CARNEGIE MELLON UNIVERSITY

School of Architecture

College of Fine Arts

Thesis

Submitted in Partial Fulfillment of the requirements for the degree of

Master of Science in Computational Design

TITTLE:

Hybrid Embroidery:
Exploring Interactive Fabrication in Hand Crafts

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Submitted to the School of Architecture
in partial fulfillment of the requirements for the degree of
Master of Science in Computational Design,
at Carnegie Mellon University.

Abstract

This research presents Hybrid Embroidery, a system for interactive fabrication that leverages the potential of computation to broaden the possibilities of the embroidery craft. Combining traditional crafting techniques of embroidery, computational design methods, computer vision, and computer numerical control (CNC), the research shows how this framework elicits a variety of innovative fabrication experiences that emphasize open-ended exploration, improvisation, and play.

Interacting with the system's algorithms in a conversational, turn-based fashion, users create generative embroidery stitching paths that result in unique embroidery pieces. Each embroidered piece acts as a module of the bigger picture in the game of exquisite corpse based on the inherent communal nature in textile crafting. Hybrid Embroidery thus offers an example of how computational methods may enrich crafts and other creative practices. Further, the research highlights implications for supporting creative exploration through real-time and direct manipulation of materials and close human-machine interaction. Through Hybrid Embroidery, this thesis documents results and challenges to reflect on how to reposition embroidery with a tradition of collectivity in traditional crafting.

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Chapter 1
Introduction

1.Introduction

This research explores how best to design an interactive fabrication system that fosters collective creation in embroidery. In an attempt to expand the current interactive fabrication framework, this research explores two questions: First, how can we enrich personal aesthetic expression via human-human-machine dialogue? Second, how can turn-based interaction provide a less-controlled environment to support design exploration?

The thesis presents Hybrid Embroidery, a novel interactive system for users to interactively produce an embroidery piece with a computer numerical controlled (CNC) embroidery machine. In doing so, the project extends existing research in the fields of computational design and interactive fabrication by both exploring an alternative to crafting with digital tools and breaking the single author setting in current digital crafting. Collaboration between diverse craftspeople with varied expression adds value and meaning to crafts, especially in the textile craft. To support this collective design, the research explores how to redesign interaction behavior. Thus, the two main objectives of this research are to support the design space in digital embroidery and explore how to expand the current interactive fabrication framework to allow diversity making in collective textile crafting. This system does not seek to foster social interaction amongst authors outright, but rather, the project aims to embed, within the design framework, a potential for sociality that can better facilitate social interaction in the future.

The project thus contributes to current debates in computational design and interactive fabrication in three aspects: First, it prototypes specific ways for computation to interact 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 re-imagining traditional crafts by allowing for creative experimentation.

Chapter 2
Background

2. Background

The research designs the interactive system to align with the cultural and technical perspectives of needlework in textiles. Within this domain, the project incorporates an interactive fabrication framework to facilitate collaboration between craftsperson and machines. However, to account for the limitations of the interactive fabrication framework, the research designs a turn-based interactive system to accommodate the collective nature of needlework.

2.1 Embroidery as Medium

Needlework, which uses a needle and thread to attach materials, includes different textile crafts, such as sewing, quilting, and embroidery. Even though they are all forms of needlework, they are distinct in terms of functionality: Sewing is a method to attach materials with yarn, and it creates the structure of the garment; quilting is the process of sewing two or more layers of fabric together to make a thicker padded material; embroidery is the craft of decorating the fabric with thread or yarn with a needle. Although the research puts focus on embroidery, it will include examples in from needlework to illustrate the positioning of the project.

Embroidery, with its cultural associations and technological development, has been deployed in several domains such as art, craft, and manufacturing. As a result of this medium's rich history, it provides us with an opportunity to think about how modern technology could enrich a traditional craft. It also allows digital practitioners to rethink the critical and cultural value that should be respected when we combine technology with craft-making.

Culturally, textile crafting is viewed as a social process of co-creation and shared ideas. Crafting skills are often taught and practiced socially because people usually learn to craft in communities. For example, parents pass sewing skills to children, and a hobbyist group exchanges knitting patterns. These social groups indicate the centrality of textile crafts to a

community, and more fundamentally, crafting is a part of ideas exchange that can influence social dynamics among the group (Gauntlett 2013). Although textile creation is the result of individuals' work, craft persons often treat it as a social accomplishment (Rosner 2018). Crafting itself allows people to express cultural and personal identity, cultivate self-awareness, and develop a sense of belonging, which in turn, enhances the quality of life and perceptions of well-being (Riley 2008).

Most importantly, crafting brings people together. Some representative projects show how needlework draws people together to form a powerful community. For example, the AIDS Memorial Quilt (Figure 2.1) sought to gather the community of makers to encourage wide participation and collaboration in making a quilt. During the movement from 1980 to 1990, panel making workshop allowed people to meet up and work on panels. Similarly, Judy Chicago's art piece, The Dinner Party (Figure 2.2), gathered craftspeople together to make meaningful pieces. Around 400 hundred people skilled in ceramics, needlework, and weaving worked together to create thirty-nine place settings, each commemorating an important woman from history. Both of these movements took needlework as a medium to unite people and speak up for those who have been traditionally underrepresented, which shows that the medium influences society beyond just its functionality and decorative potential.

The technological development of textile also speaks to its influence. Textile machines have been developing for centuries, and with the advent of modern technology, textile machines have become smaller, faster and more capable of handling complex tasks. However, the works done by machines are often too perfect and lack human texture. Hand embroidery, on the other hand, creates these textures and exhibits human uncertainty as well as dexterity. As a result, hand embroidery reveals the craftsperson's personality and establishes her unique style. And even though machines are more advanced today, there are still many embroidery stitch techniques that cannot be replicated by a machine. Aesthetically, the two are not the same.

To account for these tensions between machine efficiency and the aesthetics of handicrafts, some artists combine manual work and machines to explore the possibilities of textile art. Italian artist Angelo Filomeno, for example, created a collection of embroidery paintings by controlling the

embroidery hoop manually to embody human uncertainty on the art piece (Figure 2.3(a)). Like Filmeno, the American artist Terry Boyd combined manual work and machine work in his art pieces. Boyd utilized the machine to quickly set up the background and main features on the canvas, and afterward, he would add floating thread and other material to enrich the design and establish the artistic expression (Figure 2.3(b)). These works show how the collaboration between human and machine create a new aesthetic and method of making.



Figure 2.1 *NAMES Project AIDS Memorial Quilt, National Mall Washington, D.C., 1996. http://www.thedallasway.org/stories/written/written-stories/2015/5/10/names-project-aids-memorial-quilt*



Figure 2.2 *Judy Chicago, "Dinner Party," Elizabeth A. Sackler Center for Feminist Art, Collection of the Brooklyn Museum, 1979 © Judy Chicago*



Figure 2.3 *(a): Angelo Filomeno, "Broadway," Metallic thread on cotton,10 × 8 inches, 2019. https://www.artsy.net/artwork/angelo-filomeno-broadway (b): https://www.terrenceboyd.com/ © 2020 Terry Boyd*

2.2 Digital Embroidery

The emergence of the sewing machine brought tremendous benefit to the textile industry in the eighteenth century and contributed to mass production. Now, with the development of modern computational technologies, it enables a variety of textile application and pushes manufacturing and craft-making to another level. With the rapid development of visual computing interfaces, more designers and artists bring programming and emerging technologies into textile crafts.

Today, the power of computers enables people to program the gantry that attaches to the embroidery machine, which can replace the human hand's job at finishing the embroidery task. One of the most significant challenges that makes computer-driven embroidery different from other CNC controllable material is the physical properties of the yarn. To avoid floating yarn on the canvas, the embroidery path needs to be a single continuous line. Therefore, in digital embroidery, stitch generation and stitch simulation are more challenging than some digital fabrication techniques that can move without carrying the material. For example, a laser cutter could move without emitting laser. In the manufacturing application, many sophisticated machines could support textile production; however, there are not enough tools to support experimental and customized design. Further, the software that directly converts the image to an embroidery path are expensive and require experienced users several iterations to design a proper pattern (Nielsen 2011).

Software developments offer potential options for working with these issues. Researchers in Disney Research Lab developed a graphical method to create a sewing path for a whole-cloth quilt from a photograph (Liu, Hodgins, and McCann 2017). In the research, most of the effort lies in labeling the image, extracting the representational features, and creating a continuous sewing path by solving the Rural Postman Problem (Figure 2.4). Other research developed the creativity support tools that enhanced stitch simulations, stitch generation, and improvisation with AI to ease the learning curve(Grow 2017).

However, digital practitioners who advocate coding as their creative medium seek greater intimacy with the machine and its outputs; therefore they tend to develop their own digital tools to facilitate personal works(Nimkulrat, Kane, and Walton 2016). TurtleStitch provides an example of how to combine creative coding and embroidery as they make it an appropriate medium for programming pedagogy. TurtleStitch (Wolz, Auschauer, and Mayr-Stalder 2019), for example, is a browser-based educational programming language for embroidery that explores the possibility of programmable crafts (Figure 2.5). While studies like these primarily focus on the visual programming language, this study looks into supporting the process of generating tangible embroidery paths, enriching the design process, and broadening the visual and material possibilities of embroidery.



Figure 2.4 *The research automatically produces single-line sewing paths from labeled images. These sewing paths can be stitched by a computer-controlled quilting machine to produce whole-cloth quilts. (Source images used with permission from Flickr users Tod Kurt [https://www.flickr.com/photos/35034345966@N01/18921303129], Gilles Péris y Saborit [https://www.flickr.com/photos/ 42250269@N06/90568060 31], and Dwayne [https://www.flickr.com/photos/17816202@N00/6453595003].)*

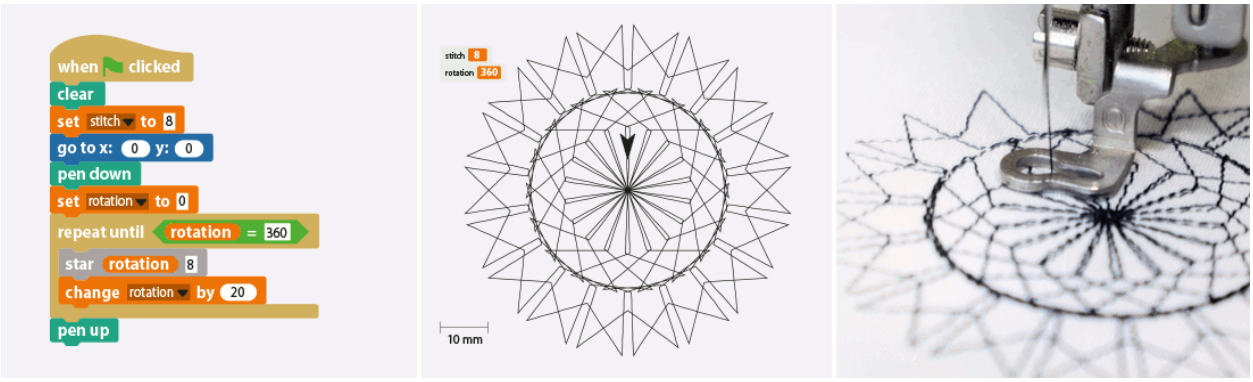


Figure 2.5 *Turtlestitch is a browser-based educational programming language (Snap!) that could generate patterns for embroidery machines.*

2.3 Interactive fabrication

Computational design methods have overwhelmingly focused on supporting the process of representing designs, not *making* them. As Pye showed, the quality of a craft is not predetermined but rather depends on the judgment, dexterity, and care which the maker exercises as he/she works directly with materials (Pye 1968). 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. These methods attempt to reconnect the human with the material world and support non-linear design iteration through the situated making process (Zoran, Shilkrot, and Paradiso 2013). Focusing on the craft of embroidery in this context, this project explores how interactive fabrication methods might take human dexterity and computational agencies into account in ways that allow for smooth iteration in processes of creative exploration.

Interactive fabrication opens avenues for combining manual and artistic practices with digital fabrication, broadening the scope of digital craftsmanship (Jacobs et al. 2017) by supporting real-time human-machine interactions during digital fabrication processes (Peng et al. 2018). Researchers in interactive fabrication have proposed that real-time control of CNC machines can narrow the gap between representation and execution that dominates most CAD/CAM processes, which removes users from the workpiece and prevents 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 (Bard 2014). In a similar vein,

Muller et al. and Willis et al. introduced alternative ways for people to work with digital tools without the constraints of a digital platform (Mueller, Lopes, and Baudisch 2012). Further to reconfigure the roles between humans and machines, the concept of "hybrid fabrication," developed by Devendorf and Ryokai, emphasizes the possibility of supporting "meaningful making" through interactive workflows (Devendorf and Ryokai 2015).

2.4 Attention Economy in Handcrafts

Current interactive fabrication frameworks are successfully putting humans back to the fabrication loop, but there are still some unexplored areas of research. Recent research in interactive fabrication focuses on adopting emerging technology to explore alternative ways to control machines, shorten the latency of real-time interaction, and provide a smooth working experience (Mueller et al. 2019). If implemented correctly, these features could support a fluent design experience with novel control methods. However, human-machine interaction could cause cognitive overload sometimes, which reduces the capacity for the participant to be creative in the design space. In the real-time interaction set ups, the user has to come up with the design idea in a limited way while the visual or audio model is packed with essential processing demand. Moreover, each maker has different thinking and making strategies; the system should be flexible enough to support various interaction rhythm between humans and machines. One of the solutions to cognitive overload is the use of segmenting, which includes time between a successive actions (Mayer and Moreno 2003). Hence, this research would explore how to segment the working process that could ease the pressure caused by interacting with digital tools and accommodate different working styles among all the potential users.

On the other hand, embroidery is often social, collective, and works along with the rhythm. The ideal needlework relies on hand-eye-mind coordination during the process (Shercliff 2015). With the muscle memory and the human tactile knowledge, once the craft person familiar with the rhythm of the stitches, the cognitive load is low when working on needlework. At the same time, the extra attention could afford social interaction or design exploration. Based on this finding, this research considers how the use of technology can reflect on this working rhythm when interacting with the social craft.

2.5 The Collective Creativity in Games

To further develop the capacity offered through collective events in needlework, games are a platform that provides an uncontrolled collective creation through a set of expectations. There are many types of games, and game researchers put them into several categories. This research draws inspiration on "progressive crafts" and "bees" (Sullivan, Salter, and Smith 2018).

