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An Innovative Design of Desktop Shuttle Loom with Open-Type Heald and Mechanically Programmable Flat-Plate Heddle

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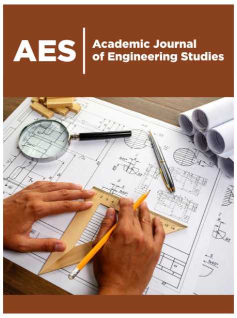

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Abstract

Textile production stands as one of humanity's oldest and most essential technologies, deeply interwoven with the development of civilizations across the globe. Weaving, in particular, is not only a practical craft but also a form of expression through pattern, structure, and material. The advent of textile machinery revolutionized fabric production by enabling efficiency, complexity, and consistency. However, traditional weaving machines-especially those capable of creating patterned textiles-often involve intricate mechanisms, such as multiple heddles and treadle systems, which create a significant barrier to entry for beginners and limit accessibility in educational settings. This research addresses these challenges by developing an innovative desktop shuttle loom equipped with a mechanically programmable flat-plate heddle and an open-type heald. The design simplifies traditional mechanical systems and introduces a novel method of converting textile patterns into loom instructions using bitmap coding. By interpreting weaving patterns as binary pixel grids, where the state of each warp thread (up or down) is pre-determined, the loom's flat-plate heddles can be shaped accordingly. Each heddle features a series of convex and concave elements that physically manipulate the warp threads, mimicking the logical flow of a computer program applied to weaving. The loom's structure is minimalistic, portable, and cost-effective, making it suitable for museum education programs, STEAM workshops, and general public engagement in textile science. The implementation includes instructional materials and video resources that guide users through the operation, from pattern creation to fabric production. Through hands-on testing and workshops, the loom demonstrated a significant reduction in the learning curve while enhancing learners' understanding of pattern logic, textile history, and mechanical principles. Ultimately, this project bridges the gap between historical textile techniques and modern coding concepts. It presents a tangible way to teach programming logic, design thinking, and cultural heritage through the act of weaving, making it a powerful tool for interdisciplinary education.

Keywords: Weaving; Pattern design; Bitmap graph; Mechanical program; Innovation heald design; Science popularization

Introduction

Textile manufacturing has been a fundamental aspect of human civilization, contributing significantly to cultural and technological development. Evidence of early textile production can be traced back to Paleolithic sites, where bone needles indicate primitive weaving techniques [1]. In ancient China, weaving technologies evolved rapidly, as documented in the classic work 'Tian Gong Kai Wu' by Song Ying-Xing [2], which describes complex drawloom mechanisms for creating intricate fabric patterns. In the West, Joseph Marie Jacquard's invention of the Jacquard loom in 1807 revolutionized weaving by introducing punched card technology, an early form of mechanical coding [3,4].

Weaving is one of the earliest mechanical technologies in human history, with roots tracing back to the Paleolithic period. Ancient civilizations worldwide developed diverse textile techniques, such as shuttle weaving, to produce intricate fabrics. The integration of mechanical components into looms has facilitated the creation of repeatable patterns and increased productivity. However, traditional weaving mechanisms, such as healding and sleying, are complex, making them difficult for beginners. This research aims to mitigate these challenges by developing a simplified flat-plate heddle and open-type heald system that leverages bitmap pattern design to transform weaving procedures into intuitive, programmable steps.

Literature Review

The development of textile machinery has been instrumental in advancing weaving techniques. The Jacquard loom, invented by Joseph Marie Jacquard in 1807, utilized punched cards to control warp and weft motions, analogous to binary coding. Similarly, in ancient China, the "*Da Hua Lou Ti Hua Ji* (Dahualou Jacquard Machine)", as shown in Figure 1, employed a combination of Wen Zong (Pattern) and Di Zong (Ground cover) mechanisms to control the warp motion through hand and foot coordination, as detailed in 'Tian Gong Kai Wu' [4].

