Advancing Culturally-Adaptive Sustainable Wind Energy Innovations: Utilizing the Semiotics of the Ruyuan Yao Ethnicity

Wenxi Jiang[a], JiaJia Jiang[b], Peng Du[c*], Kaihong Wang[d]

{jarvis000421@163. Com[a], jjj18948851329@qq.com[b], 935769845@qq.com[c], 117688888@qq.com[d]}

Guangdong University of Foreign Studies College of Art, Guangzhou, China

Abstract. This study explores the integration of Ruyuan Yao ethnic symbols into sustainable wind energy device designs, aiming to blend cultural heritage with sustainable development principles. Employing a robust methodology that includes literature reviews, field investigations, and the cross-application of binary and ternary semiotic models, this research rigorously analyzes symbol relationships from multiple theoretical perspectives. Binary relationships facilitate straightforward symbol extraction for practical application, while ternary relationships enhance user interaction by connecting these symbols with user interpretations. A bespoke design model, incorporating ethnic elements through the cross-application of binary and ternary semiotic models, was utilized for the encoding of design features; this encoded design was subsequently decoded using the KJ method, which provided quantitative assessments to validate the initial design decisions. Both the outputs of the KJ method and qualitative evaluations through renderings confirmed the model's efficacy in meeting specific user requirements and adhering to stringent design specifications. This approach not only pioneers culturally adaptive technologies but also underscores the vital role of cultural symbolism in enhancing sustainable development practices. By bridging cultural sensitivity with environmental solutions, this study contributes to the preservation of ethnic cultural heritage and enriches the field of sustainable technology with a unique cultural perspective.

Keywords: Semiotic Design; Ruyuan Yao Ethnic Symbols; Sustainable Energy Device Design;KJ Method; Cultural Adaptation; Cultural Heritage Preservation

1 Introduction

Over the last three centuries, human activities, especially carbon dioxide emissions, have profoundly impacted the global environment, potentially causing long-term shifts in climate patterns and natural ecosystems[1]. This situation highlights the urgent need for advancements in sustainability science[2], supporting key United Nations Sustainable Development Goals like SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities). These goals emphasize the protection of the environment and the conservation of natural resources by advocating for the development of green, low-carbon energy solutions. Amid growing initiatives for sustainable infrastructure, rapid urbanization has diverted resources from rural green energy projects[3], making these efforts predominantly urban-centric. These regions face significant challenges in adopting sustainable energy due to outdated

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infrastructure, a lack of expertise, and the complexities of merging modern technologies with unique cultural contexts. This scenario underscores the ongoing reliance on non-renewable energy sources and underscores the critical need for concerted efforts to bridge this gap.

Given the environmental and socio-economic challenges, the sustainable revitalization of ethnic rural areas is both visionary and essential. In light of China's ethnic diversity and numerous culturally rich villages, this study the focus here is on the Ruyuan Yao ethnic minority village to weave sustainable development principles into these unique cultural settings. The analysis delves into the cultural values of the Ruyuan Yao, employing a combination of field research and literature review. This integration deeply embeds the Ruyuan Yao's cultural symbols and totems into the design of wind energy devices, enhancing localization and relevance. Semiotic models are developed that merge ethnic cultural elements with technology, fostering innovative wind energy device designs tailored for the Ruyuan Yao village. This method highlights how Yao totems and symbols are pivotal in crafting innovative, sustainable energy pathways. Utilizing an interdisciplinary approach, the project not only promotes a shift towards cleaner, low-carbon energy frameworks but also champions culturally-adaptive technologies. By employing the semiotics of the Ruyuan Yao, the project effectively preserves and disseminates their culture. Moreover, the work enriches the dialogue on sustainable development and ethnic cultural preservation, introducing novel perspectives on culturally sensitive sustainable energy solutions.