The progressive craft game is played in a group, where one person will initiate the works and the next person will contribute to work on the same piece. One of the most famous progressive crafts is called "exquisite corpse" (Figure 2.6). Developed by surrealists, exquisite corpse, is mediated by chance, leverages play to unleash a person's unconscious, and opens up a space for radical imagination. The progressive craft aimed to revolutionize human experience and embraced the unconscious to reject a solely rational world.

Another genre of game is "bees." In this type of play, a group of people will work simultaneously on their individual projects, which will eventually become a part of the collective creation. Usually, in each bee, there will be the "Queen," who specifies what he or she wants from everyone else. People are allowed to prepare the patch at home and bring it to a quilting bee meetup, or they could work simultaneously in a shared space. Although all the participants will follow a set of expectations from the "Queen," they still treat their work as a place for personal expression. One well-known example of this type of event in textile crafting is the Quilting Bee. (Figure 2.7) The Quilting Bee is a traditional American event that gathers friends, and neighbors come together to work on creating a quilt. It can be a casual time for people chatting and working together, or it can be in the form of a competition.

Building on Quilting Bee's tradition, an HCI project eBee (Pearce et al. 2016), integrates quilting and soft circuits making into a board game (Figure 2.8). Each person works on their own electronic patch during the process, and when each piece is connected, the whole circuit will activate. eBee aims to bring the electronics-making community and handcraft community together to create a social experience aimed at bridging gender, ethnic, generational, and social gaps. Connecting the interactive system with the collective tradition of textile enriches the cultural perspective of this research. The system strives to provide a diversity of computational

modalities to support diversity in creation and allow for the building of personal identity in collective work.



Figure 2.6 *Jake Chapman and Dinos Chapman, "Exquisite Corpse," Tate, 2000. © Jake and Dinos Chapman*



Figure 2.7 *Women getting together to make a quilt. http://agatheringofstitches.com/blog/2014/1/13/a-quilting-bee*



Figure 2.8 *Completing a circuit to light up a tile on the IndieCade iteration of eBee.*

Chapter 3
Method

3 Method

The method combines the traditional crafting techniques of embroidery, computer vision, generative design methods, and a CNC machine to build an interactive framework. The research will show how this interactive framework elicits a variety of innovative fabrication experiences that emphasize open-ended exploration, improvisation, and play. This section elaborates on how the research expands the social perspective in interactive fabrication and implements the interactive system. First, I will introduce the data processing pipeline. Next, I will explain the activity designed for people to play with the system; and finally, I will illustrate the envisioned scenario for accommodating this interactive framework.

3.1 Hypothesis

The system is built to explore two aspects of digital craftsmanship. First, this research integrates computer vision and computational design techniques to realize a novel embroidery experience, where the user interact with a series of algorithmic modalities to serendipitously create unplanned embroidered pieces. The research hypothesize that this design may allow for intuitive and "conversational" interactions between the user themselves and the technical system. Do so may ultimately create meaningful making experiences and enrich the design space in digitally augmented crafts. Second, turn-taking could provide another collaborative scenario in interactive fabrication. By separating the process into turn based procedures, we suggest it could provide a flexible environment to adopt different making rhythms among players and further foster creativity.

3.2 Framework of Interactive System

This project adapts a computerized embroidery machine to build an interactive fabrication system that provides an intuitive way for designers to directly interact with material and supports improvisation in the making process through turn-based games. The system starts with machine

automation, follows with human-machine interaction to complete design iteration, and ends with collective creation in human-human interaction (Figure 3.1).

Initially, during machine automation, 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. The hardware consists of a web camera and a CNC embroidery machine with the send-path utility developed at Carnegie Mellon University's textile lab (MaCann et al. 2018). In the software implementation, I first utilize the OpenCV Library for pattern recognition and feature extraction. Second, I leverage Rhino grasshopper/Python script to achieve generative pattern design as well as PAT file translation. Finally, for modeling software, Rhino served as the interface for visualizing machine feedback (Figure 3.2).

For the implementation of human-machine interaction and design iteration, 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. These interaction modes are designed to represent a different level of control from direct manipulation, rule-driven, probability-driven, to chance. Through these modes, the research aims to explore how embedding different algorithms in the machine could reconfigure the role of humans and machines or foster different aesthetics in embroidered pieces

During the turn-taking process, the user draws on the canvas attached to the embroidery hoop and respond to machine outputs. After finishing the drawing, the player will bring the canvas to a scanning booth where an embedded camera takes a picture. Once the system receives the image, it will locate the target area and run the edge detection algorithm to collect the coordinates of the inputs. After this is complete, the analog information will transfer to digital space, and a generative pattern will be created in the embroidered form. In the end, the machine will automatically finish the embroidery task. For this task, the user can select the style of yarn and manually thread the yarn on the machine. The reaction time of the machine depends on the complexity of the shape, and generally, it takes a machine 10-20 minutes to finish the embroidery task.

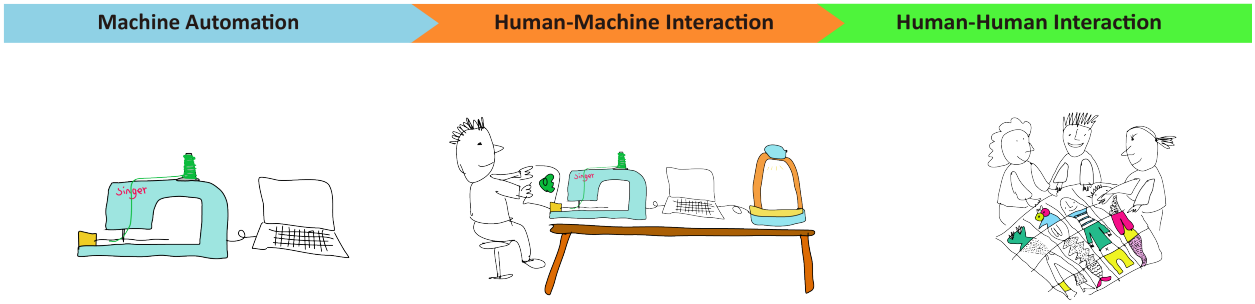


Figure 3.1 *The high-level concept of the interactive framework in social crafting concept. The figure shows the relationship between computer, machine, and human in different phases of the interactive framework.*

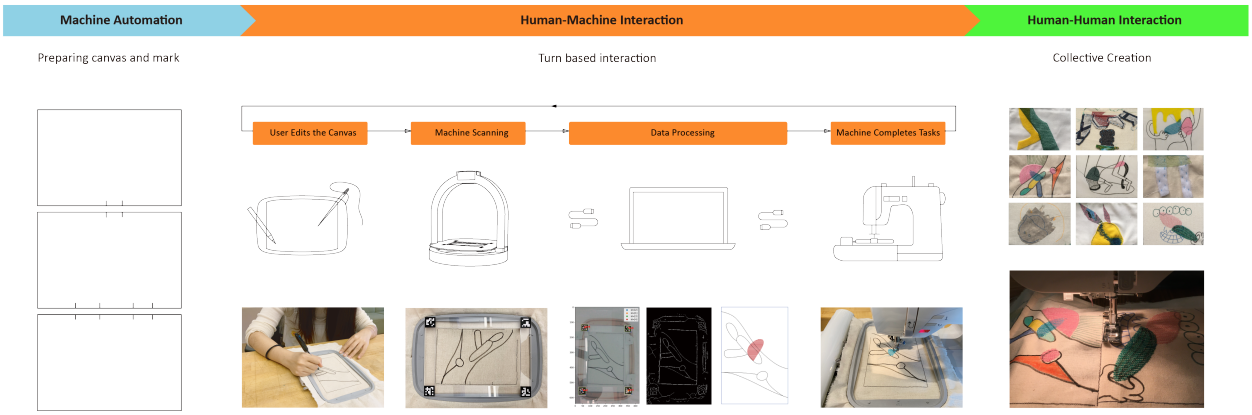


Figure 3.2 *The interactive framework*

3.3 Technical Implementation

3.3.1 Preparing Canvas

During the technical implementation, the system will run the Grasshopper script(Figure 3.3) to prepare the canvas. After that, the machine will embroider the canvas boundary and markers to the fabric for the purpose of Collaborative Exquisite Corpse. Those connection marks function as the traces left on the folding paper in the original exquisite corpse. At the end of this stage, the canvas with an embroidery hoop will be delivered to each player (Figure 3.4).

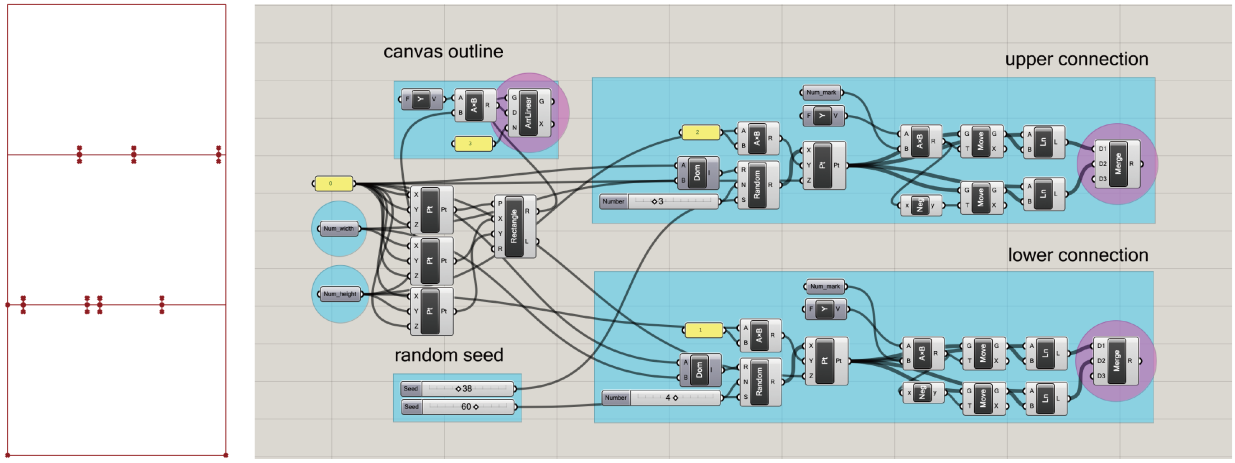


Figure 3.3 *Left: Grasshopper script that generates the canvas file Right: the boundary and the marks.*

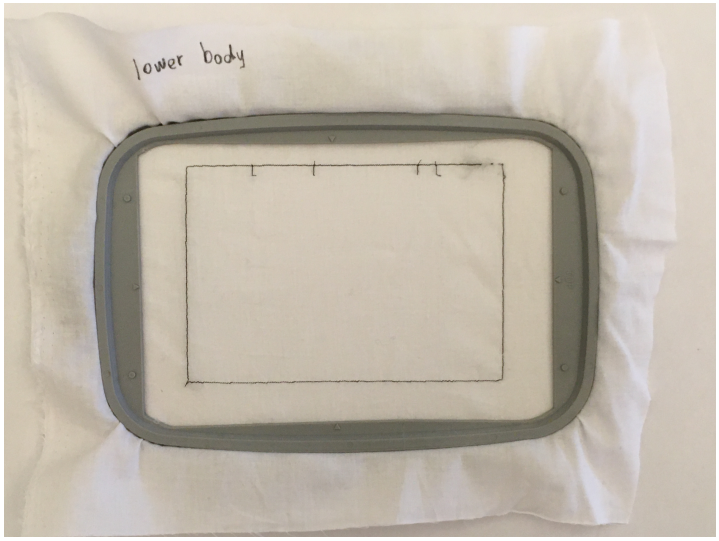


Figure 3.4 *The canvas distributed to players.*

3.3.2 Scanning System

To capture the human analog input, I built a scanning booth (figure 3.5) that helps users place the canvas in the correct orientation and establishes the ideal physical environment for capturing a high-quality image for data analysis. This scanning booth is a functional product and serves as a symbol of the connection between pure handwork and the digital world.

There are three features of this scanning booth to make it playful and intuitive during operation. First, there is an embedded camera at a fixed distance from the target canvas to control the size of the image. Second, the embedded LED light inside the base can cancel the shadow created by

the environment and provide consistent lighting quality. Finally, fiducials are designed for localization, so users do not have to worry about the possibility of manual error in positioning.

For the scanning booth design, the color and material selection help make the it look like a playful and friendly object. To build the basic structure, I used 3/4 inch plywood with a light color and 1/8 inch acrylic. The structure is composed of several elements to make it look sleek and trigger curiosity. There is a yellow dome support frame, which provides rigid support but is not visually overwhelming. A camera box to hide the electronics which makes the booth look sleek so that it may trigger a sense of curiosity. And finally, 3D printed components such as LED light and buttons add details into the scanning booth and make it look like a completed product (Figure 3.6).

