

Hybrid Embroidery: Exploring Interactive Fabrication in Handcrafts

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ABSTRACT

This paper presents Hybrid Embroidery, a framework for interactive fabrication that leverages computational methods to broaden the possibilities of the craft of embroidery. Combining embroidery techniques, generative design methods, computer vision and a computerized embroidery machine, we show how this framework elicits a variety of innovative fabrication experiences that emphasize open-ended exploration, improvisation and play. The paper documents this framework, a series of sample results, challenges and next steps. It further outlines some of its implications for supporting creative exploration through real-time and direct manipulation of materials and close human-machine interaction.

The quality of a craft is not predetermined but rather depends on the judgment, dexterity and care that the maker exercises as he or she works directly with materials [1]. However, computational design methods have overwhelmingly focused on supporting the process of representing designs, not *making* them. In recent years, researchers have started to explore the potential of computational methods to enable interactive fabrication processes that allow for the situated, real-time exploration of materials. With this context, and focusing on the craft of embroidery, this project explores how interactive fabrication methods might take human dexterity and computational agencies into account, allowing for smooth iteration in processes of creative exploration. Currently, digital embroidery methods mostly support preplanned patterns [2]. In our proposed framework, by contrast, an unexpected pattern results from users' "conversations" with one of several algorithmic modalities encoded in the system. The project contributes to current debates in computational design and interactive fabrication in three ways: First, it prototypes specific ways for computation to interface with a craft; second, it leverages computational design approaches to create generative patterns for embroidery practice; and finally, it offers a platform for engaging people in reimagining traditional crafts, allowing for creative experimentation.

Background

Interactive Fabrication

Interactive fabrication is concerned with supporting real-time human-machine interactions during digital fabrication processes [3,4]. Researchers in this space have proposed that real-time control of computer numerical control (CNC) machines can narrow the gap between representation and execution that dominates most computer-aided design/manufacturing (CAD/CAM) processes, which removes users from the workpiece, preventing them from refining their designs during the creative process. For example, researchers have shown how an open-source, robotic toolkit that integrates real-time sensing and fabrication in "high-skill domains" can challenge the dualism of seeing and doing in standard CAD/CAM workflows [5]. In a similar vein, Stefanie Mueller et al. and Karl Willis et al. introduced alternative ways for people to work with digital tools without the constraints of a digital platform [6,7]. The concept of "hybrid fabrication," which Laura Devendorf and Kimiko Ryokai developed, emphasizes the possibility of supporting "meaningful making" through interactive workflows that reconfigure the roles between humans and machines [8]. Also significant is the notion of "assisted automation," which emphasizes the roles humans play in processes that are imagined as autonomous, such as robotic fabrication, opening ways for visual, tactile and spatial exploration [9]. Interactive fabrication thus opens avenues for combining manual and artistic practices with digital fabrication, broadening the scope of digital craftsmanship [10].

Crafting with Code

The increased availability of fabrication technologies enables a variety of recreational and product-focused activities, especially crafts-making with digital tools. Digital practitioners who advocate coding as their creative medium seek a greater intimacy with the machine and its outputs [11]. With the rapid development of visual computing interfaces, more designers and artists are bringing programming and

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emerging technologies into traditional crafts [12–14]. In the domain of computational textile fabrication, woven objects are a very promising application [15]. Additionally, the programmable potential of crafts makes it an appropriate medium for programming pedagogy. TurtleStitch [16], for example, is a browser-based educational programming language for embroidery that explores the potential of programmable crafts. While applications like these primarily focus on the visual programming language, our study looks into supporting the process of generating tangible embroidery paths, enriching the design process and broadening the visual and material possibilities of embroidery.

Human-Machine Collaboration in Digital Craft

Traditionally, people have viewed crafting as a social process of co-creation [17]. Today, a growing number of researchers in computational design and human-computer interaction (HCI) have sought to combine crafting techniques with digital fabrication technologies to produce participatory experiences that result in collaborative workpieces [18–20]. These invoke the definition of craft that Daniela Rosner and Ryokai developed as the “partnership between people and technology for the creation of personally meaningful things” [21]. This brings to mind Harold Cohen’s landmark AI drawing machine AARON, which he developed with the goal of supporting his own artistic practice, as well as the work of Sougwen Chung, whose artworks thematize human-robot collaborations and their unexpected results.

Hypothesis

Drawing from the examples cited above, this research envisions integrating computer vision and computational design techniques to realize a novel embroidery experience where embroiderers interact with a series of algorithmic modalities to serendipitously create unplanned embroidered pieces. Designing for intuitive, “conversational” interactions between a craftsperson and a technical system, we may create meaningful making experiences and enrich the design space in digitally augmented crafts.