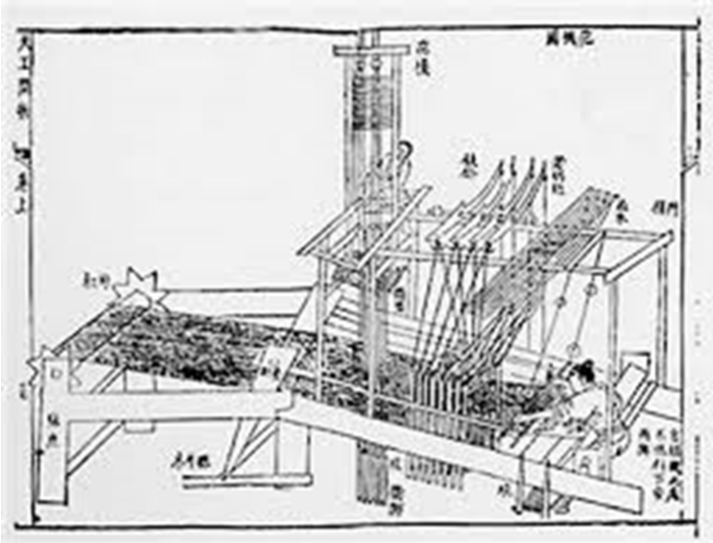
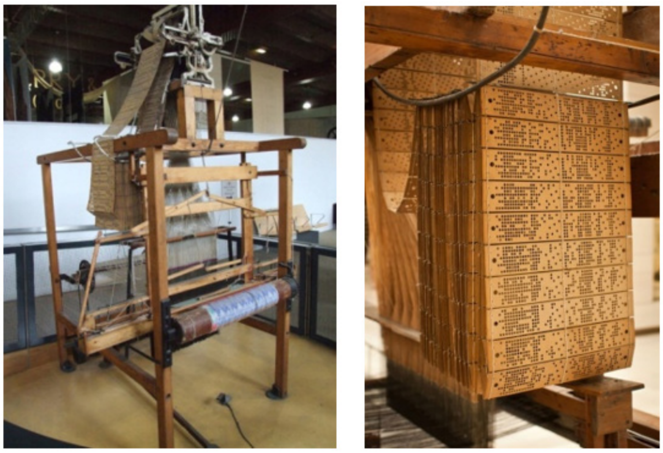


Figure 1: One kind of drawlooms in Ancient China.

Educational aids incorporating mechanized learning tools have proven effective in enhancing student engagement in science education. By integrating bitmap pattern design into weaving, the proposed flat-plate heddle design bridges traditional weaving principles with modern programming concepts, effectively simplifying the healding process [3,4].

Weaving and textile development

Weaving technology evolved significantly from primitive handlooms to complex mechanical looms. In ancient China, the development of multi-heddle drawlooms and Jacquard looms enabled the creation of intricate woven patterns, which were essential for producing court garments and ceremonial textiles. In the West, the Jacquard loom introduced punched card technology, which functioned as an early form of mechanical coding, controlling warp and weft interactions based on pre-defined patterns, as shown in Figure 2.



(a) the machine (b) punch cards

Figure 2: Jacquard machine.

Science teaching aids and mechanized learning tools

The use of educational aids in science education enhances students' conceptual understanding and engagement. Mechanized teaching tools, such as the flat-plate heddle loom, facilitate learning by translating complex mechanical principles into simplified visual and tactile experiences. Additionally, the incorporation of raster graphics in textile pattern design aligns with contemporary educational approaches that integrate coding and pattern recognition into traditional crafts.

Methodology

This section outlines the comprehensive approach taken to design and implement an innovative desktop shuttle loom with a focus on simplifying mechanical operations and teaching accessibility. The development was grounded in historical research, structural analysis, and iterative prototyping.

Structural analysis of existing looms

The study begins with a comprehensive analysis of existing loom structures, including slanting looms, drawlooms, and Jacquard looms. The primary objective is to identify key mechanical components that can be simplified without compromising weaving functionality. The focus is placed on reducing the number of healds and introducing flat-plate heddles that utilize convex-concave structures to control warp positioning.

Design and development of the flat-plate heddle

The flat-plate heddle represents a key innovation in this research. Traditional looms use multiple heddles suspended in frames, with each heddle corresponding to a warp thread that must be individually threaded through an eyelet. In contrast, this new design consolidates control into a single flat-plate unit per weft insertion sequence.

Each flat-plate heddle features alternating concave (slots) and convex (ridges) segments along one edge, as shown in Figure 3. The concave sections serve as pass-throughs for warp threads that remain stationary during weft insertion, while the convex segments apply pressure to raise or lower specific warp threads, creating the shed. This configuration allows for simple mechanical encoding of up-down warp motion, which is typically a complex process involving foot treadles and multiple healds.

