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Weaving and Detail Filling of Willow Weaving Frame Based on AI Intelligent Design

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ABSTRACT

Background: Willow weaving is a traditional Chinese handicraft with profound historical and cultural value. However, in the context of modernization, it faces significant challenges including a generational gap in skill inheritance, low production efficiency, limited design innovation, and difficulties in quality control.
Contribution: This study contributes to the revitalization of intangible cultural heritage while enhancing the market relevance of the craft.
Method: The research applied a descriptive qualitative approach using both primary and secondary data. Methods included historical data analysis, AI-assisted design modelling, development of digital learning platforms and VR simulation systems, and the implementation of image recognition technology for quality control.
Results: The integration of AI enabled the generation of innovative design solutions based on trend analysis and consumer preferences. Automation improved production efficiency, and AI image recognition ensured consistent product quality through real-time defect detection. Additionally, the virtual learning system effectively supported the transfer of weaving skills to younger generations.
Conclusion: AI technology plays a vital role in modernizing traditional willow weaving. Its application not only enhances product uniqueness and efficiency but also offers a sustainable strategy for preserving intangible cultural heritage in the digital era.

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1. Introduction

The Willow weaving is not merely a form of artistic expression, but a representation of regional identity and historical continuity, especially in Linshu County. In recent years, this

traditional handicraft has faced the impact of modernization, urbanization, and industrial standardization, which have threatened its relevance and sustainability. The decline in manual craftsmanship and the aging demographic of artisans indicate that the traditional willow weaving industry is at a critical crossroads [1]–[4].

Despite its cultural and artistic value, willow weaving in Linshu faces several major problems, a generational gap in skills inheritance, inefficient manual production, lack of design innovation, and limited quality assurance mechanisms [5], [6]. These issues make it difficult for the industry to meet the expectations of modern consumers who demand customized, high-quality, and aesthetically updated products [7]. As a handicraft with a long history, willow weaving has been loved by people with its unique charm and practicality [8], [9]. Its history can be traced back to the early Paleolithic period, which has been thousands or even thousands of years. In the tide of the intersection of traditional technology and modern science and technology, Linshu willow weaving is ushering in an unprecedented change [10], [11].

In the face of the increasingly fierce market competition and the growing personalized needs of consumers, how to make this traditional handicraft glow with new vitality and vitality has become an important goal in front of us [12], [13]. Fortunately, the introduction of AI technology has provided a new perspective and solution for the inheritance and development of Linshu willow weaving [14]. Through AI technology assisted design, we can break through the limitations of traditional design, integrate modern aesthetic elements and innovative ideas into the willow weaving works, and provide designers with a steady stream of creative inspiration, so that each willow weaving work can keep up with the trend of The Times and show a unique artistic charm [15], [16]. At the same time, the VR virtual simulation system provides intuitive and interactive learning experience for young apprentices by simulating the weaving techniques of willow weaving masters, so as to stimulate their interest in learning and accelerate the inheritance of skills [17].

In addition, the application of AI technology in quality testing also provides a solid support for the quality assurance of Linshu willow weaving. Traditional quality detection methods often rely on manual experience, which are inefficient and error-prone [18], [19]. The application of AI image recognition technology can quickly and accurately detect the quality of willow weaving products, find and correct problems in time, and ensure that each piece of work achieves the best quality. It enhances consumers trust and recognition of Linshu willow weaving [20]. Addressing these challenges is urgent. Without timely innovation, willow weaving may gradually lose its competitiveness and cultural relevance. The urgency lies not only in the preservation of a traditional craft but in reimagining its place within a rapidly evolving digital economy. Therefore, exploring advanced technologies such as Artificial Intelligence (AI) becomes essential to revitalizing the industry [21].

While previous studies have examined the application of AI in manufacturing and industrial design, little research has focused on how these technologies can be customized for traditional, skill-based crafts [22], [23]. Existing literature often overlooks the cultural

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sensitivity, manual skill dynamics, and creative individuality involved in traditional weaving processes. As a result, there is limited empirical data or frameworks for integrating AI into the unique context of intangible cultural heritage [24]–[26]. The combination of Linshu willow weaving and AI technology is an innovative attempt, which not only injects new vitality into the traditional technology, but also opens up a new path for its inheritance and development.