Technical Implementation of an Interactive Framework

This project examines the adaptation of a computerized embroidery machine for building an interactive fabrication system that provides an intuitive way for designers to directly interact with material and support improvisation in the making process through a series of turn-based games.

Hybrid Embroidery generates embroidery patterns based on users’ inputs at each round during turn-based interaction and transfers those patterns into a pat file to control the computerized embroidery machine (Fig. 1). The hardware consists of a Web camera and a CNC embroidery machine with the send-path utility developed at the Carnegie Mellon University (CMU) Textiles Lab [22]. Figure 1 illustrates the physical setup. In the software implementation, we first utilize the OpenCV Library for pattern recognition and feature extraction. Second, we leverage Rhino Grasshopper/Python script to achieve generative pattern design as well as pat file translation. Finally, modeling software Rhino serves as the interface for visualizing machine feedback.

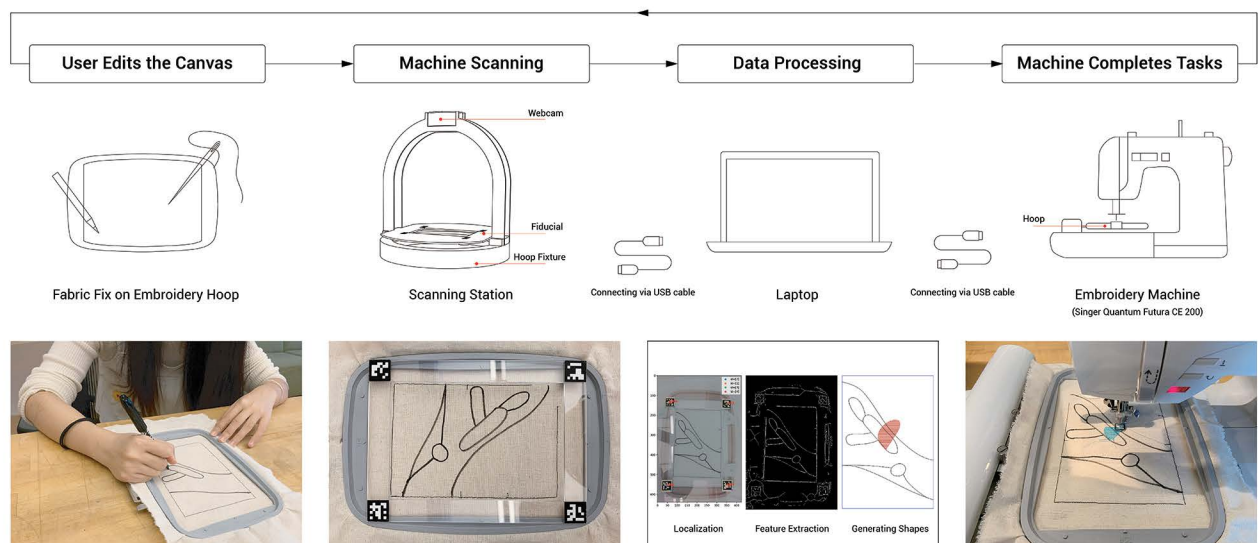


Fig. 1. Diagram of the turn-based interactive fabrication system and hardware setup.

We designed several computational approaches to experiment with different levels of control during turn-based interaction; Table 1 describes different algorithmic modalities and the role of the user and the machine. These aim to create a dialogue between user and machine, where a machine responds, with different degrees of predictability, to the user's inputs, influencing them. Each approach follows different rules and carries out different visual experiences to understand their effects on the user's making experience.

	Fully controlled → Unexpected outcomes			
Interaction Category	Direct Manipulate	Rule Driven	Probability Driven	Chance
Geometry Generation Algorithm	Drawing command	Parametric line drawing	Machine learning for embroidery	Computational randomness
User Inputs	Doodling and assigning color to the target area	Line drawing	Doodling and assigning color to the target area	Doodling
Machine Feedback	Machine fills the target area with color	Machine bridges lines according to rules	Machine fills the target with color through ML algorithm	Machine returns arbitrary shapes

Table 1. Algorithmic modalities represent different levels of control.