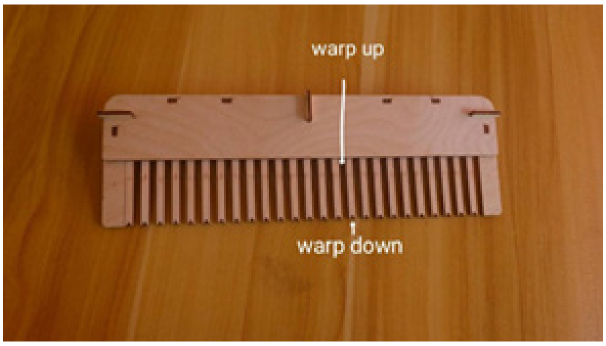


Figure 3: Concave (slots) and convex (ridges) segments along one edge.

The shape of each heddle directly corresponds to a bitmap row in the desired pattern, effectively transforming visual design into a mechanical code. By stacking or swapping flat-plate heddles during the weaving process, users can execute complex patterns without needing to reconfigure a traditional loom setup.

The innovative flat-plate heddle system employs bitmap design principles to convert patterns into warp and weft motions. Each heddle is engineered with alternating convex and concave features, resembling binary code sequences that dictate warp positioning. The healds are fabricated as rigid flat plates with integrated slots for warp insertion and positioning.

Implementation of bitmap pattern design

To complement the heddle design, bitmap-based pattern creation was implemented. Users begin by designing a textile pattern on a pixel grid, where each pixel corresponds to a binary weaving action (1=warp up, 0=warp down). This grid is translated row by row into flat-plate heddle shapes. The creation process includes the following steps:

A. The designer selects the dimensions of the textile piece, creating a grid layout (e.g., 10x10 for small-scale designs).

B. Using graphic software or a paper template, the pattern is drawn using binary shading--light for warp above weft, dark for weft above warp.

C. Each horizontal row of the bitmap is translated into the geometry of one flat-plate heddle, as shown in Figure 4.

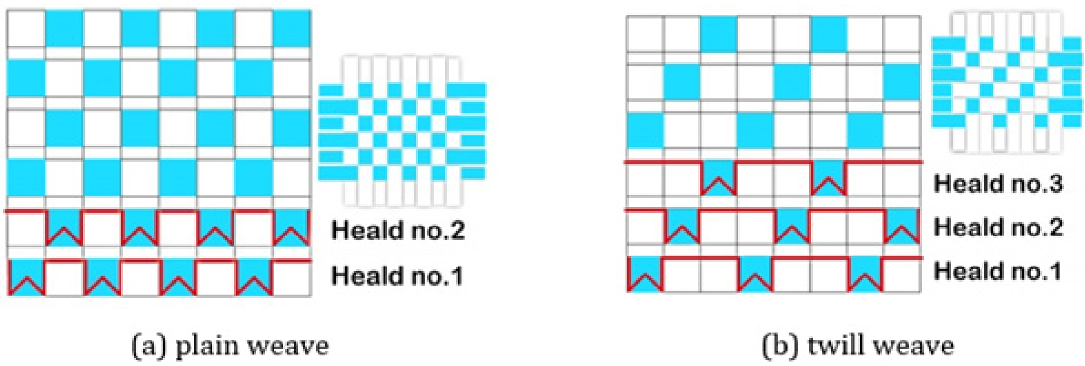


Figure 4: Bitmap concept of pattern design for the new shuttle loom.

D. These heddles are then inserted sequentially into the loom. The weaver pulls or presses each heddle, creating the warp shed based on the encoded pattern as shown in Figure 5.