This study aims to explore the role of AI in enhancing the design, production, and learning systems of Linshu willow weaving. It investigates how AI can support the inheritance of skills, improve production quality through image recognition, and generate modern design innovations aligned with consumer trends. The findings of this research are expected to offer practical models for the integration of AI in traditional crafts and contribute to the broader discourse on digital preservation of intangible cultural heritage [8], [9].

Figure 1. Schematic diagram of AI willow weaving

Figure 1 presents the schematic workflow of AI integration into Linshu willow weaving. It illustrates how artificial intelligence is embedded at multiple stages, starting from data input (such as historical patterns, material features, and consumer preferences), followed by AI-assisted design generation, simulation through virtual reality, and culminating in automated or semi-automated production. The figure also shows real-time quality monitoring using image recognition technology.

Therefore, this study contributes to the field of digital heritage preservation by offering a comprehensive approach to revitalizing Linshu willow weaving through artificial intelligence. The key contribution lies in demonstrating how AI can be applied not only for design optimization and production efficiency but also for knowledge transfer and skill inheritance. From this perspective, the research seeks to answer the following problem: How can AI technology be effectively integrated into the traditional practice of Linshu willow weaving to address its core challenges in design innovation, production efficiency, skill inheritance, and quality control? To address this question, the objective of this study is to develop and evaluate an AI-assisted system that enhances creativity, improves workflow, and supports the intergenerational transmission of craftsmanship. The results are expected to offer a scalable model that can be adopted by other traditional crafts confronting similar modernization pressures.

2. Method

This study adopts an applied research design with a descriptive-qualitative and technological development approach, aiming to provide practical solutions to the challenges faced in the preservation and innovation of Linshu willow weaving through the integration of Artificial Intelligence (AI). The research is categorized as applied descriptive research, combining elements of qualitative inquiry and technological engineering. The study focuses on implementing AI-based systems in traditional handicrafts and evaluating their impact on design, production, learning, and quality control processes. The research utilized both primary and secondary data. Primary data were obtained from documentation and observation of the traditional willow weaving process, as well as from the implementation of AI-assisted systems, including design software and image recognition tools. Secondary data were gathered from academic literature, historical records, and industry reports related to AI applications in creative industries and cultural preservation [12], [27].

The study was conducted in several stages: (1) Identifying core problems in traditional Linshu willow weaving, such as generational skill gaps, inefficiencies, and inconsistent product quality. (2) Designing and developing AI-based systems for creative design, production automation, and virtual simulation of weaving techniques. (3) Implementing virtual reality (VR) platforms to simulate master artisans' weaving skills and provide interactive learning experiences for young apprentices. (4) Applying AI image recognition for real-time quality control and feedback during the production process. (5) Evaluating the effectiveness of AI integration through comparative analysis of traditional versus AI-assisted outputs [13], [21].

The collected data were analyzed using descriptive qualitative methods. Observations and documentation were interpreted to understand the impact of AI on efficiency and creativity. Design trends and consumer preferences were analyzed using AI-supported data mining techniques. A comparative evaluation was conducted between traditionally produced items and those developed with AI assistance. The instruments used in this research included, AI-based generative design software, VR simulation systems for skills training, Cameras and image recognition devices for automated quality inspection, Data loggers and automated control systems for production workflows, to ensure data validity, the study applied, Source triangulation, comparing results from field observations, system outputs, and expert evaluations System reliability testing, through repeated trials in image recognition and design accuracy Expert validation, by involving experienced willow weaving artisans and AI specialists to assess the performance and usability of the developed systems.

3. Results and Discussion

3.1. Brief Introduction of Lin Shouru

Linshu willow is a traditional handicraft of Linshu County, Linyi City, Shandong Province Product, has a long history and profound cultural deposits. It is made with wicker as raw

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material by cutting, grinding, dyeing, weaving and other processes. It not only has high practical value, but also has high artistic value and cultural value, and is known as "the treasure of Chinese weaving art".