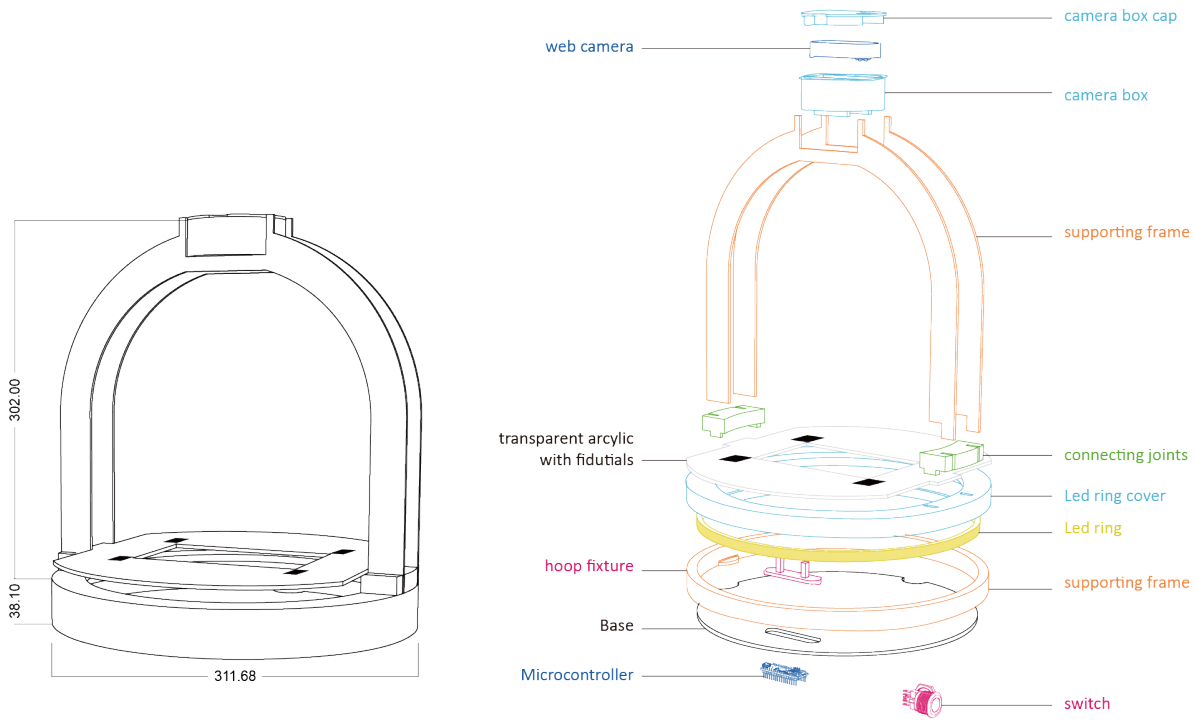


Figure 3.5 *The design of the scanning booth(mm).*

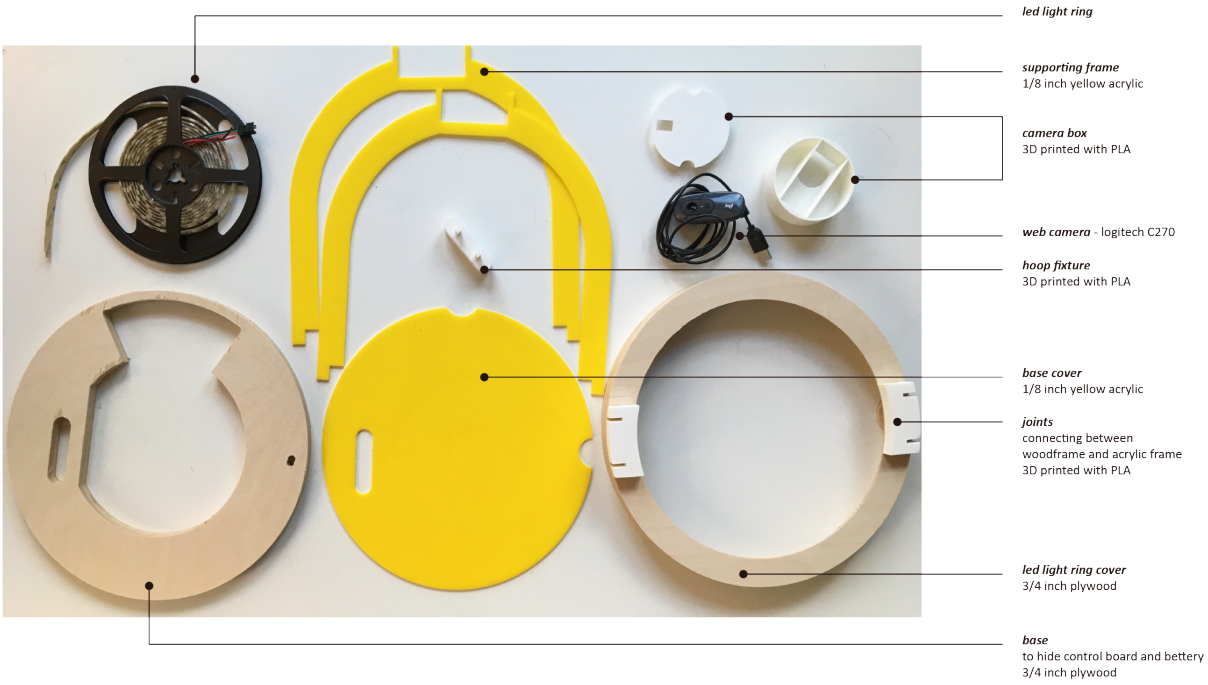


Figure 3.6 *The materials and components of the scanning booth.*

3.3.3 Image Processing

The image processing module is built to capture and analyze human analog inputs and translate those data into modeling software for further computational design. The data processing starts with the initiation of the Python application. When the user places the embroidery hoop properly, he or she will press the button to activate the application, and the Python application will trigger the camera. Once the system captures the image of the canvas with fiducials at four corners (Figure 3.7 (b)), the Python application processes the request and initiates the feature extraction with the OpenCV library (Figure 3.7 (a)). The corner points received through the localization process will crop the target data we need in the canvas. In this stage, the data is noisy and without structure.

There are several steps in the software to reconstruct human drawings and make a better digital representation in modeling software. First, the sampling algorithm averages points in every four pixels and gets the center point. Second, the clustering algorithm works on grouping the points according to the distance threshold. Any group size under fifteen data points will be eliminated to reduce the noise. Third, points will be sorted into the structured data to represent the human stroke in sequence. The sorting algorithm is aimed at finding the shortest path to connect the

points within each cluster and create output to coordinate it into a two-dimensional list. Finally, all the information will be parsed to Rhino space (Figure 3.7 (c)) through the open-source communication protocol for visualization and future parametric design process.

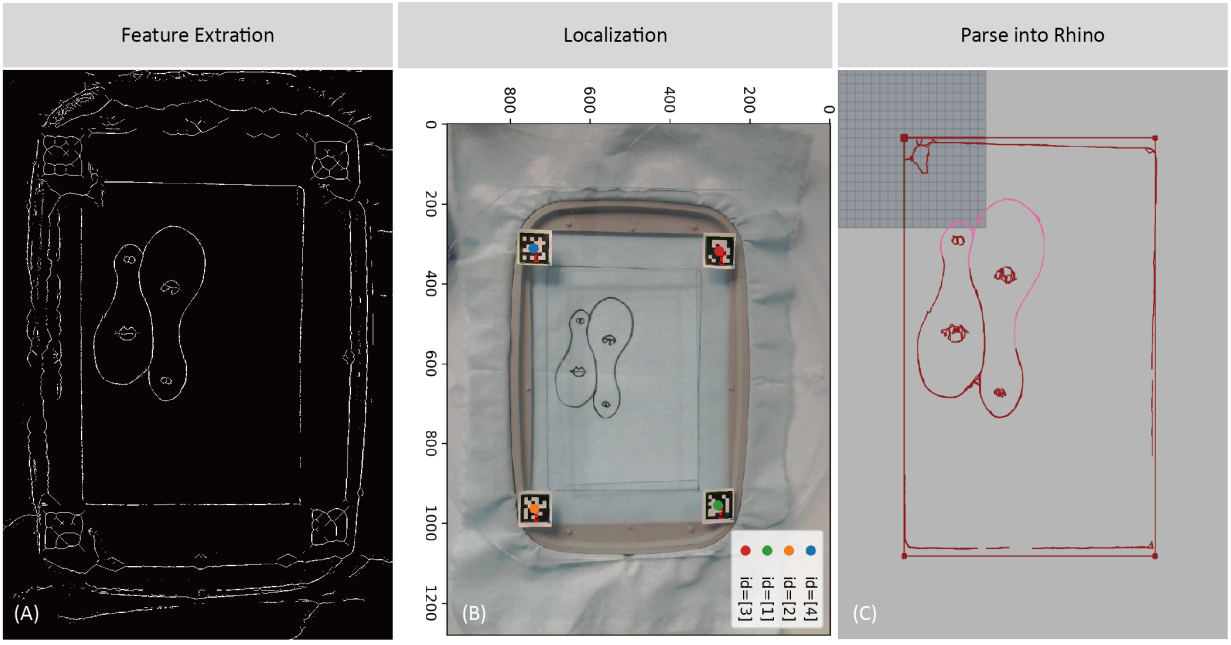


Figure 3.7 *The visualization of the data processing in each phase: (A)Feature Extraction (B) Localization and (C) Parsing to modeling software - Rhino*

3.3.4 Geometry Generation: Levels of Control

Several computational approaches are designed to experiment with different levels of control during turn-based interaction, which the various algorithmic modalities and change the role of the user and the machine as described in Table 3.8. These aim to create a dialogue between user and machine, where a machine responds with different degrees of predictability to the user's inputs and influences them. Each approach follows different rules and carries out diverse visual experiences to understand their effects on the user's making experience.

	Fully controlled outcome ⟶ Unexpected outcomes			
Interaction Category	Direct Manipulation	Rule-Driven	Probability-Driven	Chance
Geometry Generation Algorithm	Drawing command	Parametric Line Drawing	Machine learning for embroidery	Computational randomness
User Inputs	Doodling and assigning colors to the target area	Line drawing	Doodling and assigning colors 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 3.8 *Different computational modalities*.

3.3.4.1 Direct Control - Drawing Command

Within this scenario, the user consciously draws the picture and assigns the color to target regions. The machine will follow commands and finish the embroidery path. The user can draw a closed curve at each turn, and the machine will detect the curve and fill the region (Figure 3.9). The user can draw complicated shapes and assign the color to a specific region (Figure 3.10). Before the interface is implemented, the user communicates with the operating person about the color and target area or use color as an identifier on the canvas.

This research provides two strategies to create a sewing pattern to fill the target area automatically. The first mode is the straight-line hatch pattern (Figure 3.11). The challenge of generating the sewing pattern is that it should consist of a single line, so after segmenting the area into straight lines, the end of each line is connected to the head of the next line. As a result, the manipulatable parameters are orientation and the density of the hatch pattern (Figure 3.13). The second mode is the concentric spiral pattern (Figure 3.12). In this case, because it difficult to generate a single line hatch pattern when the shape has irregular boundaries, the spiral curve is used to offset along the boundary to fill the area. For this mode, the manipulatable parameters in this mode are the density of the pattern (Figure 3.14).

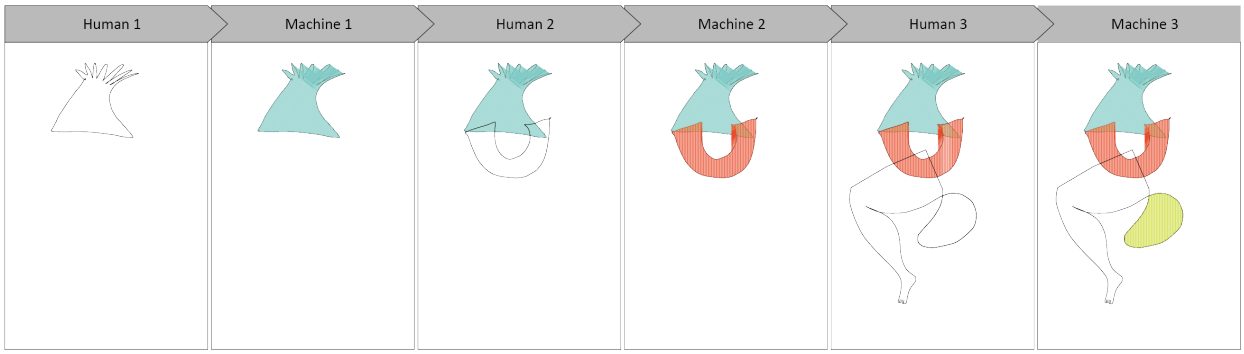


Figure 3.9 *The image shows the turn-taking process under the direct manipulation mode. Players draw one close curve as input at each turn.*

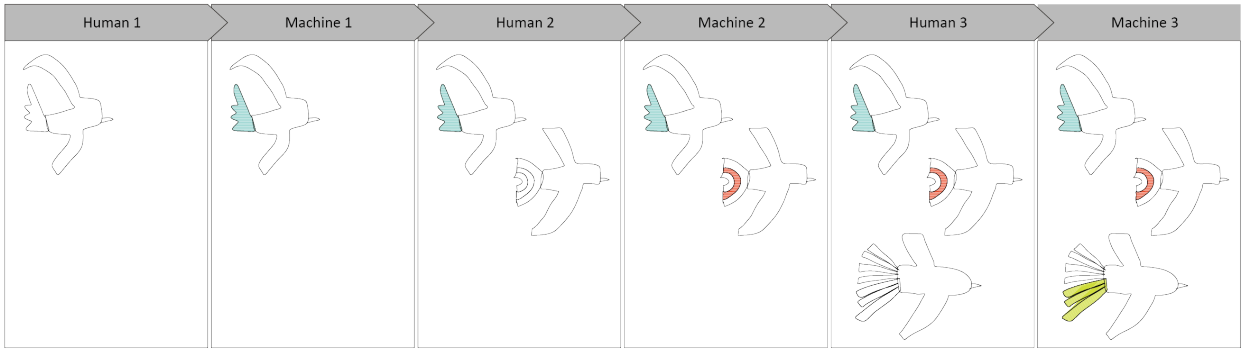


Figure 3.10 *The image shows the Turn-taking process in direct control mode. Players doodling at each time, and assign the coloring area.*

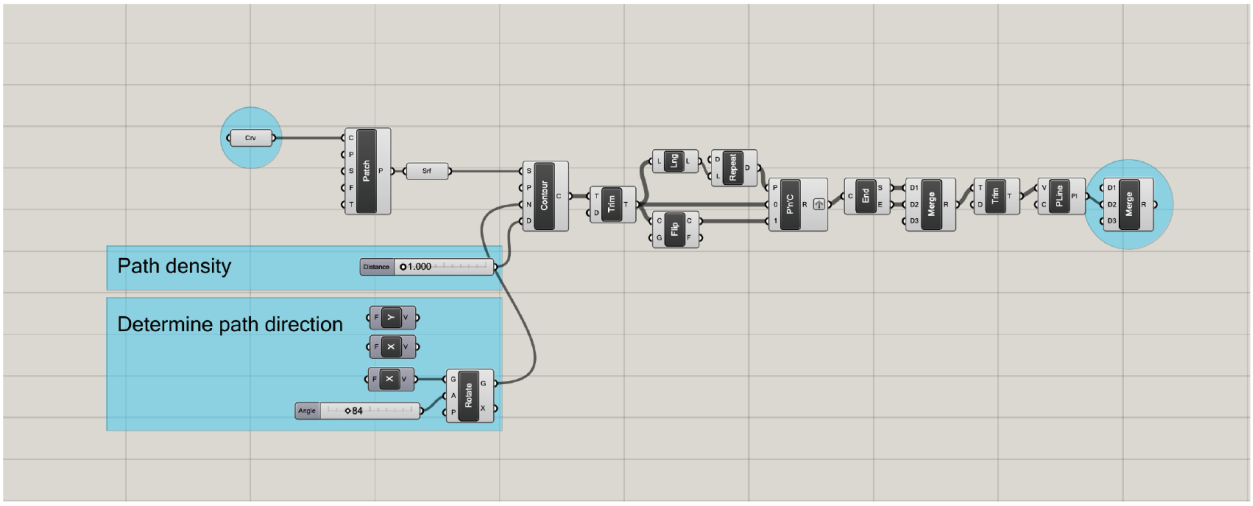


Figure 3.11 *The image shows the Grasshopper script for generating a continuous straight line to fill the close shape.*