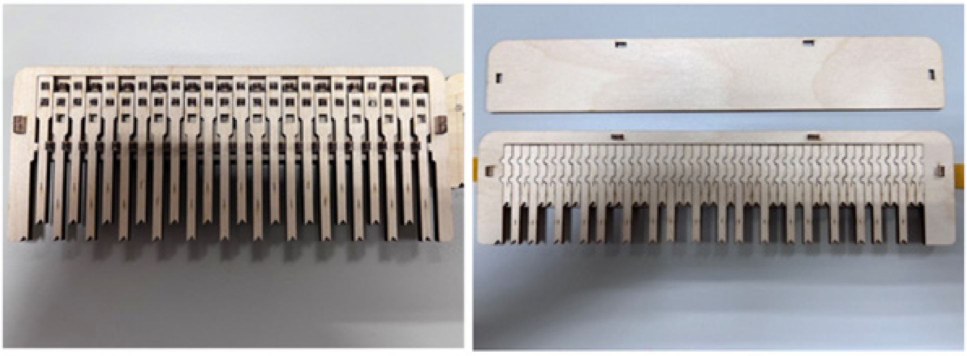


Figure 5: Two heald designs for mechanically programmable patterns.

This method greatly reduces the learning curve associated with traditional pattern drafting and heddle threading. By using bitmap logic, students and beginners can quickly associate design with mechanical function, encouraging experimentation and understanding of textile logic.

The study adopts a bitmap pattern design framework to simplify the weaving process. Patterns are created as pixelated grids, where each cell represents a warp or weft position, as shown in Figure 6. And a bitmap design with low resolution is regarded as the frame of wefts and warps. The binary coding of these grids is directly translated into the flat-plate heddle's geometry, enabling intuitive pattern programming without traditional healding techniques.

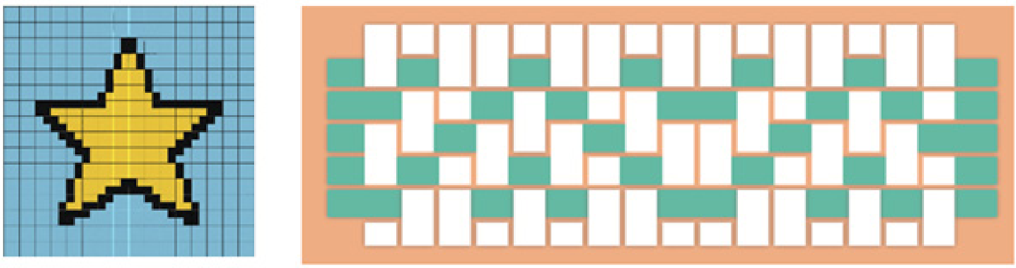


Figure 6: Demonstration of bitmap pattern design.

Operation process of the new design

Figure 7 is the innovative design of loom. The operation of the new loom design is streamlined into a step-by-step process that promotes clarity and accessibility:

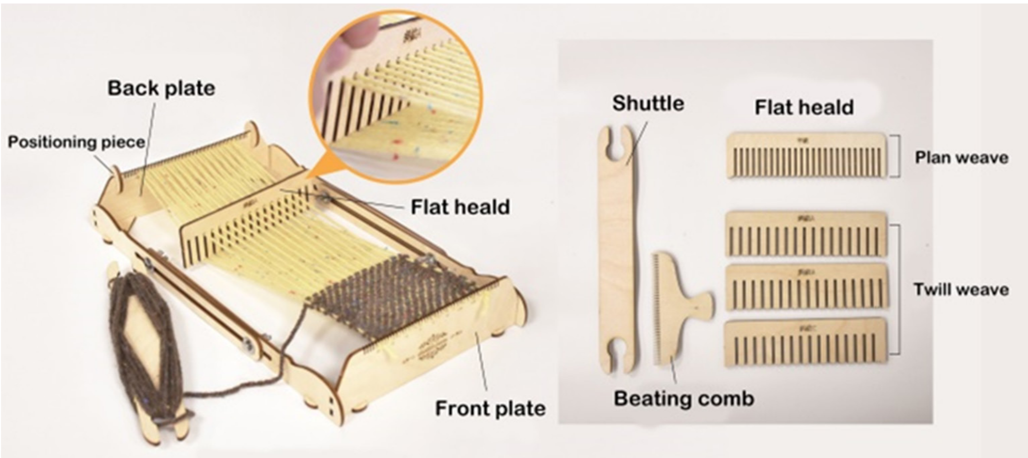


Figure 7: The innovative design of loom.

Step 1: Preparation — Warp threads are passed through fixed rear tension guides and aligned to the loom's base.

Step 2: Heddle Selection — For each pattern row, the corresponding flat-plate heddle is selected and inserted into the top slot of the heddle mount.