1.1Analysis of Cultural Values of the Ruyuan Yao Ethnic Group

Nestled in formidable mountains, the Shaoguan Ruyuan Yao community is renowned for its rich cultural heritage, deeply intertwined with the natural landscape and ancestral history. This study prioritizes cultural sensitivity towards the Ruyuan Yao, acknowledging their unique characteristics, traditions, values, and customs. By integrating these cultural insights into all aspects of project planning and implementation, this research seeks to promote sustainable development and cultural coexistence. Specifically, the "Worship of Panwang" ceremony, recognized as National Intangible Cultural Heritage in 2006, encapsulates the spiritual and cultural depth of the Ruyuan Yao. With rituals including chanting, libations, and dancing, the Panwang Festival, boasting a history of over 1700 years, is crucial in preserving Yao culture. In terms of embroidery, the Ruyuan Yao hold totemic symbols in high regard; patterns such as octagonal designs represent blessings, wutong tree patterns symbolize prospe rity, lotus motifs signify purity, and deer patterns denote gratitude, all integral parts of the "Seal of Panwang."

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the “Seal of Panwang.” These designs reflect the Yao’s reverence for nature and their commitment to historical preservation, thereby acting as pivotal markers of Yao identity and cultural symbols. Nevertheless, rapid urbanization presents significant challenges to these cultural expressions. The study employs Ferdinand de Saussure’s binary relationships for symbol extraction, enhanced by Charles Sanders Peirce’s ternary relationships for a more profound semiotic analysis. This method facilitates the design of sustainable wind energy devices transitioning from basic two-dimensional representations to complex three-dimensional models. Integrating semiotic theories with culturally adaptive wind energy solutions, this research blends traditional heritage with modern technologies, highlighting the crucial role of cultural symbols in advancing sustainable technology.

1.2Background of Semiotics Research

Symbols, serving as external manifestations of internal concepts, have been fundamental to human communication from its earliest days. For instance, ancient hieroglyphs, which combine pictorial and symbolic meanings, effectively convey complex messages in a simple visual form. The evolution of complex societies necessitated the development of semiotics, a field dedicated to analyzing the creation, use, and significance of symbols and their societal roles. Ferdinand de Saussure introduced the concept of a binary relationship, emphasizing a straightforward correlation between the “Signifier”, the form of a symbol, and the “Signified”[4], its underlying meaning. Building on this, Charles Sanders Peirce expanded the theory into a “triadic relationship”, which includes the “Representamen”, the form; the “Object”, the content it denotes; and the “Interpretant”, the interpretative process[5]. This evolution from binary to triadic relationships illustrates the deepening complexity of semiotic theory over time.

Further investigations have explored the application of semiotics in design. For instance, leveraging Saussure’s framework, Yang Bei and colleagues innovatively applied Yi ethnic graphical elements in clothing design[6]. Similarly, drawing on Morris’s framework, Li Chun and his team reinterpreted and redesigned regional symbols from the cultural artifacts of the Hongjiang Ancient Commercial Town[7]. Utilizing Peirce’s triadic theory, Ni Taile and collaborators decoded literary and visual symbols from Li Bing’s works for cultural product design[8]. Furthermore, Sun Shengbo and colleagues conducted a comparative analysis of the applications of semiotics in cultural and creative design, highlighting the strengths and limitations of the three semiotic methodologies[9]. It is notable that the application of semiotic methods has primarily focused on two-dimensional visual fields such as graphic design, clothing design, and packaging, leading to a homogenization of products and a lack of innovative structural design.

This study draws on a broad application of semiotics and innovatively combines the binary and triadic models of semiotics to establish a comprehensive analytical framework. By employing binary relationships as the foundation for initial symbol extraction and leveraging triadic relationships to delve deeper into user psychology and environmental contexts, this dual-layered method not only facilitates direct interpretation of information but also supports deep-level analysis, thus fostering a more comprehensive understanding of semiotic principles. This research contributes to expanding the theoretical foundations that guide design practices, not only circumventing the pitfalls of relying solely on one-dimensional semiotic strategies

but also enhancing the role of semiotics in the development of user-centric and environmentally conscious design solutions.