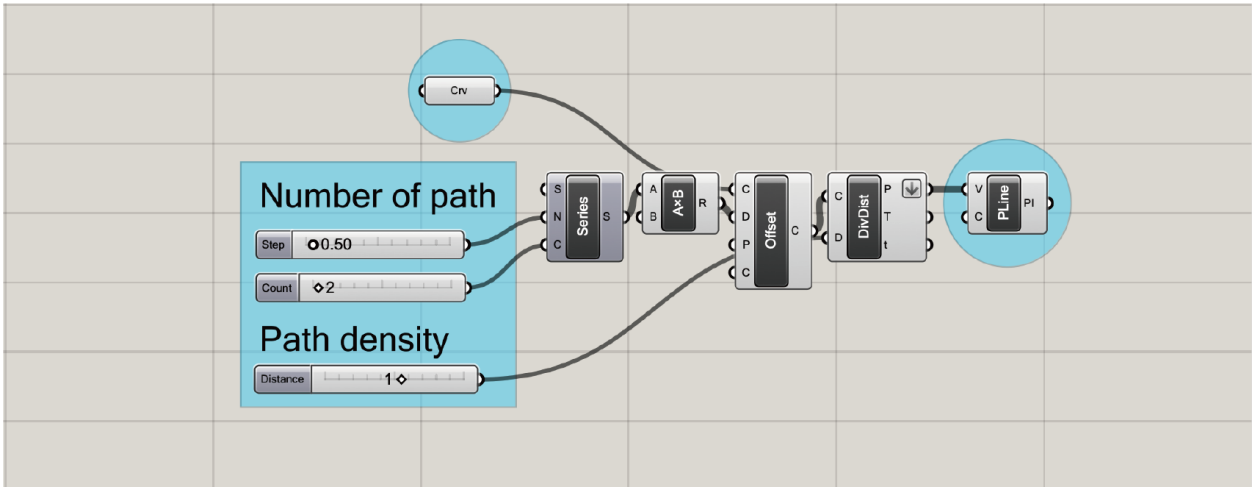


Figure 3.12 *The image shows the Grasshopper script that generates a spiral curve to fill the area.*

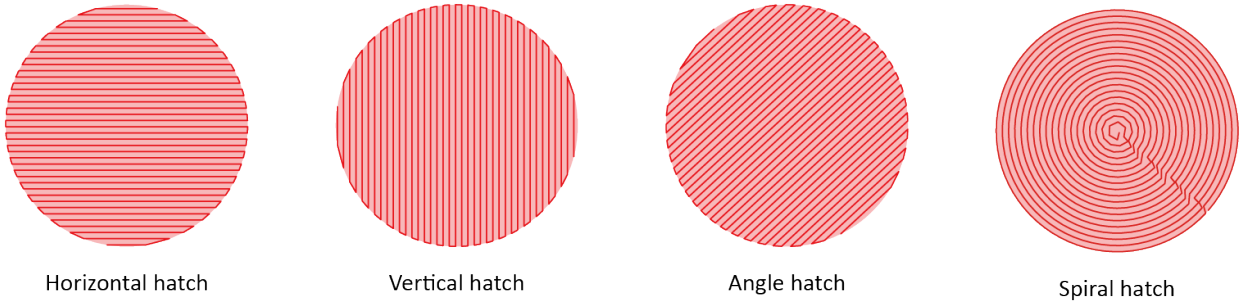


Figure 3.13 *Different geometry that could fill the target area.*

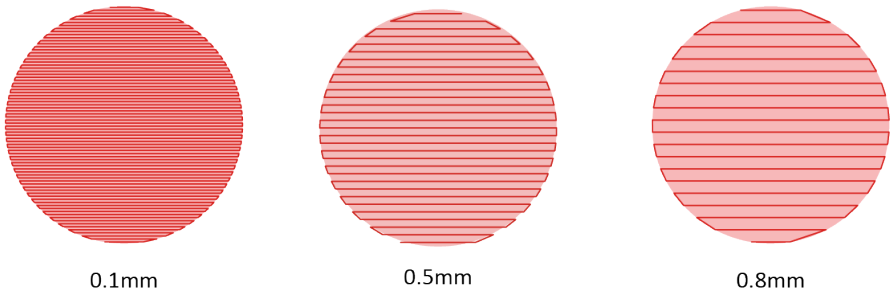


Figure 3.14 *The image shows the different density of the hatch pattern.*

3.3.4.2 Rule Driven: Parametric Line Drawing

The function will take in two curves and return continuous lines traveling back and forth between them (Figure 3.15). Every time users add a new curve, it updates the previous set so that it could generate a new pattern in every round (Figure 3.16). In this mode, the user is expected to interact with the system with curve drawing and observe the computational output. During the turn-taking, the user will gradually figure out the rules and come up with the drawing strategy.

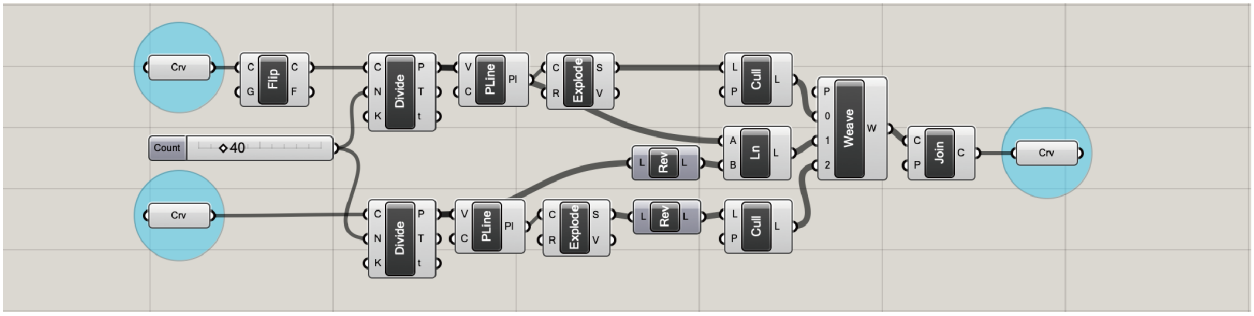


Figure 3.15 *The image shows the Grasshopper script for generating parametric line drawings.*

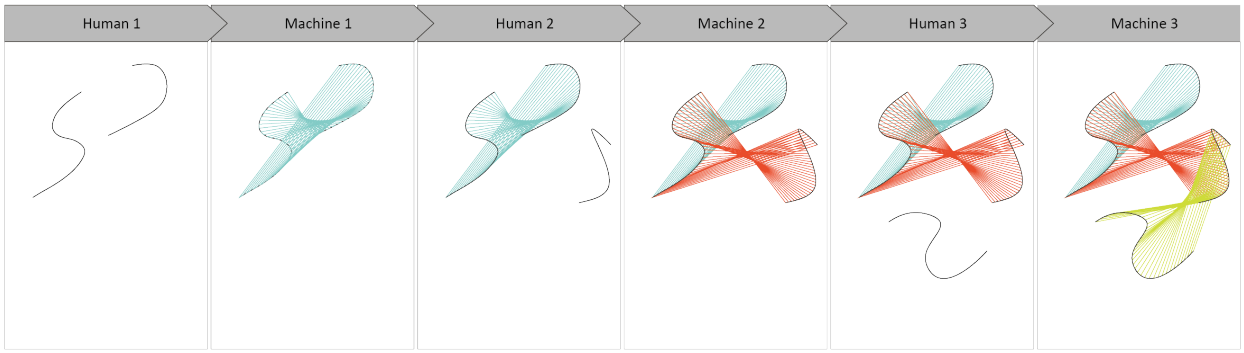


Figure 3.16 *Turn-taking process in rule-based interaction mode. Black lines represent human's input and colored lines represent machine response.*

3.3.4.3 Probability Driven: Model-based deep reinforcement learning

This experiment implements the machine learning algorithm for coloring human's drawings with embroidery. I utilized LearningToPaint (Huang, Heng, and Zhou 2019) to build this mode. LearningToPaint is a painting AI that can reproduce paintings stroke by stroke using deep reinforcement learning. The algorithm will take in an image and generate layers of simulated strokes. In this project, the system adds one more layer on the output stroke and turns those strokes into an embroidery path. During the interaction with the machine, the player will initiate the interaction with a doodle and assign colors of each section after the scanning. Currently, the research utilized photoshop to produce the image with color information.

3.3.4.4 Chance: Computational Randomness

In the random mode, the system will generate random points surrounding the target curve and draw a close curve by interpolating those points (Figure 3.17). Similar to the direct manipulation mode, the system will then turn the shape into a single sewn line. In this mode, the human user initiates the interaction by drawing. Once the machine generates arbitrary shapes as feedback, the

player could use their imagination to interpret the shape and improvise on top of the computational outputs (Figure 3.18).

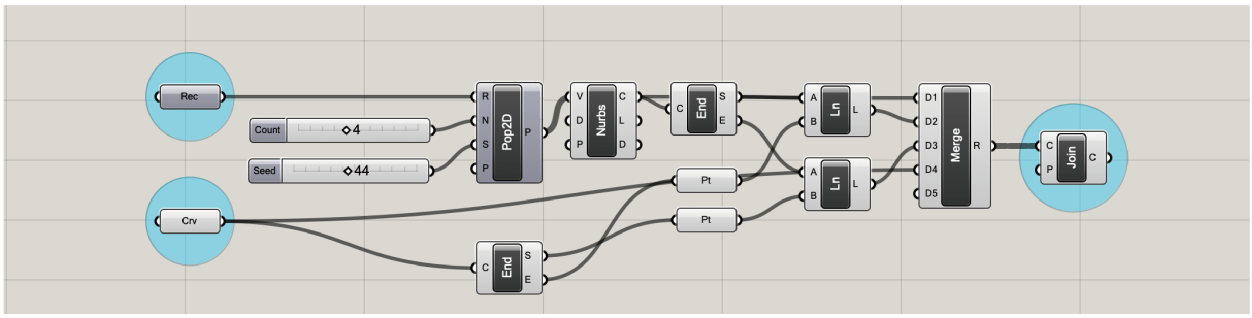


Figure 3.17 *The image shows the Grasshopper script for generating random shapes.*

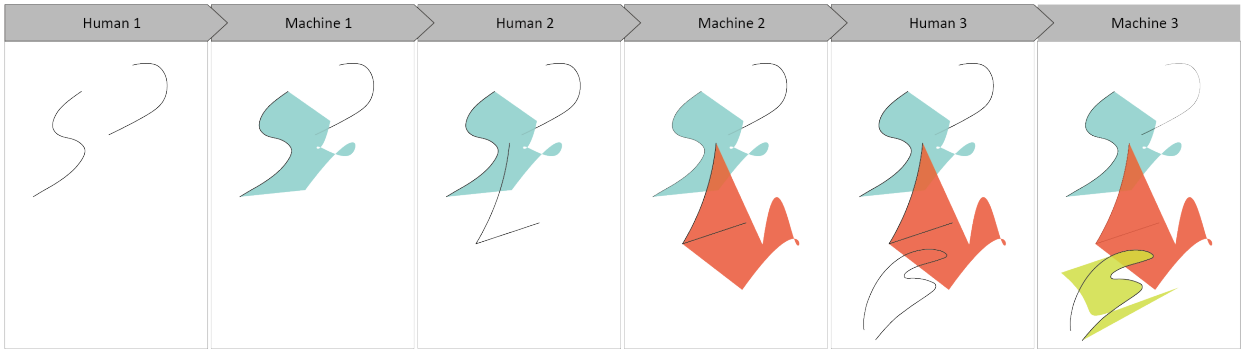


Figure 3.18 *The image shows the turn-taking process. The black lines represent human's input.*

3.3.5 Embroidery Path Generation

This part of implementation is tailored to needlework to address the challenges of computational textile crafting. Once the algorithm generates the shapes, the system will automatically create a single sewing line that could cover the area. There will be another script to convert this single sewing line into machine code. The embroidery machine then takes in a PAT file to run tasks. Inside the PAT file, all coordinates should present in the Hexadecimal system. A Grasshopper script (Figure 3.19) transfer the coordinate in Rhino into the Hexadecimal System for the machine. During the process, the user can adjust the stitch width based on the design (Figure 3.20). The limitation of the stitch width for a Singer CE200 is seven pixels. Once the file is ready, I send it to the CNC sewing machine.

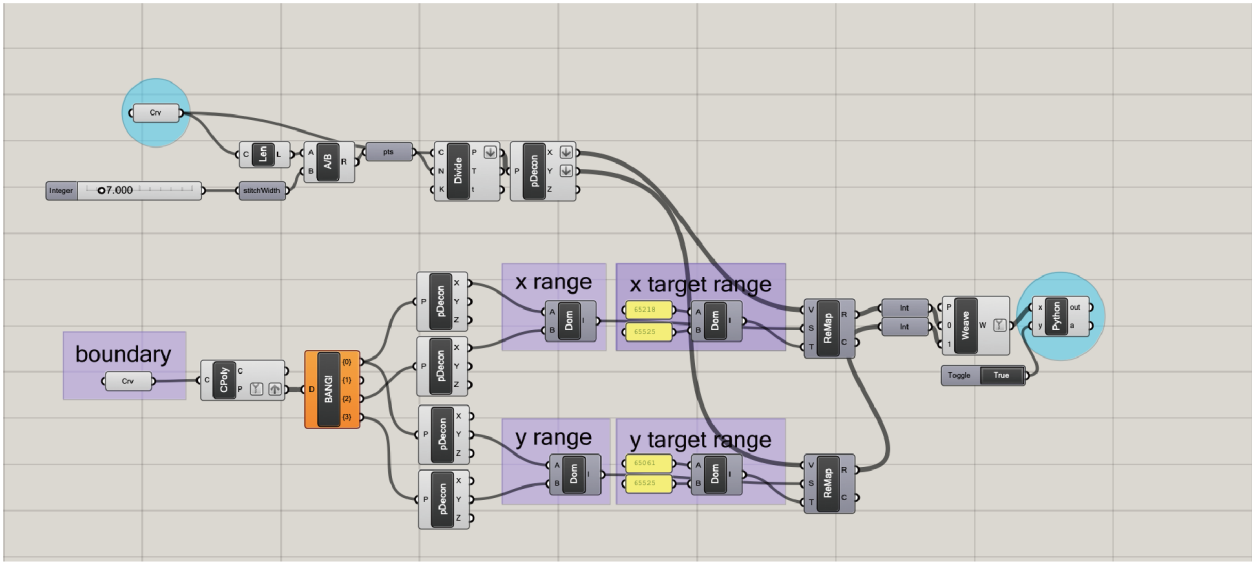


Figure 3.19 *The image shows the Grasshopper script of generating an embroidery path.*

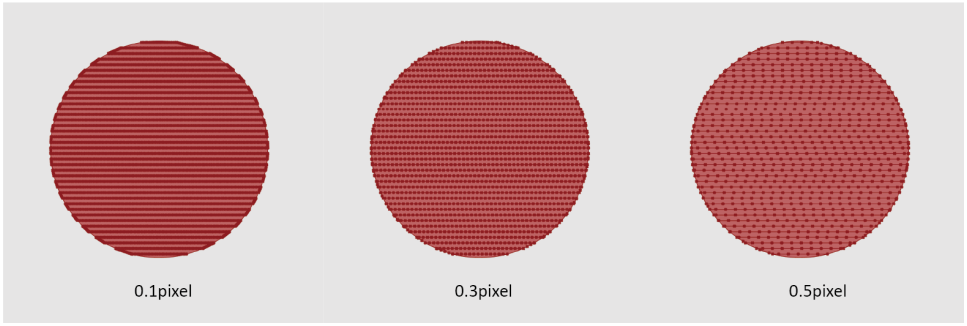


Figure 3.20 *Different stitch width.*

3.4 Activity Design: Collaborative Exquisite Corpse

The interactive system is built to explore the alternative scenario of computational textile crafting and offers a platform for engaging people in re-imagining traditional crafts to allow for creative experimentation. Besides supporting a single person's creative exploration in the new medium, the research also envisions a different making scenario by incorporating the traditional textile crafting event into the design framework through a speculated future.