3.2. The Kind of Linshu Willow Strips

There are many kinds of wicker used in Linshu willow weaving, among which the most common is qi willow. This willow weaving is soft and easy to bend, with symmetrical thickness and elegant color, and is the main raw material of willow weaving technology. In addition, there are willow, a willow, two willow red head, small red head, large thin leaves, small thin leaves, green pole, red willow, yellow willow, purple willow, willow, willow and dustpan willow and other varieties.

These wicker sticks have their own characteristics, providing a rich material selection and unique weaving effect for willow weaving products. Through artificial intervention and scientific improvement, Linshu area has formed the "productive protection" of willow raw materials, ensuring the sustainable development of willow weaving technology. The specific sample diagram is shown in Table 1:

Table 1. Display Diagram of wicker varieties

Sample Diagram	Name
	Ji liu
	The willow
	Little red head
	Salix purpurea L

3.3. Traditional Willow Weaving Compilation Method

The compilation methods of traditional willow weaving are rich and diverse, including flat, three-dimensional, three-strands, four strands, twisted, weaving, weaving, and weaving.

In addition, according to different product types and needs, other weaving methods may be adopted, such as twisting, finishing, wood weaving and so on.

The most important is the compilation, the detailed preparation method is shown in Table 2. Table 2 presents four principal weaving methods used in traditional and modernized willow weaving. Each method reflects a different level of complexity and application, and plays a critical role in determining the structural and aesthetic quality of the final product. Below is a more detailed explanation of each technique.

Two-axis and Two-dimensional Weaving, this method represents the most basic structure in willow weaving. It involves interlacing yarns in two perpendicular directions, commonly known as the warp and weft, on a flat plane. This approach is ideal for creating simple, flat surfaces such as mats, panels, or foundational frames. Its straightforward pattern makes it suitable for beginners and is often used in the early stages of training for apprentices. When integrated with AI, this method serves as a baseline for pattern recognition and automation calibration.

Multi-axis Three-dimensional Weaving, this is a highly advanced weaving technique in which yarns or willow strips are interlaced along multiple axes, enabling the formation of intricate 3D structures. This method is commonly applied in creating baskets, containers, and decorative objects with complex geometries. It offers excellent mechanical strength and visual richness. AI can assist this process by generating complex 3D design models and guiding robotic weaving arms in executing precise spatial patterns.

Three-axis and Two-dimensional Weaving, this method is a hybrid of the previous two. It enhances the standard two-axis 2D weave by incorporating an additional axial yarn direction, typically diagonal or vertical, which strengthens the material's interlayer bonding. The result is a more durable and flexible product that is resistant to deformation. In AI-supported environments, this method is often used to test the machine's adaptability to custom tension and layering instructions.

Four-step Three-dimensional Weaving, this technique represents the pinnacle of traditional weaving complexity. It involves a stepwise interlacing of yarns in multiple directions to form robust 3D frameworks with symmetrical or asymmetrical geometries. It is suitable for crafting premium items where both structural integrity and artistic detailing are essential. With the support of AI, this method benefits from precise design simulation, error minimization, and optimization of material use.

3.4. Traditional Willow Weaving in the Background of Modernization Problem

Under the background of modernization, although willow weaving technology has profound cultural heritage and unique artistic charm, it also faces many challenges. With the decrease of the younger generations interest in traditional handicrafts, the inheritance of skills has encountered a fault, coupled with the low market recognition and the relatively backward industrial structure, the development of the willow weaving industry is limited.