1.3Construction of Semiotics Research Approach

Design progresses iteratively from simple to complex concepts, embodying a dynamic evolution process. This research conducts an interdisciplinary analysis of Ruyuan Yao ethnic embroidery symbols, starting with an exploration of Ferdinand de Saussure's binary relationships. Saussure's binary relationship model emphasizes the compositional and semantic aspects of symbols, highlighting the link between a symbol's physical form and its conceptual representation. This relationship is essential for extracting external features and internal meanings of symbols, facilitating clear visual and material interpretations that capture the cultural essence of the Ruyuan Yao for integration into sustainable devices. The deployment of these devices in ethnic villages, with specific stylistic and structural requirements, requires employing Charles Sanders Peirce's triadic relationship method to refine the design process. This method enriches the analysis by emphasizing the interpretive and meaning-generative aspects of symbols, illustrating that their significance extends beyond mere form to encompass interactions with interpreters. This enhancement is particularly achieved through focusing on Peirce's "Interpretant" phase, which amplifies the design's ethnic relevance and contextual sensitivity, ensuring designs align with ethnic identity.

By utilizing surface binary relationship analysis and deep ternary relationship analysis, traditional two-dimensional Yao motifs are transformed into three-dimensional designs for sustainable wind energy structures (as illustrated in Figure 1), this methodological advancement not only deepens designers' understanding but also ensures that design practices are attuned to user needs and relevant societal contexts. This study underscores the transformative potential of cultural symbolism in the development of sustainable technologies, marking a significant progression in integrating cultural considerations into environmental strategies.

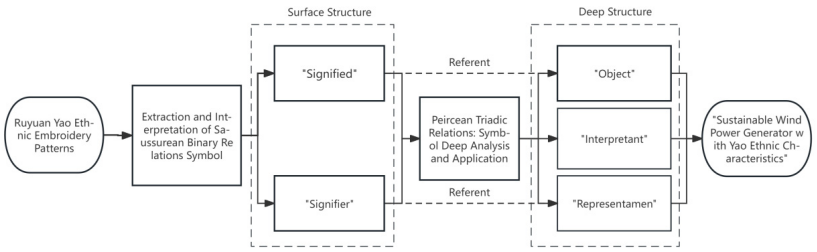


Fig. 1. The research design process of Yuyuan symbols in the context of semiotics

2 Materials and Methods

2.1 Surface Interpretation of Yao Embroidery Based on Saussurean Semiotics

Analyzing Ruyuan Yao ethnic embroidery symbols from the perspective of the binary relationship semiotics initially conceptualized by Ferdinand de Saussure, this study examines

these symbols, highlighting two-dimensional linguistic structures: the “Signifier,” representing the physical form of the symbol, and the “Signified,” denoting its spiritual or meaning dimension. The interplay between form and meaning forms the essence of a complete symbol. Saussure’s model of binary relationships emphasizes the natural depiction of symbols, facilitating their expressive restoration through visual and tactile engagement.

By conducting field surveys and questionnaires, this research categorizes the external features of Ruyuan Yao embroidery—shapes, colors, structures, materials, and patterns—as the “Signifier” within this binary framework. Conversely, historical allusions, cultural essence, blessings, and aesthetic elements within specific contexts make up the “Signified.” Beyond augmenting visual aesthetics, Yao embroidery embodies rich “Signified” content, thus preserving the spiritual foundation of the ethnic culture.Interpreting Yao embroidery requires delving beyond the surface, systematically organizing, extracting, and interpreting both superficial and deeper aspects of the embroidery symbols, as illustrated in Figure 2.