In developing the creative activity, the research draws experience from traditional crafting games. Among all the craft games (Sullivan, Salter, and Smith 2018), progressive crafts and bees are selected to be the element of activity design because of they align well with communal nature of needlework. Progressive crafts, which involve two or more people, refers to the game that one person initiates and another person continues. Bees involve groups of people

who work together simultaneously to create individual crafts, which all become part of a bigger work.

Among all the progressive crafts, the research drew most inspiration from one a parlor game: the Exquisite Corpse. With roots in surrealist poetry, Exquisite Corpse is a creative strategy that represents a release from the constraints of the rational world and becomes a tool to unlock a person's imagination. To play this game, each participant takes turns drawing sections of a body on a sheet of paper and folds it to hide individual contributions, which leave only traces for the next person. Each player then adds a body part without knowing other parts, and in this way, a bizarre and uncanny creature is born. Within this progressive craft, each person is allowed to explore the system at their own pace and style to finish their individual work that finally contributes to the bigger picture.

With inspiration from the surrealist's parlor game, the activity design in this interactive framework is called Collaborative Exquisite Corpse. The envisioned working scenario will be a group of people who work in a shared space, which will be separated into manually working area and machine operating area to distinguish digital and analog work (Figure 3.21). This design is intended to create a flexible working timescale, adapt to individual needs, and promotes collaboration during the making process. By relying on turn-based interaction, the working rhythm of the system changes and alternates to accommodate different needs. To ensure these needs are met, there are different expectations at each stage of the production. Rather than folding the paper at the first stage, the system will separate the canvas into three pieces. On each canvas are drawing instructions, which tell users which part to draw, such as upper body parts, and markers that indicate where to start and end drawing. During the working section, people are encouraged to edit the canvas freely and exchange ideas as well as skills. When the user wants machine inputs, they will bring the canvas to the scanning station, an image of the canvas will be captured and sent to the computer. Once user inputs are passed into the data pipeline of the interactive system, the machine will start preparing the response. After several iterations, many pieces of body parts will be created. Participants can then gather all the pieces and assemble them, like the collaborative working section in quilting bees (Figure 3.22).



Figure 3.21 *The envisioned scenario of the interactive system deployed in the shared space. People in the drawing are using this system to conduct collective creation.*

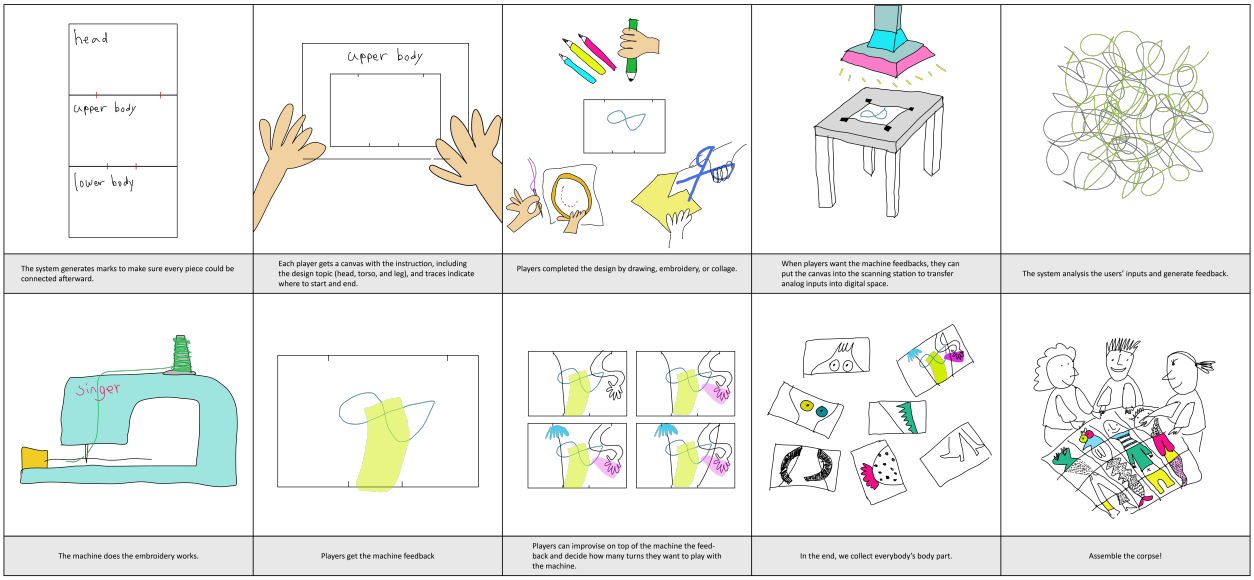


Figure 3.22 *The user journey of interacting with the system in the Collaborative Exquisite Corpse.*

3.5 Workshop Design

This research invited a group of people in Assemble Pittsburgh, a community space for art and technology, to examine how the system could work in the collaborative working scenario. The target participants are the member of "Girl's Maker Night," which empowers girls in grades 5-8 by making connections between hands-on STEAM learning and the world. In their previous

class, they had been taught hand embroidery and had experience of playing Exquisite Corpses; therefore, they are an ideal group to play with the system.

3.5.1 Workshop Setup

Location: Assemble, 4824 Penn Ave, Pittsburgh PA 15224
Date: Monday 16:00 - 18:00, March 16, 2020
Participants: 5 female middle-school students.
Staffing:Yi-Chin Lee, principal investigator, facilitate with scanning process and operating the machine
Anny Chen, instructor in Assemble, facilitate with handiworks

Equipment:
One Singer CNC embroidery machine
One Singer sewing machine
One Brother sewing machine
Three embroidery hoops that match with Singer machines
Three 6" circle embroidery hoops

Materials:
Some fabric, embroidery floss, sewing yarn, needles
Computational Modality: Random Mode

The workshop will take place in the main classroom on Assemble's first floor. The workshop is part of the activity in the Assemble educational program's Girls' Maker Night, and the principal investigator will be the guest expert in that section. There will be five middle school students, and two Assemble staff who participate in the workshop. The tables are arranged in a c-shape (Figure 3.23), and all students, staffs, and equipment are close to each other. There are three main sections in the space (Figure 3.24). First is the handwork area. Here, the table will be the students' main working area with all the hand tools and materials available (Figure 3.25). The tools could support students to do hand embroidery, fabric collage, and drawing. Second, the Interaction Area will include the human-machine interaction booth. When the user wants to play with the system, they can go to this table to initiate the turn-based creation with the machine. The third section is the assembling area. In this section, I want to share other textile techniques with the students; therefore, I will offer two sewing machines (Figure 3.26) for users to sew the corpse.

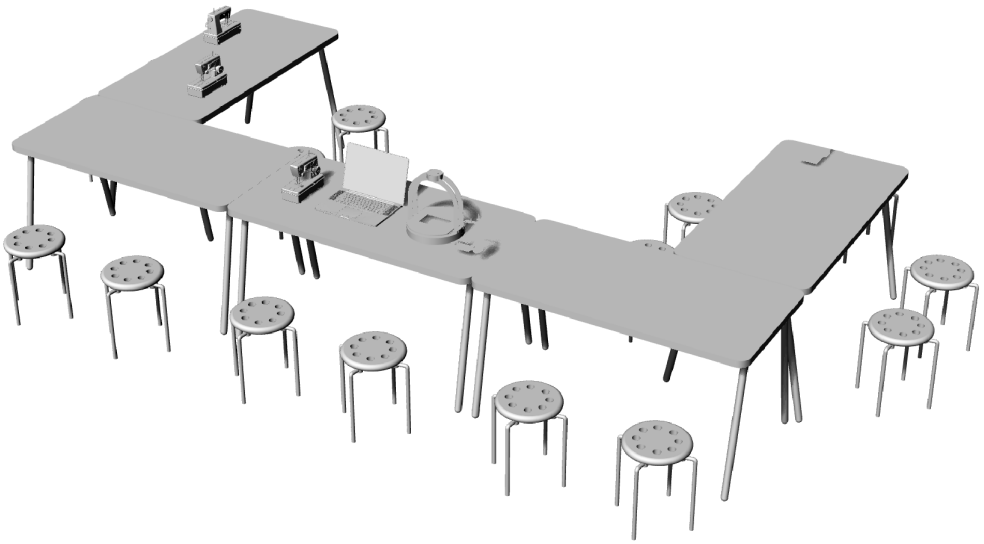


Figure 3.23 *Proposed Workshop setup in Assemble, Pittsburgh.*

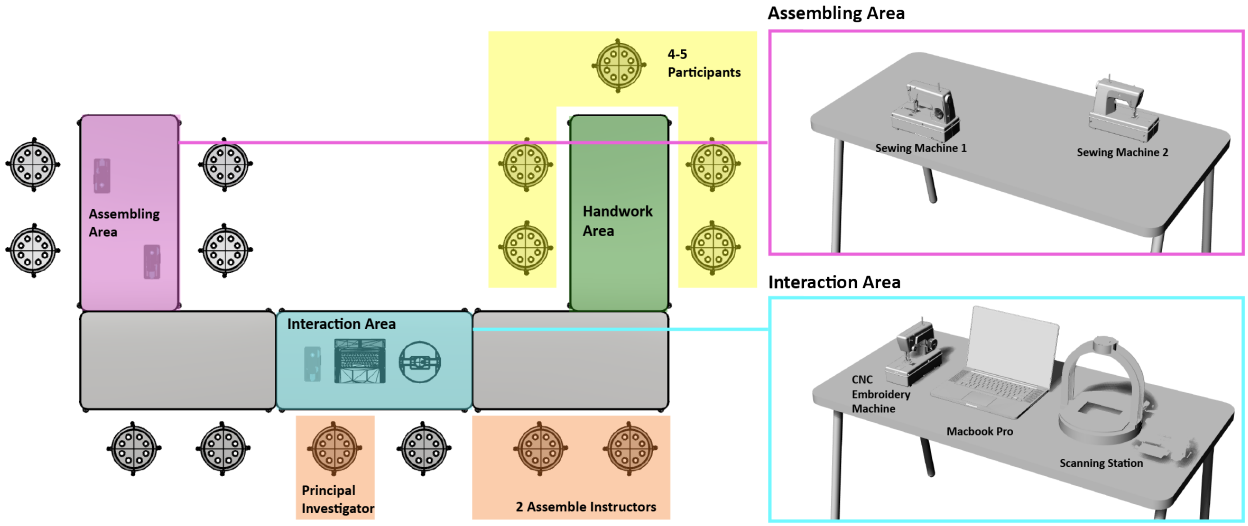


Figure 3.24 *Floor plan for the workshop.*



Figure 3.25 *Hand tools and materials provided for handworks.*



Figure 3.26 *Three machines used in the workshop.*

3.5.2 Workshop Protocol

In this workshop, there are three main tasks to complete. First, I will introduce the project, including a high-level description of how the system works, the design of the activity, and what they are expected to do afterward. Second, I will introduce all the tools and materials I have brought to Assemble. Most of the students are familiar with the hand embroidery from the previous class, so I will focus on teaching them how to operate the sewing machine. Once all the introduction and tutorials are finished, students will start the activity. During the making process, I will monitor the human-machine interaction part and facilitate technical issues; Anny, the Assemble instructor, will help with the hands-on part. In the final stage, the students will have to arrange the pieces and figure out how to sew them up as a team. After every corpse is done, I will take photos of their works, so they can take the corpse they have created home.

3.5.3 Observation Goal

As the investigator in this workshop, the main focus is observing will be on how students interact with the machine. As I observe I will assess success according to three key indicators: 1) The number of turns the payer is willing to play until they think the works finished; 2) the strategy they use for selecting the different modes; and 3) how they respond to the machine feedback.In addition to observing these indicators, I will also take notes on how well the system works in the collaborative environment and how it could better mediate the social dynamic in the workshop for future development reference.

Chapter 4
Results

4. Results

4.1 Human-Machine Interaction

The experiments that were conducted with a fully functional system focused on analog data collection and building human-machine dialog exploration. The hardware setup in the experiment includes a CNC embroidery machine and a scanning booth that connects with the laptop via a USB cable (figure 4.1). The user initiates the interaction by creating a design on the plain canvas and bringing the canvas to the scanning booth (figure 4.2). To use the scanning booth, the user places the hoop in the base (figure 4.2(b)) and activates the camera on top (figure 4.2(c)). Once the data is successfully passed to the computer, the user can take out the embroidery hoop and fasten it to the machine (figure 4.3(a)). In its current setting, the user can manually select the yarn and thread they like.



