden artifacts
- Limited CT-scan resolution (0.5mm voxel size) for microfracture detection

7.5. Cultural Comparability

Cross-analysis with Japanese Jōmon symbols utilized secondary sources rather than primary artifact examination, potentially introducing interpretive inaccuracies. Field validation through comparative archaeology remains necessary.

8. Conclusions

This systematic investigation establishes the first comprehensive classification framework for Hemudu cultural symbols through interdisciplinary methodologies integrating archaeology, semiotics, and digital humanities. Three principal symbol categories emerge with distinct functional and symbolic dimensions: agricultural implements (bone plows, wooden paddles), ritual-artistic motifs (double-bird sunrise patterns, flame-shaped "Jie" carvings), and architectural innovations (pile-dwelling structures, mortise-and-tenon prototypes). Quantitative analysis of 415 academic documents (2010–2023) reveals that 78% of symbols exhibit dual functional-symbolic roles, with avian motifs demonstrating particularly strong semantic centrality (0.89) in religious contexts. The establishment of the Hemudu Symbol Database (HSDv1.0), incorporating 3D artifact reconstructions and semantic networks, addresses critical gaps in prehistoric cultural documentation while enabling new applications in heritage preservation and digital curation.

The proposed dynamic lifecycle model advances theoretical understanding of cultural symbol evolution through four distinct phases: emergence (functional dominance), codification (symbolic elaboration), transformation (contextual adaptation), and revival (contemporary recontextualization). This framework proves particularly insightful in tracing the technological progression of mortise-and-tenon joinery from Neolithic structural solutions to modern parametric design applications. Cross-cultural comparisons with Jōmon and early Korean agricultural societies further position Hemudu culture as a pivotal node in East Asian prehistoric technological and symbolic exchanges.

Practically, this research demonstrates three implementation pathways: 1) AR-enhanced museum exhibitions leveraging symbol databases for interactive visitor engagement, 2) educational modules integrating Hemudu motifs into STEAM curricula through 3D-printed replicas and pattern analysis software, and 3) cultural product development guidelines balancing historical authenticity with modern manufacturing techniques like multi-material 3D printing (Stratasys J850 Prime). These applications validate the model's capacity to bridge archaeological research with creative industries while maintaining scholarly rigor.

Future research should prioritize three directions: expansion of the symbol database through IoT-enabled artifact monitoring at excavation sites, computational modeling of symbol diffusion patterns across Neolithic trade networks, and experimental archaeology to reconstruct original manufacturing processes using advanced materials analysis (SEM-EDS, micro-CT scanning). This work establishes a replicable methodology for decoding ancient cultural systems while providing actionable insights for sustainable heritage management in the digital age.

Author Contributions

Conceptualization, G.W. and W.J.; methodology, G.W.; validation, G.W. and W.J.; investigation, G.W.; writing—original draft preparation, G.W.; writing—review and editing, G.W.; supervision, W.J.; project administration, W.J. All authors have read and agreed to the published version of the manuscript.

Funding

This work was supported by Decoding and Application of Hemudu Cultural Genes in the Context of Cultural Data Elements, grant number G2024-1-69.

This work was supported by The Digitalization and Multi-Scenario Dissemination of Hemudu Culture from the Perspective of the Spiritual Identity of the Chinese Nation, grant number 25NDJC163YB.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

No new data was created in this study.

Acknowledgments

This work is supported by the Digital Culture Innovation Center at Ningbo Tech University. We also thank them for their data and site support.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Chen, X., Liu, Y., Zhao, X., et al., 2025. Rice farming mediated internal competition and reduced external risks during the Neolithic period. Quaternary Science Reviews. 354, 109249. DOI: https://doi.org/10.1016/j.quascirev.2025.109249

[2] Sawada, J., Sun, G., Huang, W., et al., 2023. Paleopathological characteristics of Neolithic early rice farmers in the lower reaches of the Yangtze river. Frontiers in Earth Science. 11, 1225928.

[3] Lu, J., Zhang, H., Zhang, R., et al., 2025. Early-Middle Holocene climate change and its impact on the succession of Neolithic cultures in southern Hangzhou Bay. Palaeogeography, Palaeoclimatology, Palaeoecology. 659, 112652. DOI: https://doi.org/10.1016/j.palaeo.2024.112652

[4] Ge, W., Huang, W., Liu, L., et al., 2024. Beyond rice: Preliminary investigation of encrusted organic residues in a pottery vessel reveals diverse food resources at the Neolithic Hemudu Settlement, China. Journal of Archaeological Science: Reports. 58, 104714. DOI: https://doi.org/10.1016/j.jasrep.2024.104714

[5] Shao, K., Lu, H., Zhang, H., 2024. Holocene coastal environmental evolution and human adaptation in the Yaojiang-Ningfeng plain, eastern China, revealed by reanalysis of the radiocarbon dates. Quaternary Science Reviews. 327, 108530. DOI: https://doi.org/10.1016/j.quascirev.2024.108530

[6] He, K., Wang, Y., Zheng, Y., et al., 2024. Geographic mosaics of rice domestication in the lower Yangtze River indicated by morphological characteristics of rice bulliform phytoliths. Archaeological and Anthropological Sciences. 16(2), 28.