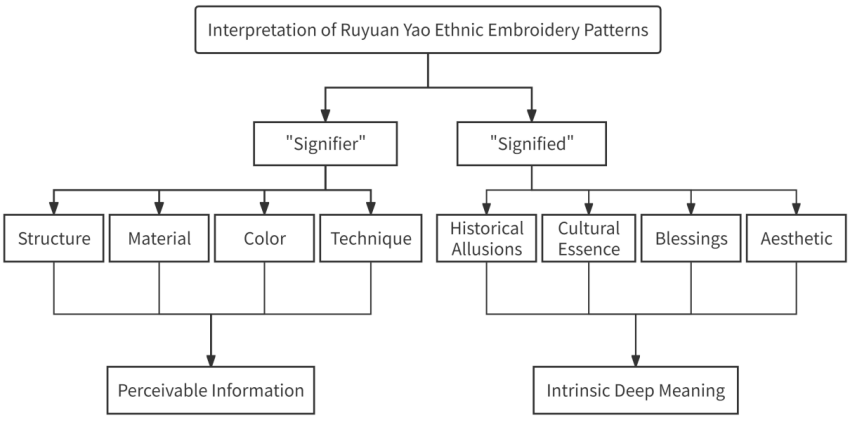


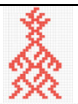
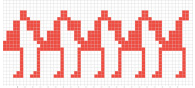
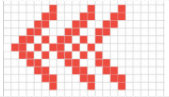
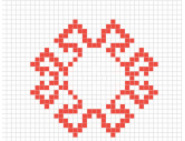
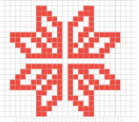
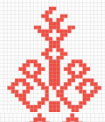
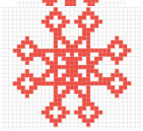
Fig. 2. Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol.

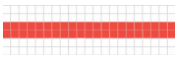
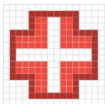
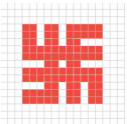
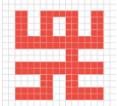
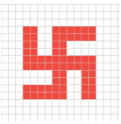
Through comprehensive surveys, interviews, and documentary analysis, this study explores the symbolic systems of the Ruyuan Yao community, which has conserved its rich history through oral narratives, craftsmanship, and patterned totems. These elements weave ancient folklore, customs, and myths into the fabric of their historical legacy. Yao embroidery, known as “female red,” epitomizes the spiritual essence of Yao culture, perpetuating beliefs passed down through generations. As emblems of luck, protection, and reverence, Yao embroidery holds a central role in the Yao’s cultural heritage.

This research utilizes Ferdinand de Saussure’s binary relationship model to illuminate the intricate interactions between symbolic representations and cultural meanings. Professor Chen Qixin categorizes Yao embroidery motifs into human figures, animals, plants, geometric shapes, and symbolic motifs[10], each carrying distinct cultural significances. Through extensive fieldwork and analysis, this study documents and organizes the visual manifestations of Yao embroidery, employing Computer-Aided Design (CAD) software to precisely illustrate these motifs as shown in Table 1.

In-depth analysis within the binary relationship framework aligns “Signifier” with “Signified,” effectively capturing the historical narratives, customs, and traditions of the Ruyuan Yao community. Referencing Maslow’s hierarchy of needs, the evolution of these motifs mirrors significant socio-historical shifts, marking the community’s transition from basic survival activities to a more complex agrarian society. Embroidery designs go beyond decoration, reflecting the Yao’s advancements in societal civilization and profound spiritual beliefs. These motifs not only symbolize ethnic identity but also bolster community pride and cohesion, playing a pivotal role in maintaining the identity and unity of the Yao people.

Table 1. Analysis of Characteristics of Yao Embroidery Graphic Symbols (Partial)

Category	Symbol name	Symbolic graphics	Symbolic meaning
Human patterns	Male human patterns		Intelligence and courage combined
	Female human patterns		Virtuous wife and loving mother
Animal patterns	Deer patterns		Adoration, worship, gratitude
	Bird patterns		Life propagation, continuous and uninterrupted
	Fish patterns		Abundance year after year, ample food and clothing
	Spider patterns		Ward off evil, dispel disasters, and cure diseases
	Centipede patterns		
Botanical Patterns	Octagonal flower patterns		Gratitude, blessings, and pest control
	Pinecone patterns		Vitality, resilience
	Lotus flower patterns		Pure and elegant, beautiful and clean