Figure 4.1 *Hardware setting of interactive system-Hybrid Embroidery. The setup includes a CNC embroidery machine, a laptop for control, and a scanning booth.*

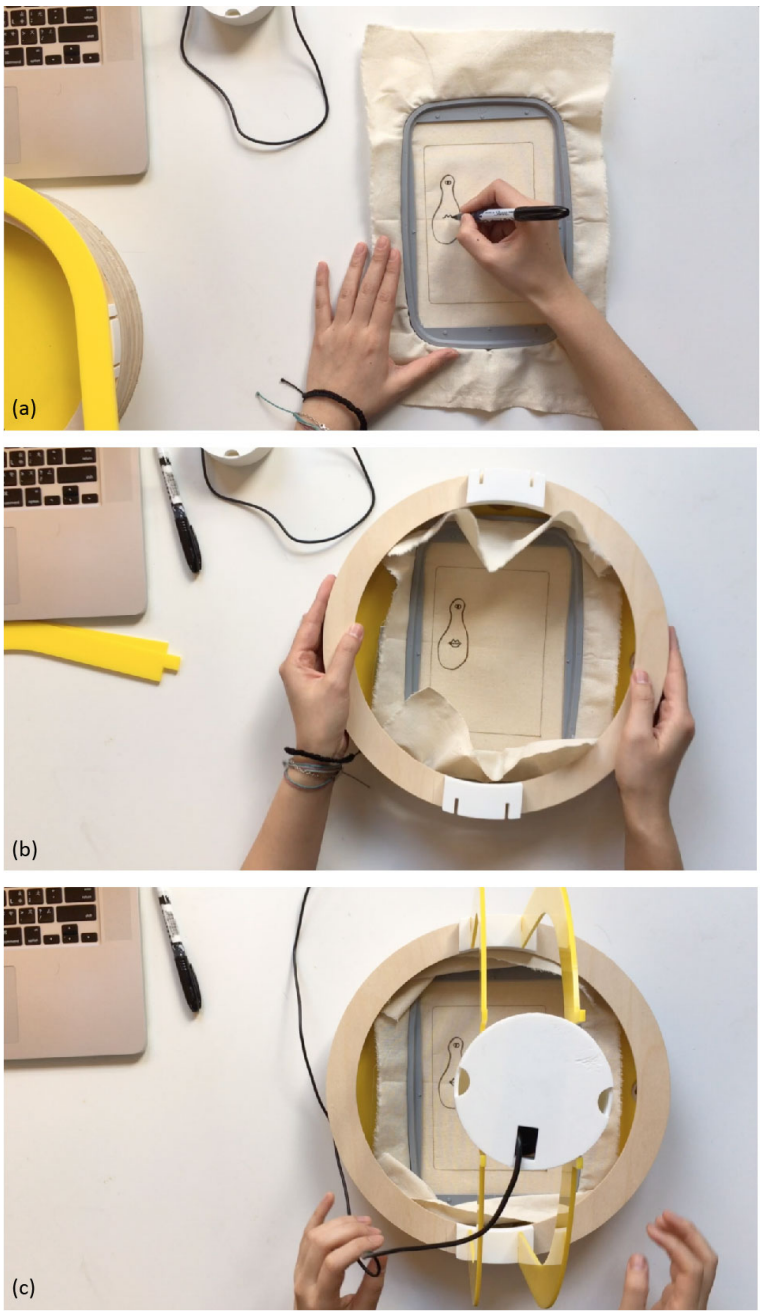


Figure 4.2 *Player operates the scanning booth.*



Figure 4.3 *Players could select yarn color and threading the machine manually.*

Once the preparation work is all set, the user activates the program on the computer to generate the machine output and presses the button on the embroidery machine to run the task. After the machine finishes the work, the first round is done (figure 4.4). At this stage, the user can carry on the play by responding to the machine output (figure 4.5). In this example, the machine running under the random mode as represented by the final piece in figure 4.6.



Figure 4.4 *The Player initiates the interaction by drawing on the plain canvas.*



Figure 4.5 *The Player conducts the second round by replying to the random machine outputs.*

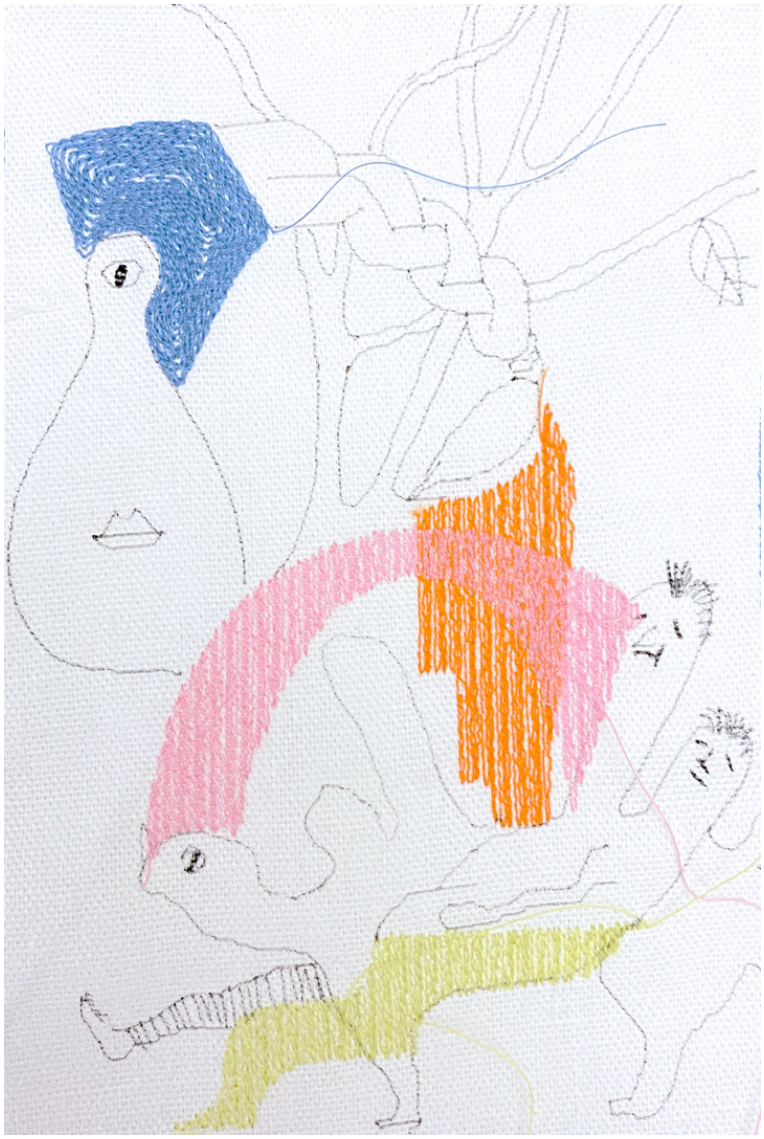


Figure 4.6 *The final result after interacting with the system under the random mode*

4.2 Affordances and Limitations of the System

The software design connects each computational module to translate human analog input into digital representation to achieve human-machine interaction. The visualization of data processing (Figure 4.7) shows the information losing bit by bit during each data processing process. In the current prototype, the computer vision algorithm is working well to capture line drawing with a distinct color, but not working well to capture the contour of the surface. Also, when the color of the yarn is light, the system can barely detect the feature. Since the ideas of the interactive system are to welcome users to explore different material and fabric manipulation techniques, the software should be able to capture features in various categories, such as line drawing, surface, and texture.

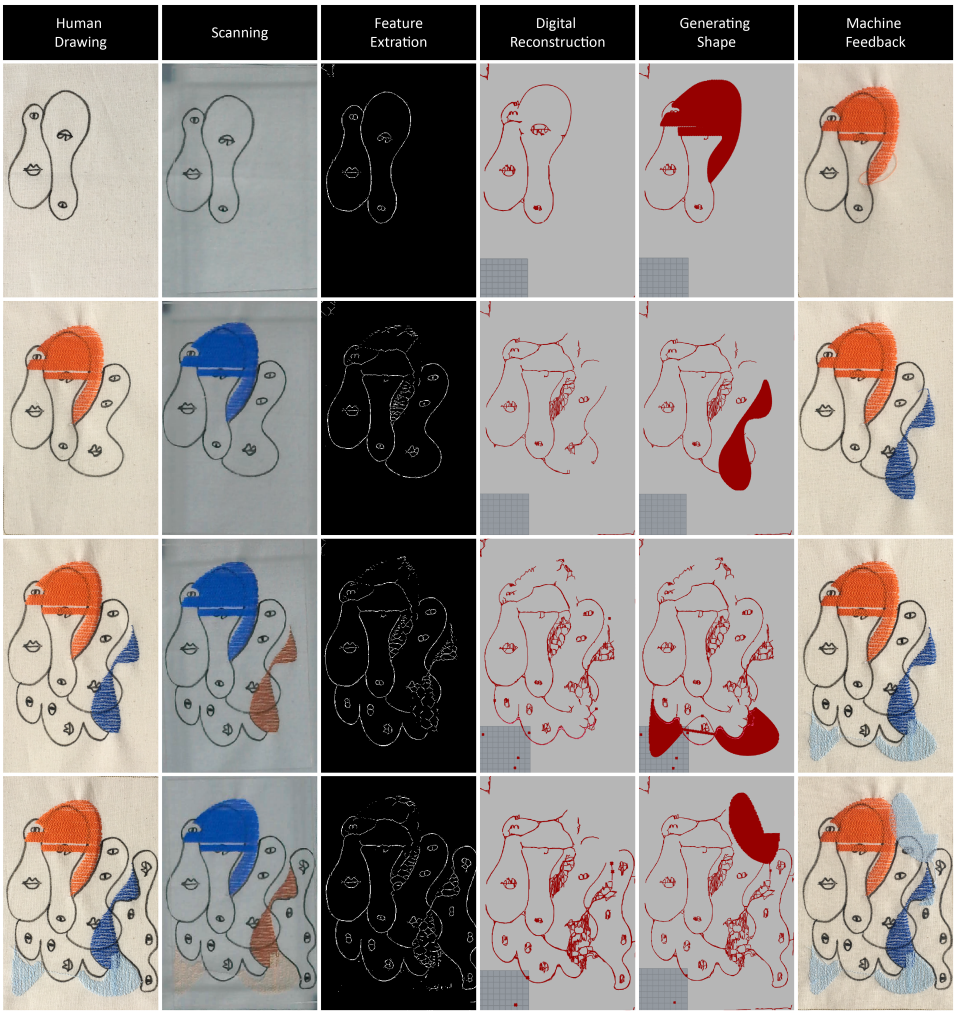


Figure 4.7 *Visualize each data processing process, showing how the shape is generated and how human improvised on top of the machine feedback.*

The scanning booth and fiducial are designed for positioning. In the current prototype, humans manually place the transparent panel with fiducial, which can cause errors. We can see some offset in the final piece (Figure 4.8). I believe making extra stopper to facilitate placing fiducial will improve the position a lot.

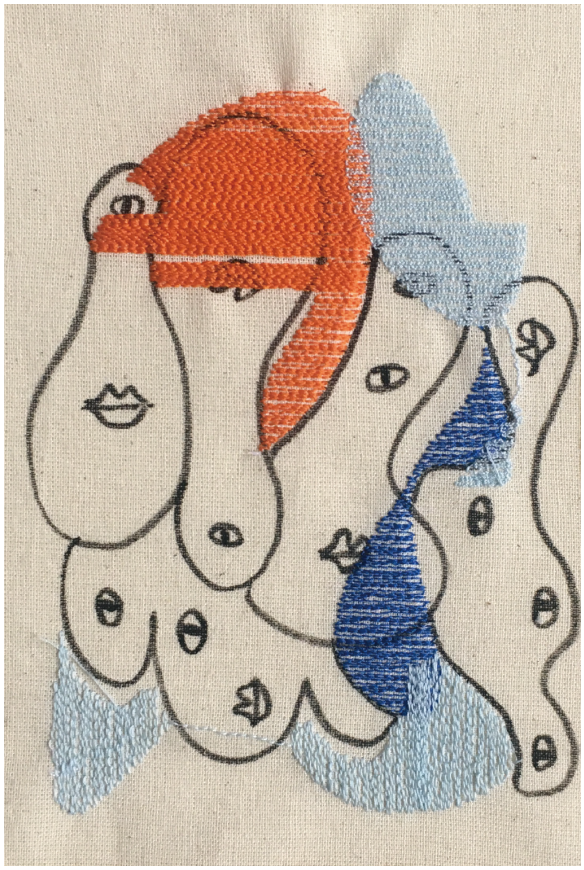


Figure 4.8 *The final result of turn-taking in random mode*

4.3 Design Space

The different modalities and turn-taking mechanisms are designed to enrich the design space with different aesthetics expression on the embroidery pieces to create a human texture. The resulting embroidery piece shows that the system did encourage the exploration of shape, color, and usage of materials in digital crafting.

4.3.1 Shape Improvising

The random mode will generate unexpected shapes, which helps trigger the imagination and as users improvise on the canvas. This represents a novel step that is different from the traditional,

preplanned pattern design often used. These results are depicted in the figures below, which shows the way the system generates imaginative production. In Figure 4.9, the person thinks of the blue and pink shape as human organs. In response, the person draws the arm and hand to protect those organs during her next turn. We see a similar imaginative responses in Figure 4.10, where the person thinks of the first pink output as a nose and responds with a mustache. In the following turn, the person thinks of the green shape as cucumber, so she adds texture on top of the green shape and draws a hand to hold the cucumber. In another instance (Figure 4.11), the user has more control of the overall design, but the computational shape still influenced where the outline of the abstract figure the person draws in the next turn.