Hybrid Embroidery users select one of the different algorithmic modalities and make a drawing that serves as the starting point for the turn-taking process. During the turn-taking process, the user draws on the canvas attached to the embroidery hoop, responding to machine outputs. After the drawing is finished, a camera above takes a picture of the canvas. Once the system receives the image, it runs the edge detection to locate the new points and update the coordinates of the latest stroke to generate new patterns. In the end, the machine automatically finishes the embroidery task. In the current setting, the user could select the style of yarn and manually tread the yarn on the machine. The reaction time of the machine depends on the complexity of the shape; generally, it could take the machine 10–20 minutes to finish the embroidery task.

Result

Direct Control: Drawing Command

The user consciously draws the picture and assigns the color to target regions. The machine will follow commands and finish the embroidery path (Fig. 2).

Rule Driven: Generative Line Drawing

The function will take in two curves and return continuous lines traveling back and forth between them. Every time users add a new curve, it updates the previous set, so that it could generate a new pattern in every round (Fig. 3).

Probability Driven: Model-Based Deep Reinforcement Learning

This experiment implements the machine learning algorithm for coloring humans' drawings with embroidery. We utilized "LearningToPaint" that Zhewei Huang et al. developed [23], which is a painting AI that can reproduce paintings stroke by stroke using deep reinforcement learning. The algorithm will take in pixel-based image inputs and generate layers of strokes as outputs (Fig. 2). The algorithm is modified for the embroidery purposed in this experiment.

Chance: Computational Randomness

We borrowed concepts from the surrealist games Collage and Exquisite Corpse that encourage open-ended exploration and trigger people's imagination. In this research, we morph the rules of Exquisite Corpse and play this game on top of the fabric. The invasion function will keep tracking users' doodling strokes and takes in the last stroke as input.

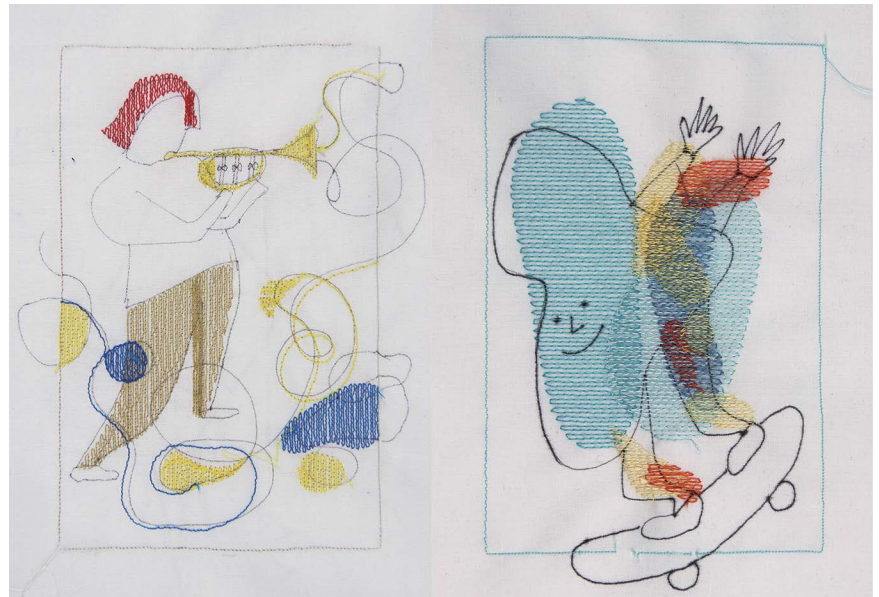


Fig. 2. Yi-Chin Lee, machine embroidery and hand drawing on muslin fabric, 6 × 4 in, December 2019. Left: The user participates with hand drawing and assigns colors in each area. Right: The machine generates embroidery paths based on the "LearningToPaint" algorithm to color the human drawing. (© Yi-Chin Lee)