Geometric Patterns	Twin tree patterns		Abundant harvest of grains, prosperous livestock
	Chinese parasol tree flower patterns		Remembrance, commemoration of loved ones
	Elongated drum patterns		Family reunion, steadfast love
	Boundary patterns		Embracing nature, reverence for the landscape
	Squeeze patterns		Spirit of inquiry, perseverance
	Sawtooth patterns		Labor, craftsmanship culture
	Tofu grid patterns		Food, customs, ethnic integration
	King Pan seal patterns		Gratitude, worship, auspiciousness and good fortune
Symbolic Patterns	Tang Dynasty seal patterns		Remembrance of ancestors, illustrious figures
	Ancient king seal patterns		
	Over-the-mountain Yao character patterns		Literate culture
	Patterns resembling the Chinese character "万"		Hope and prayers for the sun's light

2.2In-depth Analysis of Yao Embroidery in Ruyuan Based on Peircean Semiotics

Charles Sanders Peirce's formulation of the triadic relationship in semiotics represents a profound advancement over Ferdinand de Saussure's binary schema, introducing a nuanced framework for the interpretation and comprehension of symbols. Peirce's semiotic model identifies three critical elements: the "Representamen," the symbol's form; the "Object," which conveys the concept or cultural meanings; and the "Interpretant," the interpretive

process that connects the observer with the symbol's deeper significance. This methodology underscores the dynamic and interactive nature of symbols, focusing on the interpretative process and enriching the analysis of symbols' roles within societal constructs.

Employing Peirce's triadic framework, this investigation delves into the embroidery symbols of the Ruyuan Yao ethnic group, aiming to reveal intricate cultural insights. The analysis begins by identifying the physical traits of the embroidery as "Representamen," explores their cultural and symbolic significances as "Object," and interprets these symbols within the context of Ruyuan Yao's cultural identity. Furthermore, the study integrates Hou Ning's Luoyang model to deepen the cultural analysis[11]. Within this context, the "Representamen" encompasses tangible attributes such as form, structure, materials, and colors, while the "Object" probes into the symbols' cultural essence, including names and meanings. The "Interpretant," pivotal to this approach, deciphers the symbol's impact, connecting with the audience's sensory perceptions and closely aligning the design with user expectations and requirements.

This research integrates Ferdinand de Saussure's binary model with Charles Sanders Peirce's triadic relationship in the design of sustainable wind energy devices, reflecting the Ruyuan Yao ethnic embroidery. By translating "Signifier" and "Signified" from Saussure's model into "Representamen" and "Object" in Peirce's framework for wind energy design. Thus obtaining the Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol. For further details, see Figure 3. This interdisciplinary approach not only preserves local cultural heritage but also blends it with modern technology. This semiotic crossover ensures the design retains its ethnic intuitiveness while integrating user experience and application context.

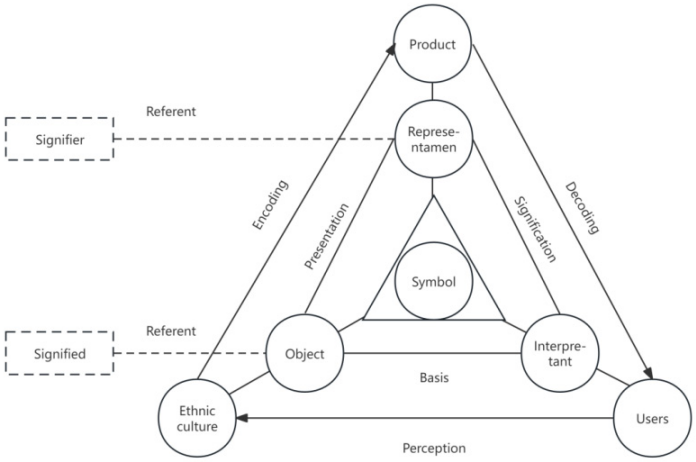


Fig. 3. Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol.