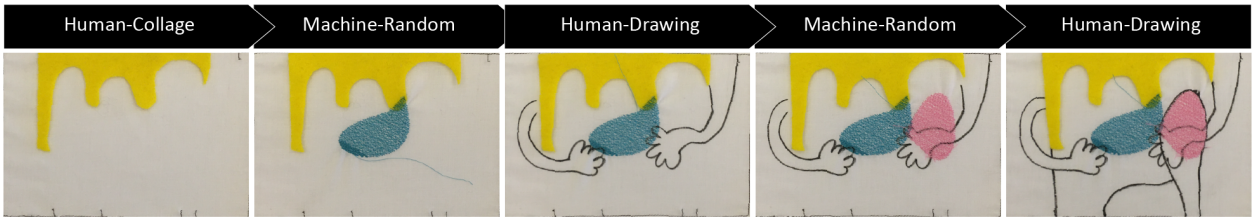


Figure 4.9 *humans interact with the system in random mode to create a body section.*

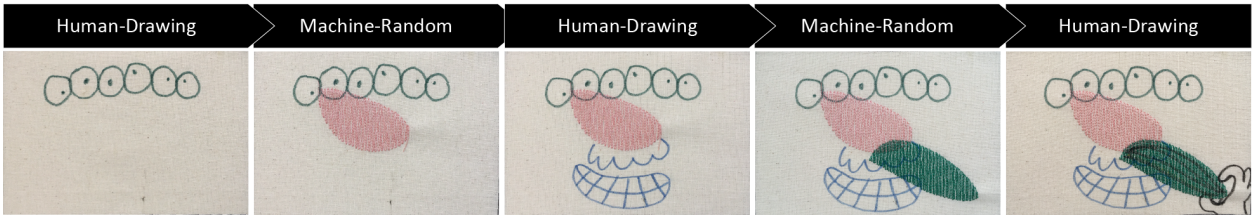


Figure 4.10 *The Player interacts with the system in random mode to create a head section.*

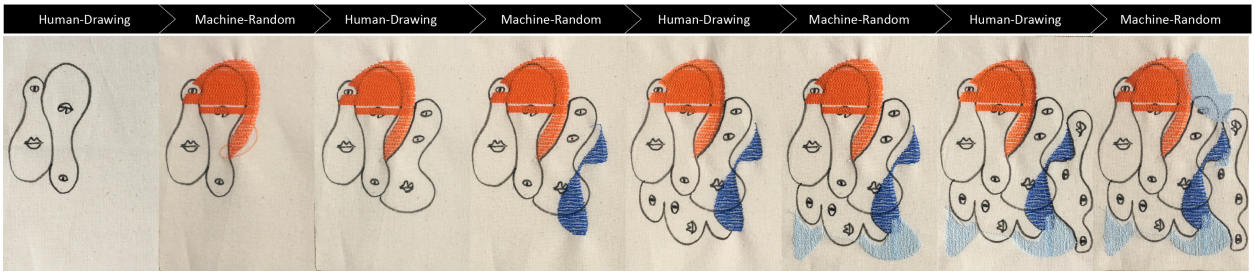


Figure 4.11 *humans interact with the system in the random mode and creating a family of interesting potato-like figures.*

4.3.2 Material Exploration

A human hand can manipulate all kinds of soft material that with a machine would be difficult to handle. In the results shown below (Figure 4.12), the machine creates color shapes in the background, and people add different materials to complete the design. The flexible turn-taking

fashion provides a flexible working schedule, so people could work in the comfort of their place without the pressures of time. With this flexibility and the provided sewing toolkit, users are able to explore all kinds of material in the textile craft. The results demonstrate how the system supports creative making and encourages interaction between the maker and the materials.

Several examples illustrate the way the system supports and encourages creativity. First of all, it allows for experimentation with material. For example, in Figure 4.12 (a), the author sewed latex balloons on the canvas to make flamingo, which could never be done with machine automation. In the machine's turn, it generated a shape around the feet. The author intentionally selected the blue color so that the shoe could match with the waterside scenario. Aside from the creative freedom to choose different materials, Figure 4.12 (b)) also demonstrates how authors can strategically leverage the machine's efficiency. She let the machine generate the main shape in a short time, so she could have a base to start with. When it comes to her turn, she manually added wool felt as decorative details to enrich the design. The system also affords the possibility for those who may be familiar with textiles to explore the possibilities of different design textures. In Figure 4.12 (c), the author who is more experienced with the machine, fixed the yarn on the canvas by placing them under the needle while the machine is outputting random shapes. During her turns, she manually sewed the yellow thread and intentionally created the texture by leaving the loop on top of the canvas. Finally, as depicted in Figure 4.12(d), there is the possibility of establishing style and creativity through found material quickly. In this embroidery, the author cut images from a magazine and attached that on canvas by hand sewing them. In this example, the green hand embroidery path also adds a sense of eeriness to the canvas, which may be a style that is hard to create through the use of a machine. In another turn, this same author sewed the reflective paper in response to the yellow shape generated by the machine. Throughout all of these examples, we see how different material texture makes the embroidery piece alive, unique, and capable of displaying personal creativity.

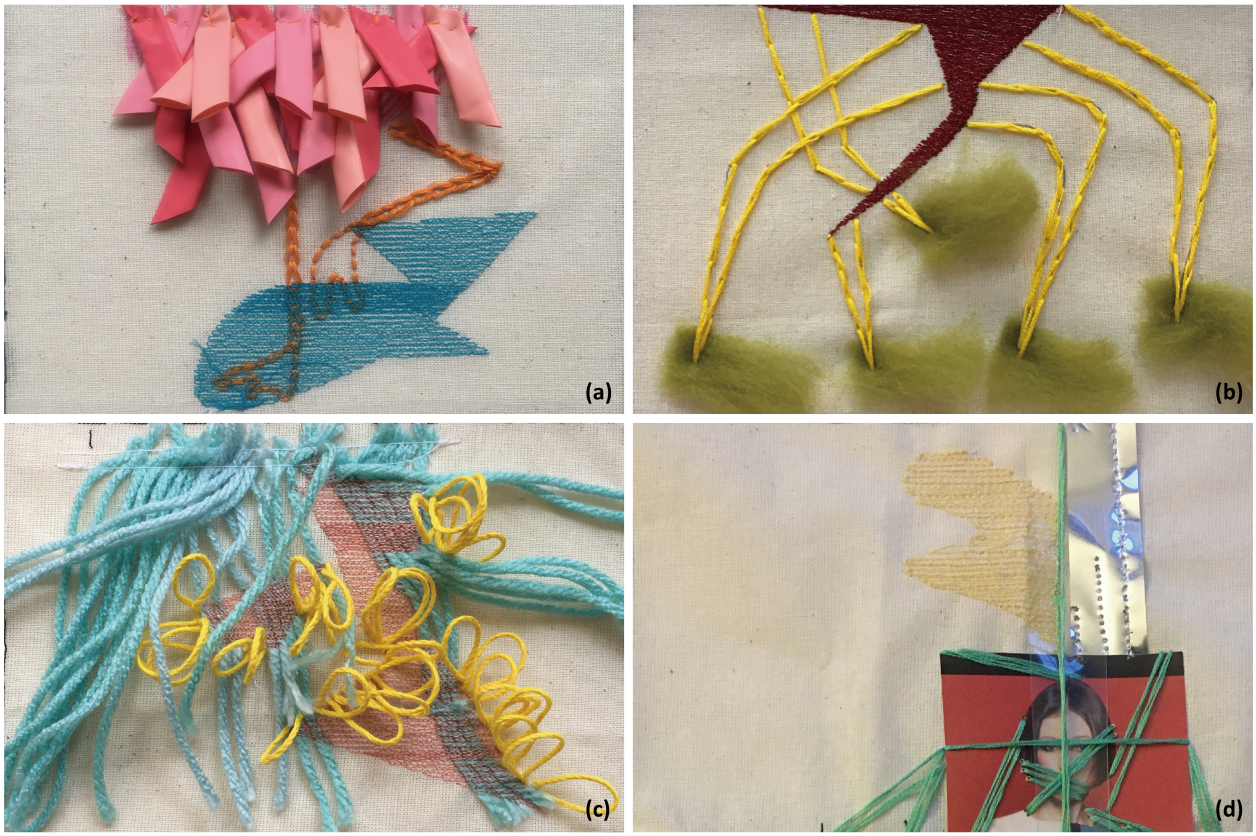


Figure 4.12 *Users of the Hybrid Embroidery system explore different soft material to adding analog texture to the embroidery piece.*

4.4 Comparison of the Results

Comparison between modes: direct manipulation and probability driven mode

In figure 4.13, both pieces are created by the same author but operated in a different mode. The left one is done in direct manipulation mode, and the right one is done in probability driven mode. As the results illustrate, the different filling algorithms set up markedly different characters even though the drawings are from the same person with a similar style.



Figure 4.13 *Left: The image shows the result from direct manipulation mode. Right: Result from probability driven mode.*

Comparison between Rounds

Under the interactive system, the user could get various outputs from the same mode. As the observation suggests, each input is in a similar length, and the author attempts to let each machine output partially overlay. According to the result (Figure 4.14), it demonstrates that while interacting with the machine in the same mode, a person's artistic style remains.

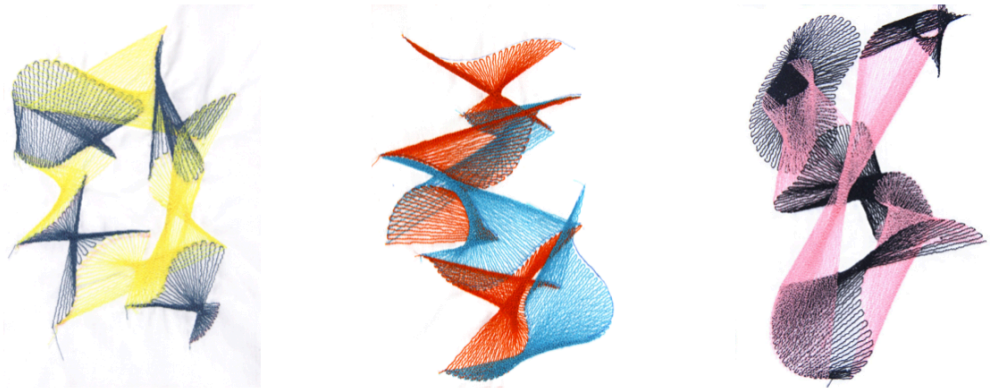


Figure 4.14 *The image shows the results from the same person operating in the rule-based mode at different times.*

Comparison between Authors

From observing different users operate the same mode (rule-driven mode), we can see how this interactive system supports different aesthetics among users. Each player has their understanding of the rule and explores the system differently. One user explores the rule with short open curves

(figure4.15(a)); one user draws with long curve and close shape centering the center of the canvas (figure4.15(b)); and, one user draws with complicated winding curves all around the canvas (figure4.15(c)). The results shows the diversity of line drawing and indicates that the system has the ability to support personal style and expression even in the same mode.

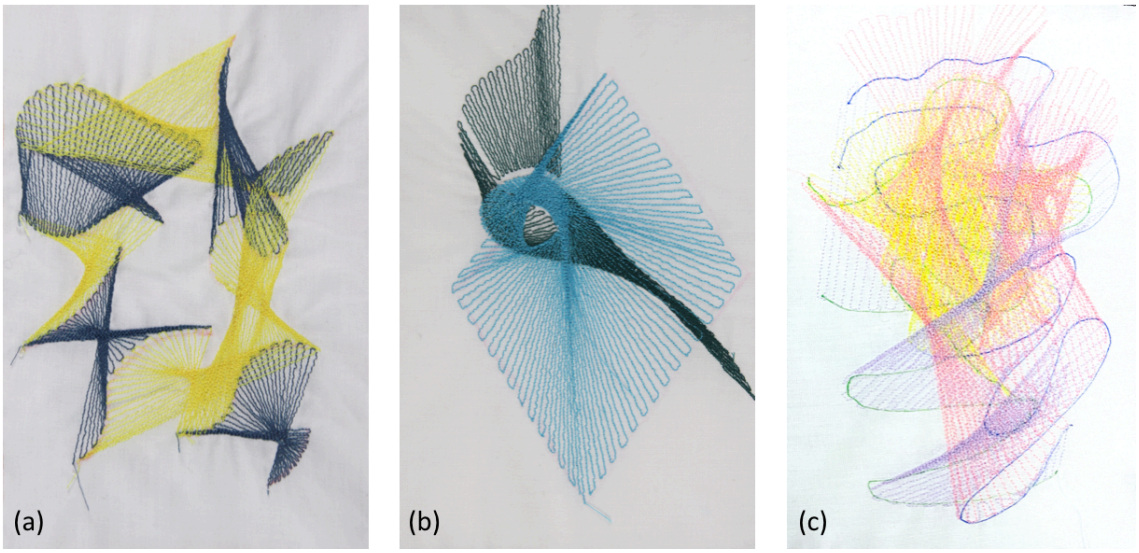


Figure 4.15 *Results from different players operate the rule-based mode.*

4.5 Limitation

Interface Support

Although the results show the system could respond to users' input in different modalities, without the interface, the current experiment still needs a human supervisor to control the process. During the human-machine interaction, the researcher assists the player in selecting the design mode and setting the parameter to generate the embroidery path.

Feature Detection

Within each modality, the system also has a limitation on differentiating human inputs in each turn. In the current process, the system still needs a manual assistant to clear previous data and make sure the machine generates shape on top of the new human inputs.

Probability Driven Design

Among all the modalities, probability driven shape generation demonstrates the most interesting results, but is still far from complete compared to other modes. The limitation comes from the design of the probability driven algorithm and the selected medium.

First, in the LearningToPaint algorithm, the algorithm is designed to redraw human's input with its calculation. In most cases, the input needs to be a complete image; otherwise, the machine will not work well when responding to the simple inputs. However, in the open-ended creation, the human may not know what they exactly want when initiating the interaction. Therefore, how to achieve turn-taking in probability driven shape generation is still not clear.

Second, the LearningToPaint algorithm is built for generating a painting stroke based on the dataset. When implementing this algorithm into the system, the computer directly transfers the oil paint stroke into the sewing pattern. Embroidery is very different from layer-based painting, so directly transferring strokes to sewing patterns could cause many issues. The single line sewing path will be hard to generate, and the player needs to change the thread when the machine switches the color of the stroke. Not to mention the canvas will be very thick because of the layer of thread. However, there are some successful results (Figure 4.16) from a experienced player who manually assisted in the selection of proper strokes. There is only one turn-taking; in this case, the human initiates the interaction with the doodling, and the machine takes several paths to finish the design. The way to explore the machine learning algorithm in this system is to redesign the algorithm tailored to the qualities and characteristics of embroidery.

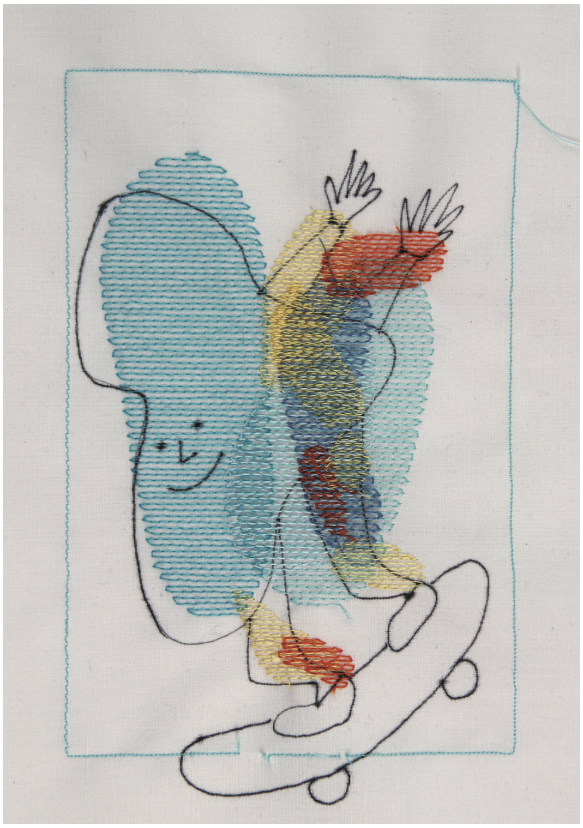


Figure 4.16 *Result create from probability driven mode.*

Embroidery Path Generation

Generating one single sewing line to be filled with complex shapes is challenging. One solution provided in this system is to fill the area with a spiral pattern. A defect of this solution is that the center part of the shape will fail under the curve offset function (figure 4.17). In response, the system should implement the shape morphing algorithm to adjust the path to make the spiral pattern more sophisticated. The other shortage of the sewing path generation is that the system did not implement traditional zigzagging pattern into the algorithm. The zigzag pattern has higher coverage on the target area, and it could add thickness to the canvas, which makes the embroidery piece more solid. The zigzag feature could be the next step for software implementation.