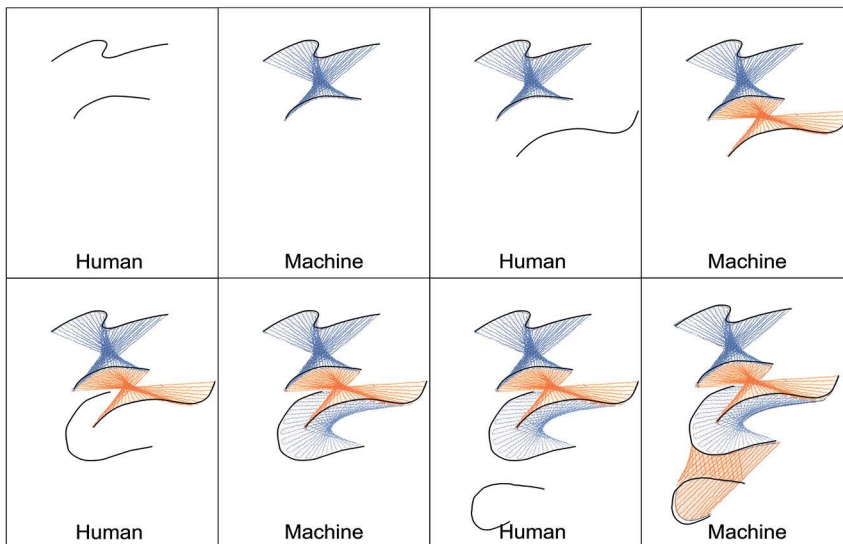


Figure 3.1

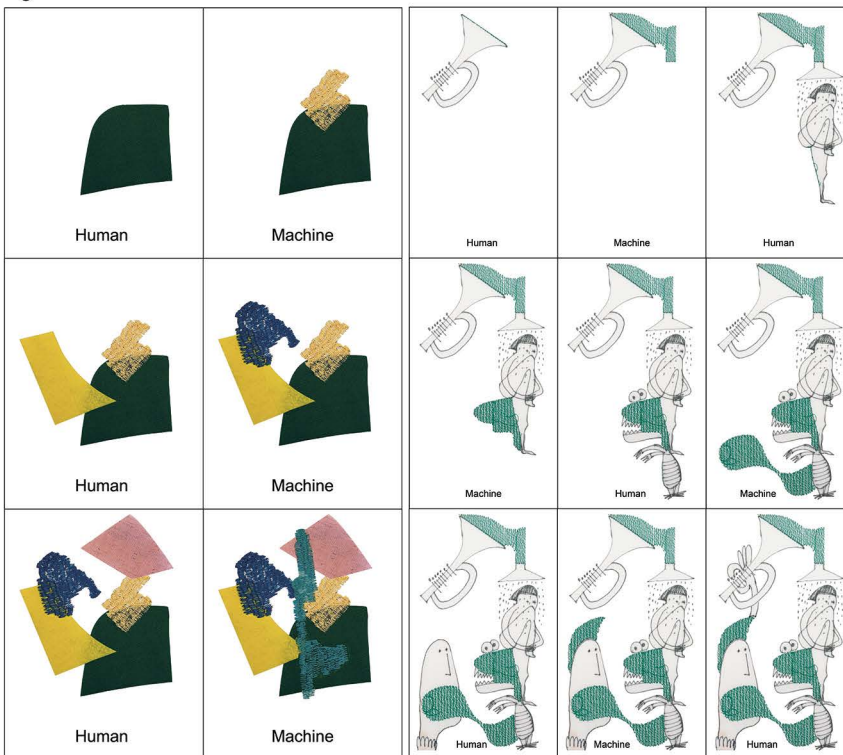


Figure 3.2

Figure 3.3

Fig. 3. 3.1 Yi-Chin Lee, machine embroidery and hand drawing on muslin fabric, 6 × 4 in, December 2019. The process of parametric line drawing. 3.2 The process of material collage with embroidery. 3.3 The process of Exquisite Corpse on embroidery. (© Yi-Chin Lee)

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The system will run random seeds to generate arbitrary geometry. Users can use their imagination to interpret the shape and keep on drawing (Fig. 3). In another case, Collage, users can insert all kinds of soft material under the needle, as long as it can poke through. During the making process, the system takes in a closed curve and returns a path partially overlaid on top of the contour, so that the collage piece can be fixed on the canvas. In this mode, users can play with the system through soft material that naturally provides a close edge for better detection (Fig. 3).

Conclusion

Hybrid Embroidery proposes a novel way for users to interactively produce an embroidery piece with a CNC embroidery machine. The project extends existing research in the fields of computational design and interactive fabrication by exploring an alternative way for crafting with digital tools. As documented above, the framework facilitates open-ended exploration and improvisation, enriching the process of making with aspects of play. The prototypes presented raise questions about how human-machine systems may support users with a diversity of skill levels and aesthetic inclinations, and how we may design systems that support digital craftsmanship without aiming to replace humans. We believe these are noteworthy questions today for a range of creative and manufacturing industries.

Future Work

The research plan involves a series of workshops among crafts makers in Pittsburgh in the spring of 2020. We are particularly interested in exploring the communal dimension of crafts and how this framework might support it. We plan to develop more turn-based modalities on top of this system and offer more interactive modes for groups of people to engage with embroidery. As a result of the COVID-19 health crisis, the proposed workshop was postponed. We hope to conduct it once the situation has cleared.

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