The research utilizes methods such as selection, combination, replication, deconstruction, reconstruction, mirroring, and abstraction to encode the form and essence of ethnic symbols, aligning them with user needs and device specifications. These methods help skillfully encode the essence and morphology of ethnic symbols into the design of sustainable wind energy

devices, ensuring a harmonious balance between cultural significance and functional efficacy. Subsequently, users decode the content of the products through the KJ method. Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol, by analyzing symbols' physical attributes, cultural significance, and psychological impact, enables designers to create devices that align with the ethnic cultural identity, meeting both aesthetic preferences and functional requirements. Emphasizing the dynamism and interactivity of symbols, this holistic design philosophy not only champions the preservation and progressive enhancement of rural cultures but also deepens the awareness and comprehension of ethnic traditions. Incorporating culturally-adaptive innovations and leveraging the Ruyuan Yao's semiotics, this methodology emphasizes the pivotal role of cultural symbolism in enhancing sustainable technology development.

Emphasizing a user-centric research approach, this study employs the KJ method, developed by Japanese anthropologist Jiro Kawakita in 1964, to delve deeply into user experiences and organize design requirements to satisfy both explicit and implicit user needs. This structured approach was applied to analyze responses from 185 surveys—including 83 local residents and 102 tourists—highlighting varied perspectives on sustainable wind energy. Local residents mainly support the installations for their utility in providing electricity, cultural identity, and promoting sustainable concepts, while tourists appreciate their novelty and educational value, as shown in Table 2. The results obtained from the KJ method effectively decoded the design products, validating that the designs, guided by the Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol, meet the design requirements. It enhanced the comprehension of cultural content conveyed to users, thus facilitating effective communication of symbolic information.

In terms of design strategy, the study prioritizes the aerodynamic optimization of wind turbine blades and the use of durable, eco-conscious materials to enhance energy efficiency and prolong device longevity. This approach skillfully integrates sustainability with functional and aesthetic design considerations. Ultimately, the project embodies a holistic design philosophy that incorporates Ruyuan Yao cultural symbols into the aesthetic and functional aspects of wind energy devices, transforming them into mediums for storytelling and cultural expression. By aligning sustainable technology with the semiotics of the Ruyuan Yao ethnicity, the devices become cultural emblems and practical tools, fostering cultural exchange and advancing sustainable development in rural settings with a culturally informed approach.

Table 2. List of User Requirements and Device Characteristics for Sustainable Wind Power Devices

Index	Primary Functionality Item	Secondary Functionality Item
1	Indigenous Residents	Visual identification
2		Cultural inheritance
3		Energy supply
4	External Visitors	Image ambience
5		Cultural cognition
6		Aesthetic value
7	Characteristics of Wind Power Devices	Curvilinear design
8		Angle of attack elevation
9		Durability of sustainable materials

3 Design Application

The device product design is a pivotal element in the sustainable wind energy device model for the Ruyuan Yao ethnicity. Historically, sustainable wind energy devices have primarily focused on technical and economic aspects, often overlooking issues such as visual pollution in public device design. Hence, the sustainable wind energy device design for the Ruyuan Yao ethnicity faces challenges in form, color, emotional resonance, interactivity, material sustainability, and visual pollution. To address these, this paper uses the Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol to decode the semantics and characteristics of Ruyuan Yao embroidery symbols, organizing 22 symbols and, through filtering based on their symbolism, usage frequency, and recognition, selects four representative embroidery symbols: the deer pattern, the octagonal flower pattern, the lotus flower patterns, and the twin tree patterns.