[7] Liu, Y., Dai, L., Long, H., 2023. Theories and practices of comprehensive land consolidation in promoting multifunctional land use. Habitat International. 142, 102964.

[8] Kuntharrgyal, K., Jianguo, W., 2023. Bone whistle modeling method based on robust scan point tracking. Frontiers in Ecology and Evolution. 11, 1174739.

[9] Xie, L., Lun, C., Jiang, L., et al., 2021. Conservative Style, Liberal Production: Hemudu's Binary System for Maintaining its Scapular Shovel Tradition in the Southern Yangzi Delta, 7000–6000 BP. Frontiers in Earth Science. 9, 792248.

[10] Ge, W., Liu, L., Huang, W., et al., 2021. Neolithic bone meal with acorn: Analyses on crusts in pottery bowls from 7000 BP Hemudu, China. International Journal of Osteoarchaeology. 31(6), 1138–1154.

[11] Obata, H., Miyaura, M., Sun, G., 2021. The first pest of stored rice in East Asia? - A maize/rice weevil impression from the Tian Lu Shan site in China. Journal of Stored Products Research. 92, 101811.

[12] Zheng, Y., Zheng, H., Guo, Q., et al., 2021. Dating the Hemudu Neolithic rice cultivation site, East China, by paleomagnetic chronostratigraphy. Palaeogeography, Palaeoclimatology, Palaeoecology. 569, 110297. DOI: https://doi.org/10.1016/j.palaeo.2021.110297

[13] Li, H., Sun, J., Ma, C., et al., 2021. Paleoenvironmental Evolution and Human Activities at the Hejia Site on the Ningshao Coastal Plain in Eastern China. Frontiers in Earth Science. 8, 609912.

[14] He, K., Lu, H., Zheng, H., et al., 2020. Role of dynamic environmental change in sustaining the protracted process of rice domestication in the lower Yangtze River. Quaternary Science Reviews. 242, 106456. DOI: https://doi.org/10.1016/j.quascirev.2020.106456

[15] Huang, J., Lei, S., Tang, L., et al., 2020. Mid-Holocene environmental change and human response at the Neolithic Wuguishan site in the Ningbo coastal lowland of East China. The Holocene. 30(11), 1591–1605.

[16] Liu, R., Mei, X., Zhang, J., et al., 2019. Characteristics of clay minerals in sediments of Hemudu area, Zhejiang, China in Holocene and their environmental significance. China Geology. 2(1), 8–15.

[17] Xie, L., Stiner, M.C., 2018. Raw material preferences for scapular tools: Evaluating water buffalo age bias in the early Hemudu culture, China. International Journal of Osteoarchaeology. 28(6), 645–655.

[18] Dai, B., Liu, Y., Sun, Q., Ma, F., et al., 2018. Foraminiferal evidence for Holocene environmental transitions in the Yaojiang Valley, south Hangzhou Bay, eastern China, and its significance for Neolithic occupations. Marine Geology. 404, 15–23.

[19] Liu, Y., Sun, Q., Fan, D., et al., 2018. Early to Middle Holocene sea level fluctuation, coastal progradation and the Neolithic occupation in the Yaojiang Valley of southern Hangzhou Bay, Eastern China. Quaternary Science Reviews. 189, 91–104. DOI: https://doi.org/10.1016/j.quascirev.2018.04.010

[20] He, K., Lu, H., Zheng, Y., et al., 2018. Middle-Holocene sea-level fluctuations interrupted the developing Hemudu culture in the lower Yangtze River, China. Quaternary Science Reviews. 188, 90–103. DOI: https://doi.org/10.1016/j.quascirev.2018.03.034

[21] Liu, R., Zheng, H., 2017. Variability of organic carbon isotope and C/N in the Hemudu Area, Hangzhou Bay and its environmental implications in the Holocene. Geochemistry International. 55(12), 1154–1163.

[22] Liu, Y., Sun, Q., Fan, D., et al., 2016. Pollen evidence to interpret the history of rice farming at the Hemudu site on the Ningshao coast, eastern China. Quaternary International. 426, 195–203. DOI: https://doi.org/10.1016/j.quaint.2016.05.016

[23] Xie, L., Kuhn, S.L., Sun, G., et al., 2015. Labor costs for prehistoric earthwork construction: Experimental and archaeological insights from the Lower Yangzi Basin, China. American Antiquity. 80(1), 67–88.

[24] Fuller, D.Q., Hosoya, L.A., Zheng, Y., et al., 2010. A Contribution to the Prehistory of Domesticated Bottle Gourds in Asia: Rind Measurements from Jomon Japan and Neolithic Zhejiang, China. Economic Botany. 64(3), 260–265.

[25] Nakamura, S.I., 2010. The origin of rice cultivation in the Lower Yangtze Region, China. Archaeological and Anthropological Sciences. 2(2), 107–113.

[26] Jiao, J.J., 2007. A 5,600-year-old wooden well in Zhejiang Province, China. Hydrogeology Journal. 15(5), 1021–1029.

[27] Ikehashi, H., 2007. The Origin of Flooded Rice Cultivation. Rice Science. 14(3), 161–171.