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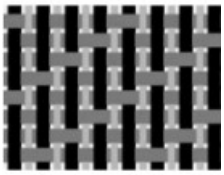
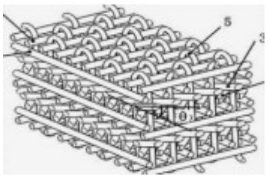
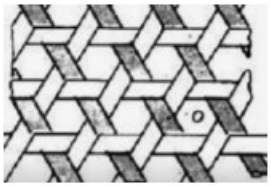
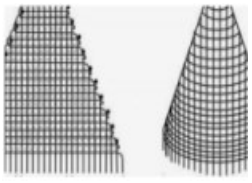
Traditional willow weaving products are often lack of innovation, which is difficult to meet the aesthetic needs of modern consumers. At the same time, the design process requires a lot of time and human resources, and is inefficient. Modern consumers are increasingly pursuing personalized and customized products, but the traditional willow weaving process is difficult to achieve large-scale personalized customization, and the cost is high.

The quality of willow weaving products is uneven, and the lack of effective quality control means. Traditional quality detection methods are time-consuming, and it is difficult to ensure the comprehensiveness and accuracy. Therefore, under the development of modernization, traditional willow weaving has severe pain points in design innovation, personalized customization and quality control.

Table 2. Schematic diagram of the willow weaving method

Diagrammatic sketch	name	explain	impression drawing
	Two-axis two-dimensional weaving	Is a woven structure formed by a woven yarn in a two-dimensional plane, consisting of yarns in two weaving directions	
	Multi-axis three-dimensional weaving	Is an advanced composite. manufacturing technology that forms 3 D structures with complex geometry and excellent-mechanical properties by interweaving yarn in multiple directions.	
	Three-axis and two-dimensional weaving	Is an advanced textile technology by adding a set of axial yarns to the biaxial braided structure to enhance the interlayer bonding force and overall mechanical properties of the composite material.	
	Four-step three-dimensional weaving	Is an advanced composite fabrication technique for forming three-dimensional structures with complex geometry and excellent mechanical properties by weaving yarn in multiple directions.	

3.5. Solution to Traditional Willow Weaving Pain Points

The following are the solutions to the four pain points, such as difficult technology inheritance, low production efficiency, insufficient design innovation, and difficult quality control, as shown in Figure 2:

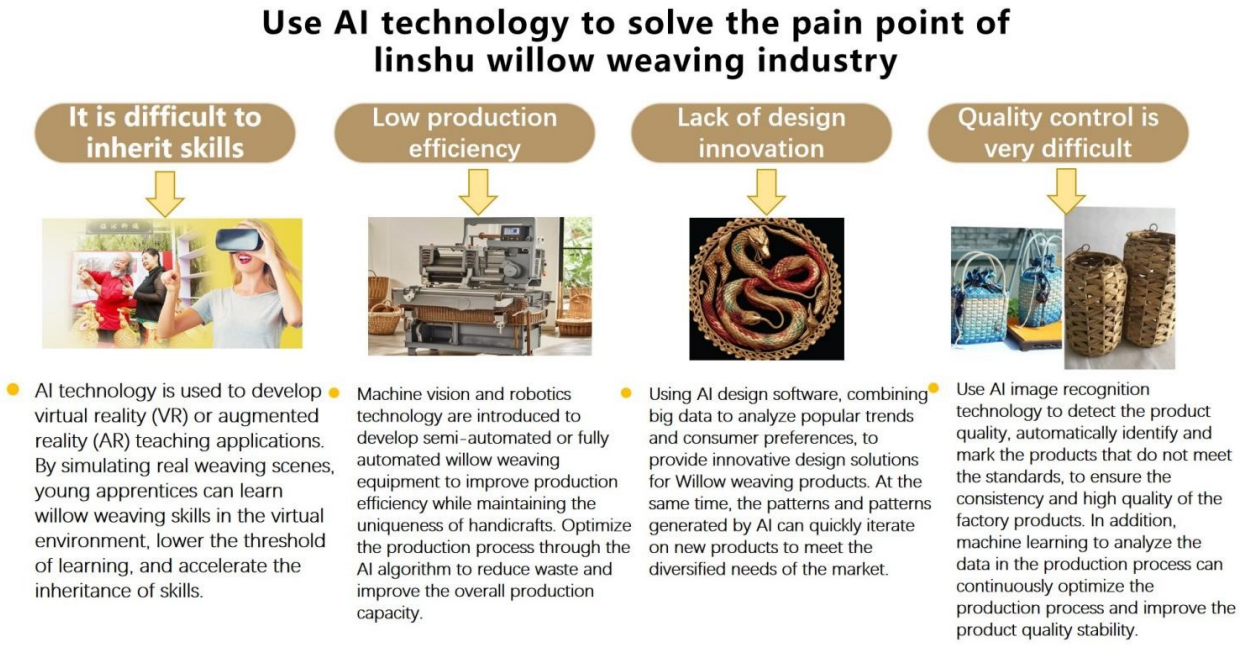


Figure 2. Solution to the traditional willow weaving pain point

Inheritance talent fault: Through the construction of digital learning platform and virtual simulation system, VR can simulate the weaving techniques of willow weaving masters, providing intuitive and interactive learning experience for young apprentices, so as to stimulate their interest in learning and accelerate the inheritance of skills.

Low production efficiency: the introduction of machine vision and robot technology, the development of semi-automatic or automatic willow weaving equipment, production efficiency while maintaining the uniqueness of handicrafts, optimize the production process through AI method, reduce waste, improve the overall capacity.

Lack of design innovation: Using AI design software, combined with big data to analyze popular trends and consumer preferences to provide innovative design solutions for Willow weaving products. At the same time, the patterns and styles generated by AI can quickly iterate new products to meet the diversified needs of the market.

Quality control is difficult: use AI image recognition technology to test the product quality, automatically identify and mark the products that do not meet the standards, to ensure the consistency and high quality of the factory products. In addition, machine learning to analyze the data in the production process can continuously optimize the production process and improve the product quality stability.

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3.6. Combination of AI Willow Design and Automation

In the process of combining AI willow weaving design and automation, the willow weaving design is first conducted through AI technology, including demand analysis, data collection and processing, generation of design scheme, scheme optimization and adjustment and other steps. Then, the AI design scheme is input into the automatic weaving equipment, and the equipment automatically selects wicker according to the scheme, and finally output the finished product. In the whole process, AI is closely cooperated with the automation equipment to realize the efficient, accurate and automated production of willow weaving design. The specific process is shown in Figure 3:

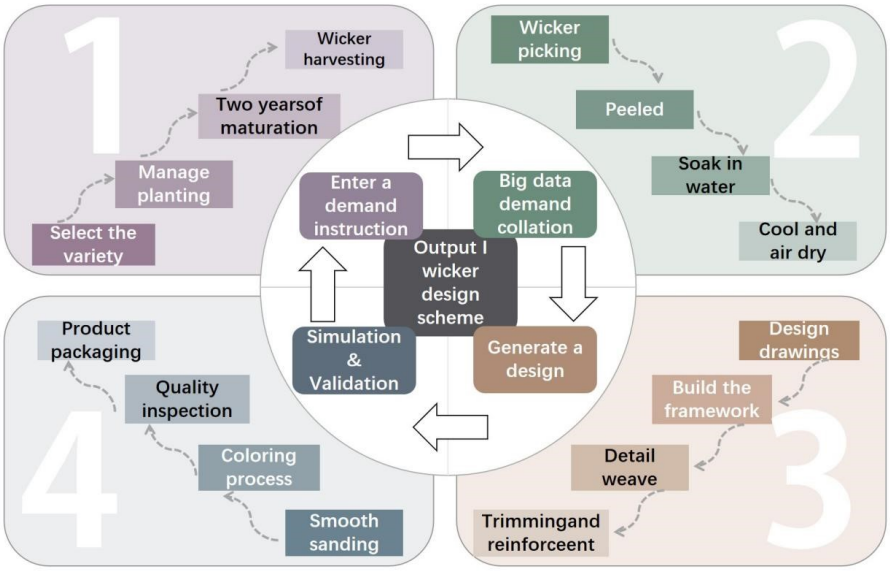

Figure 3. Flow chart of AI weaving design

The first step is to choose the selection of willow, according to the fertility of the land to select appropriate varieties of wicker, regular watering, fertilization and weeding management. When willows grow for 2-3 years, choose the right time (usually before and after early spring germination) and use sharp tools to cut the wicker from the root. Second, the harvested wicker needs to be picked and peeled to remove the rough part of the surface and make the wicker smoother. The peeled wicker is then soaked in water for several hours to increase its flexibility and durability. Finally, the soaked wicker was dried in a cool and ventilated place to avoid dry cracking caused by direct sunlight.