(1) Addressing user needs, this study applies both foundational and in-depth semiotic analyses to encode the sustainable wind energy device. This process involves transforming and reconfiguring four selected Ruyuan Yao embroidery symbols to design both horizontal and vertical axis wind turbines tailored to the unique attributes of each symbol. For instance, the octagonal flower and lotus flower patterns are adapted for horizontal axis turbines, whereas the deer and Twin tree patterns are suited for vertical axis turbines, optimizing each design to leverage the inherent symbolic meanings and structural characteristics. The choice of horizontal versus vertical axis turbines, each aligning with different operational principles and applications, is informed by the detailed symbolic analysis, ensuring the turbines' design is congruent with both functional specifications and cultural significances. This design strategy not only fulfills functional energy needs but also embeds local cultural values into the technology, demonstrating a deep respect for the Ruyuan Yao heritage through the thoughtful integration of cultural symbols.

(2) Utilizing Saussure's binary relationship, this study meticulously extracts fundamental geometric shapes—such as circles, triangles, and parallelograms—from the Ruyuan Yao embroidery, focusing on their inherent radiating, repeating, and symmetrical forms. The design predominantly incorporates direct and diagonal lines, reflective of the characteristic angles at 45°, 90°, and 180° found in Ruyuan Yao embroidery, thereby maintaining fidelity to the traditional line variation rules. In terms of “Signified” analysis, the research interprets the deep-seated cultural elements embedded within these symbols: the deer pattern signifies gratitude and worship, the octagonal flower pattern signifies blessings, the lotus flower patterns denote purity and cleanliness, and the Twin tree patterns are interpreted as respect and protection for the natural environment, adding to the device’s cultural content and social significance through the integration of sustainable development principles. Artistic design techniques such as deconstruction, reconstruction, rotation, mirroring, and hollowing are rationally applied to further refine symbol design and integration, ensuring that the design aligns with both Ruyuan Yao cultural values and modern sustainable development goals. By synthesizing original symbolic meanings with contemporary sustainability concepts, and embedding these meanings within the device, the project significantly elevates the cultural heritage and social value of the wind energy solutions.

(3) Based on Peirce's triadic relationship theory, this study rigorously analyzes psychological factors of users and environmental contexts in the interpretation of symbols. The surveys are designed to refine symbol representation, design style, and ambiance to align with user expectations and requirements. Following the initial design phase, modifications to blade curvature and attack angles—tailored to specific wind energy device characteristics—significantly enhance energy efficiency. The device utilizes high-performance bamboo fiber composites, or "bamboo steel," valued for their durability and sustainability, which demonstrate superior strength, low environmental impact, and resistance to extreme conditions[12]. Recyclable regenerated nylon is used for the device's surface, intricately woven to mimic the material characteristics of Ruyuan Yao embroidery, thus enriching its cultural aesthetic. These innovations enhance the device's efficiency and eco-friendliness while deepening its cultural significance and social impact.

(4) The design incorporates an original color scheme of red, yellow, black, white, and green—colors that reflect the Ruyuan Yao symbols and embody the ethnic ethos of deity worship, solemnity, abundant life, and harmonious coexistence. Red symbolizes the bloodlines of ancestors, vitality, and sacred power, representing respect and worship for family, ancestors, and traditions. Yellow, the color of the sun, signifies harvest, brightness, and the vitality of life, representing energy and abundance. Black, often seen as solemn, mysterious, and awe-inspiring, carries symbolic significance in embroidery bases, denoting sanctity and solemnity. White typically symbolizes purity, innocence, and nobility, used in solemn and sacred occasions like weddings, funerals, and other significant ceremonies, showcasing the pursuit of purity and reverence. Green, symbolizing life, nature, and harmony, reflects the importance of the natural environment to the mountain-dwelling Yao people, representing the vitality of nature. The design inspired by Ruyuan Yao symbols transforms the sustainable wind energy device into a powerful medium for storytelling and cultural expression. Through its rich interactive forms and spatial presentations, it not only provides partial energy for the community but also serves as an ethnic landmark, integrating sustainable development concepts into village revitalization plans, thus improving local living conditions and enhancing tourists' experiences, as detailed in Figure 4.