Step 3: Shed Formation — The heddle is pushed forward or pulled backward depending on its convex geometry, lifting specific warp threads and forming the shed.

Step 4: Weft Insertion — A shuttle carrying the weft thread is passed manually through the shed.

Step 5: Beating-Up — The weft is pushed into position using the integrated comb or beater bar.

Step 6: Advance — The woven fabric is gently rolled forward using the tension bars, and the next heddle is inserted.

These steps are repeated row by row, with users able to swap heddles as easily as cards, making it possible to follow a bitmap pattern mechanically without recalibrating the entire loom. This modularity is a key strength of the design and reinforces its utility in educational environments.

Results and Discussion

The innovative flat-plate heddle design demonstrated a reduction in mechanical complexity, effectively transforming weaving patterns into programmable binary sequences. The implementation of bitmap pattern design facilitated the coding of warp and weft actions, analogous to early punched card systems in Jacquard looms. This approach not only simplified the weaving process but also aligned with educational strategies that integrate mechanical principles and coding concepts in science education.

Efficiency and functionality analysis

The simplified flat-plate heddle system demonstrated a significant reduction in mechanical complexity compared to traditional multi-heddle looms. The use of bitmap pattern design facilitated intuitive pattern coding and reduced the learning curve for novice weavers. Additionally, the open-type heald system allowed for easier warp insertion and modification, enhancing overall weaving efficiency. In addition to the changeable heald pieces, the design can extend application of color matching changes. The color of the weft threads can also be changed. As shown in Figure 8, area 1 has yellow latitude lines, area 2 has green latitude lines, and area 3 has a mixture of yellow and green latitude lines.

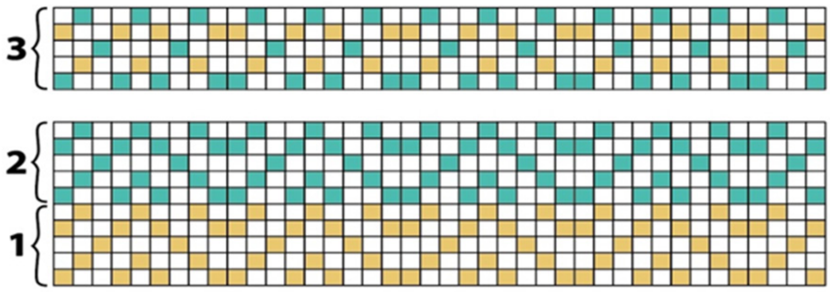


Figure 8: Comprehensive application of heald geometry and yarn changes.

Educational applications and impact

The innovative shuttle loom and flat-plate heddle system were integrated into educational workshops at the National Science and Technology Museum, targeting students and adult learners. The workshops emphasized the connection between traditional textile crafts and modern mechanical design, highlighting the principles of coding, pattern recognition, and mechanical movement through hands-on weaving activities.

Conclusion

This research successfully developed a mechanically programmable flat-plate heddle and open-type heald system for desktop shuttle looms, incorporating bitmap pattern design to simplify the weaving process. The educational application demonstrated positive outcomes, effectively combining traditional weaving techniques with contemporary coding concepts. Future work will focus on expanding the system's functionality and integrating digital interfaces for advanced pattern programming.

The research successfully developed a mechanically programmable flat-plate heddle and open-type heald system for desktop shuttle looms. By integrating bitmap pattern design, the system reduces the mechanical complexity of traditional looms, making weaving more accessible to beginners. The educational implementation demonstrated positive learning outcomes, promoting textile science as a viable subject for interdisciplinary learning in STEM education. Future work will explore the potential for scaling the system and integrating digital interfaces for advanced pattern programming.

References

1. Soffer Olga (2004) Recovering perishable technologies through use wear on tools - Preliminary evidence for upper paleolithic weaving and net making. Current Anthropology 45(3): 407-413.
2. Song YX (1637) Tian Gong Kai Wu.
3. Lin JL (2023) An innovative design of desktop shuttle loom with open-type heald. Journal of Engineering Proceedings 55(1): 36.
4. Research Report of National Science and Technology Council (2024) Developing a creative design of shuttle loom with mechanically programmable flat heald, National Science and Technology Council, USA.