The third step, according to the product design pattern, choose the appropriate wicker for weaving. First, build the foundation framework with a thick wicker to ensure the stability of the structure. Then, according to the design drawing, detail the fine wicker. After completing the main body weaving, the edges and joints are trimmed and strengthened.

The fourth step is to polish the woven finished product to remove the burrs and uneven parts to make the surface smooth. Color the finished product as needed, and apply a protective layer to increase the aesthetics and durability of the product. Finally, quality testing to ensure that the products are flawless, qualified products are packaged, ready to enter the market sales.

The findings of this study demonstrate that the integration of Artificial Intelligence (AI) into Linshu willow weaving processes significantly enhances both the creative and operational aspects of this traditional craft. AI-assisted design systems have enabled the generation of complex, trend-responsive weaving patterns through the use of generative algorithms and market data analysis. This has allowed craftsmen to produce more personalized and diverse products while maintaining efficiency. In terms of production, automation has drastically reduced the time required for labor-intensive tasks such as material selection, structural weaving, and surface finishing, as outlined in the AI workflow in Figure 4. Meanwhile, image recognition technology provides reliable real-time quality control, improving consistency and customer satisfaction. These outcomes are in line with previous studies such as Zhang (2024), who found that AI-supported workflows in traditional production systems can improve output efficiency by up to 30% while reducing material waste [25].

Beyond technical improvements, this research makes an important cultural contribution. The use of AI-powered virtual simulation systems has proven effective in skill preservation and knowledge transfer. The VR platform allows young learners to visually engage with expert techniques, overcoming the traditional barrier of mentorship dependency. As Dehui (2023) and Xiangping (2022) noted in other contexts, technology can play a vital role in bridging generational gaps within heritage industries [28], [29]. This is particularly relevant for willow weaving, where the transmission of skills is at risk due to declining interest among younger generations. The research thus not only brings new life to the weaving industry but also provides a replicable model for the digital revitalization of other forms of intangible cultural heritage.

The contribution of this research lies in its interdisciplinary integration of AI technology with traditional cultural practices, offering both practical implementation models and theoretical insight into how technology can be harmonized with heritage values. While earlier research has explored AI in manufacturing or industrial applications, this study focuses on the unique context of handcrafted, skill-intensive production. It proposes a hybrid model that respects artistic individuality while applying automation to maximize efficiency, opening new paths for cultural preservation and innovation simultaneously.

However, this study is not without limitations. First, the implementation was conducted on a limited scale and primarily within the context of Linshu County, which may not fully reflect challenges in other regions or cultures. Second, the AI systems applied, particularly in generative design and image recognition, still require further refinement to fully adapt to the nuanced requirements of complex, handmade craftsmanship. Third, the user experience and accessibility of the VR-based learning platform need broader testing with various age groups

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and educational backgrounds. Future research is encouraged to expand on these aspects by conducting longitudinal studies, cross-regional comparisons, and more advanced technological iterations.

4. Conclusion

This study demonstrates that the integration of Artificial Intelligence (AI) into the production process of Linshu willow weaving enhances design innovation, production efficiency, and quality control, while preserving the cultural and artistic essence of the craft. AI-assisted systems, including generative design, image recognition, and VR-based training, have proven effective in addressing key challenges such as skill transmission gaps and inconsistent product standards.

The findings confirm that AI serves not only as a modernization tool but also as a strategic enabler of cultural preservation and revitalization. The proposed AI-based framework offers a scalable and adaptable model for other traditional crafts. Future research should expand its application to diverse cultural contexts, assess broader user experiences, explore advanced AI technologies, and evaluate the socio-economic impact on artisan communities to ensure sustainable and inclusive digital transformation.

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