The design of the sustainable wind energy device, guided by the Semiotic Interpretation Model of the Ruyuan Yao Ethnic Symbol, is featured in the project titled "Artistic Empowerment in Village Revitalization: Sustainable Ecological Transformation Strategies for Yangbei Village in Ruyuan Yao Autonomous County" (Project No. pdjh2024b154). This project, which aims to integrate sustainable technology with cultural preservation, involves detailed methodologies including surveys conducted with 83 local residents and 102 tourists, group discussions with community leaders, and evaluations by three experts in rural development. The initiation of this project was marked by its approval based on rigorous evaluation criteria focusing on cultural relevance and technological innovation. Feedback from these diverse methodologies indicates that the wind energy devices are well-received for both their functional benefits and cultural significance. This research not only provides a robust theoretical foundation for integrating traditional symbols into modern technology but also showcases practical implementations that enhance the local community's engagement with their cultural heritage, as demonstrated by increased local and tourist interest in the project's developments.

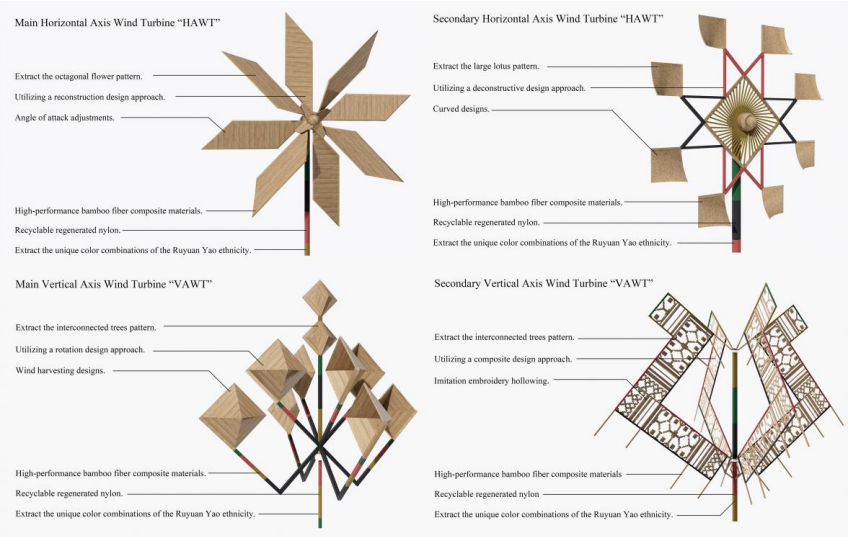


Fig. 4. Design rendering of a wind power generation device

4 Conclusion

This research integrates the innovative integration of Ruyuan Yao ethnic symbols into the design of sustainable wind energy devices, aiming to align ethnic cultural heritage with sustainable development objectives. Utilizing a comprehensive methodology that includes literature review, field investigations, and the development of semiotic models, the study thoroughly analyzes both binary and ternary relationships of symbols. Binary relationships enable the direct extraction of symbols, while ternary relationships connect these extractions to user interpretations, tailoring the design more precisely to meet specific user needs. This leads to a tailored design model that accurately addresses the needs of the Ruyuan Yao ethnic group, incorporating ethnic elements into the product design seamlessly through semiotic models. Simultaneously, the KJ method is employed for a detailed examination of user preferences, assisting in the decoding of the design. Our findings validate the effectiveness of the semiotic-based design model in meeting user requirements and product characteristics. Moreover, design renderings, informed by insights from the KJ method, confirm the model's practicality, making substantial contributions to the fields of sustainable development and ethnic cultural heritage preservation. This research not only pioneers pathways for sustainable development that integrate rural cultural preservation but also creates a bridge between historical and futuristic perspectives, fostering a deep appreciation for ethnic cultural heritage within the context of sustainable technological progress. By advancing culturally-adaptive sustainable wind energy innovations and harnessing the semiotics of the Ruyuan Yao ethnicity, this study highlights the pivotal role of cultural symbolism in enriching sustainable technology development, marking a significant advancement in integrating cultural sensitivity into environmental solutions.

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