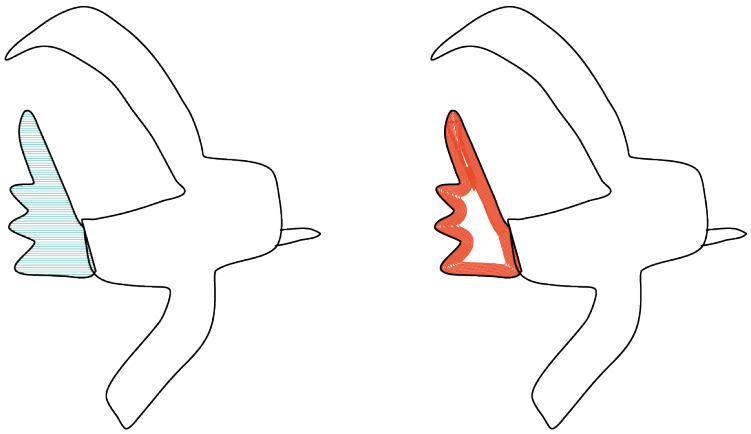


Figure 4.17 *Left: The machine fills the area with the horizontal hatch pattern. Right: The machine fills the area with a spiral pattern.*

4.6 Discussion

4.6.1 Human-Machine Interaction in Design Space

One of the main objectives of this thesis is to facilitate the interaction between humans, embroidery, and machines. There are some interesting findings about how people perceive machine as collaborator. People often hold back while handing the canvas to the machine. They will keep asking questions about what kind of the shape the machine will generate, and how they can fix it if they don't like the machine's work. These reactions show that people don't fully trust the machine when collaborating with them. For the skillful player, they were skeptical of the machine's feedback and concerned that the machine will break the composition of the canvas. And also, the more effort the player invests; the more reluctant they were to accept machine feedback. On the contrary, the player who is not familiar with making is more open with the machine feedback.

Despite the fact that people are hesitant about machine feedback, most of the results are satisfying. The unexpected outcomes make the player look forward to the result in the next round. The following feedback from users illustrates the overall feeling of excitement and satisfaction afforded by the system:

> "For the experience, the part I like the most is waiting for the machine to draw on top of mine. I think it's nice that I can choose the color for the machine so that I'm still in control and can make sure the machine won't ruin it. "

> "If I create a work that I really like and feel a very satisfying status of the piece, then I do not want the machine's feedback, as I have no control over it and I don't want it to break the balance of my creation."

> "After the machine adds to my work, I feel a distance to it, but I like the surprise."

4.6.2 Flexible Workflow Encourage Material Exploration

The turn-based interaction provides a less constrained environment that allows users to have chances to explore material manually and think about how to combine those texture with machine outputs. During the experiment, users were engaged in handcrafting. They were excited about attaching materials with a different texture such as reflected paper, magazine, and sponge on the canvas. For some, learning how to operate a sewing machine with different sewing mode took up most of the time, but users felt satisfied when they able to use a sewing machine to make a pretty pattern. Other supports such as hand embroidery equipment and all kinds of soft materials did offer a space for exploration. Generally, people were excited to attach unusual materials such as reflective plastic, furry yarn, and fabric with texture onto the canvas. This deep engagement with materials and tools is not easy to achieve if people and machines are collaborating under real-time interaction.

As one player indicates:

> "I feel engaging during the activity, especially bodily engagement when I use different materials and different tools to create a physical product. I also enjoy watching the machine work automatically, but the shape it creates was very abstract that I did not have much thinking about it. "

Chapter 5
Conclusion

5. Conclusion

5.1 Conclusion

Under the scope of the interactive fabrication framework and textile crafting, the experiment results show that a turn-based interactive system has the potential to support collective creation in an embroidery craft. Importantly, the interactive system provides design insight toward user behavior and software development.

As the results indicate, the design of interaction behavior and specific technology choices can support different values in crafting. First, through turn-based interaction, the system lowers the cognitive load caused by human-machine interaction. Second, in implementing image-based data processing, the system operates in a less controlled environment. Third, by developing software for four computational modalities, the system demonstrates how creative coding can foster different aesthetic styles within embroidery. Finally, the different levels of control programmed into the system reconfigure the role of humans and machines. The system allows researchers to rethink the relationship among the agents, which will hopefully inspire the consideration of a few questions. Can this system serve as perfect labor in the direct control mode? Will people consider the machine as a creative partner while it embedded the machine learning algorithm? Eventually, the research aims to offer a space or people to learn and explore the beauty in embroidery.

5.2 Contribution

Hybrid Embroidery proposes a novel way for users to create 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 of crafting with digital tools. The framework facilitates open-ended exploration and improvisation, enriching the process of making with aspects of play. On the one hand, the different computational modalities facilitate

diverse dialogues between makers and the machine. On the other, turn-taking creates a flexible working environment to support different paces and styles for users.

The prototypes presented raise questions concerning 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 at the replacement of humans. I believe these are essential questions today for designers in the creative and manufacturing industries.

Ultimately, within the scope of the successful implementation of the proposed experimental setup and by centering textile craft in STEM research, this thesis hopes to foster the conversation with inclusive and feminist design in ways that reformulate embroidery beyond just the aesthetic and functional.

5.3 Future work

The current interactive system is a working prototype to serve the experiment's purpose, and there is still room to improve efficiency and scanning accuracy. Besides those technical issues, there are several aspects the research can develop further to enrich digital fabrication in needlework. Those aspects include the introduction of hybrid aesthetics, support of collective work, and observation of how the system could mediate social dynamics in the field.

First, researchers could explore hybrid aesthetics through developing various algorithms. To develop concepts of hybrid aesthetics, the current system focuses on four algorithms that represent different control levels by the machine. In the software side, there is still plenty of space to combine parametric design, creative coding, machining art, and other computational methods to the system. In the view of interaction design, different ways to reconfigure the relationship between humans and machines could also enrich the system's design space.

Second, the system could support collective work through games. The design of the interactive system aims to focus on the collective tradition of needlework. The proposed activity, Collaborative Exquisite Corpse, is an example of how Hybrid Embroidery can facilitate creative exploration and collective work. The interactive system is constructed by several independent

building blocks, which if shifted, has the potential to be deployed in different environments and adapt to various collective gaming scenarios.

Lastly, the system could help others design systems that mediate social dynamics. Social interaction that happens in crafting processes is different among different people. Some people like to talk while making; some people feel more comfortable focusing on their own work. In the experiment, most of the conversation is surrounding the technical issue. When the player is not sure about how to handle the material or operate the machine, they will start to talk to me or with each other. The skillful player will be more comfortable to explore the machine and try out the new material. On the other hand, the player who is not familiar with crafting will often initiate the conversation to ask for help. Besides the technical issues, users rarely talk about the design and exchange their ideas. Most of the time, users are sitting separately and focus on their own pieces.

The meaning of social interaction could be different among different people, which largely depends on context. To some users, chatting is not the only way to be social. People enjoy working in a shared space and knowing that other people are doing a similar thing. There are so many factors that could shape the social interaction, and this research does not aim to manipulate social interaction and contribute to social science research. However, based on the preliminary experiment on testing the system in social scenarios, the interactive system did provide a space for collective work and provide a topic to trigger collaboration among people as a creative medium. This research facilitates collective work to demonstrate the potential in supporting social crafting. The preliminary results and analysis of the collective practices in shared space and the remote scenario (play-by-mail) are recorded in the Appendix to strengthen the argument.

Chapter 6
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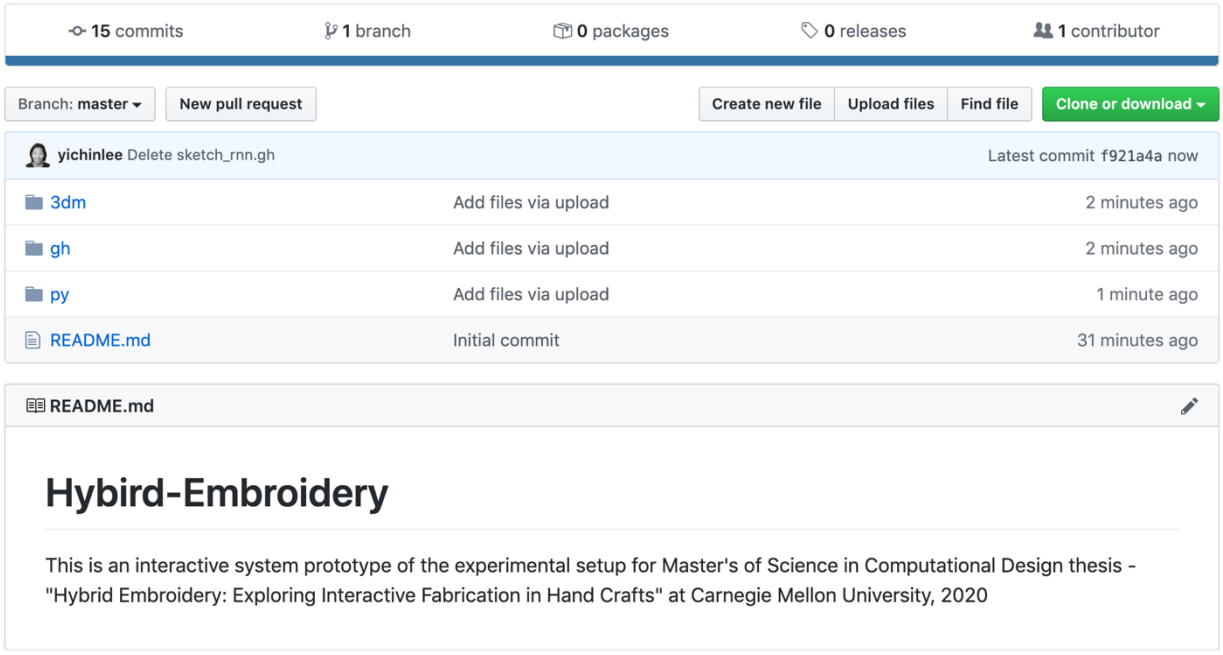
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Chapter 7
Appendix

7. Appendix

7.1 Development Files and Codes

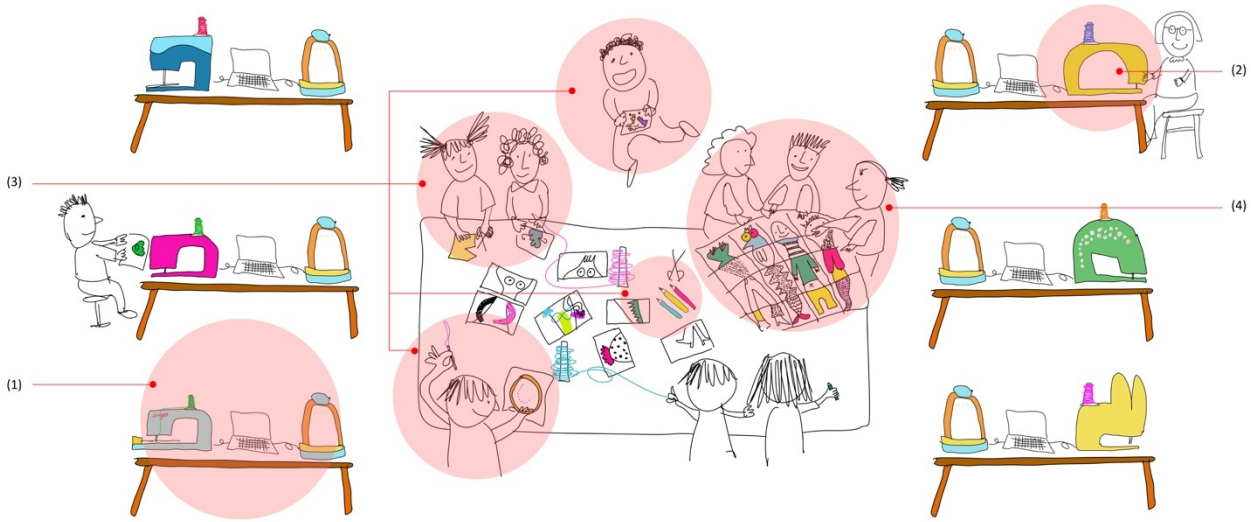
Link to GitHub: https://github.com/yichinlee/Hybird-Embroidery.git



7.2 Observation of System Deployed in Social Context and Details

7.2.1 People in Shared Space

Here is an illustration of the envision working space and scenario in the future.



(1) Interactive Station

Several interactive stations deploy at the side, and each unit includes a scanning booth, a CNC embroidery machine, and a computer. Providing interaction stations is a way to avoid the line and provide various outputs during the activity.

(2) Computational Modalities

Each machine in the interactive station embeds a different algorithm. Users are encouraged to walk around the stations and try out a different design.

(3) Handcrafts Area

All the hand works will be done in the center table. We encourage users to come back to the handcrafts area to work after receiving the machine feedback. Users could share ideas and have conversations. The tools provided here are hand embroidery tools, markers for drawing, and fabric for collage.

(4) Assembling Process

The center table also provides a space for collective work at the end of the activity.

Before launch the formal workshop with the students in Assemble, Pittsburgh, the research had invited several students at Carnegie Mellon University to test the system. There are four people with an art-related education background involved in the preliminary experiment. In the

collective piece (Figure 7.1), each body section is done separately from different authors and assembled together by a commercial sewing machine. It took them two hours to finish the piece. During the experiment, the researcher provides all the tools and material they would need: fabric and yarn for hand embroidery, some magazines for collage, fabric, and paint for drawing.

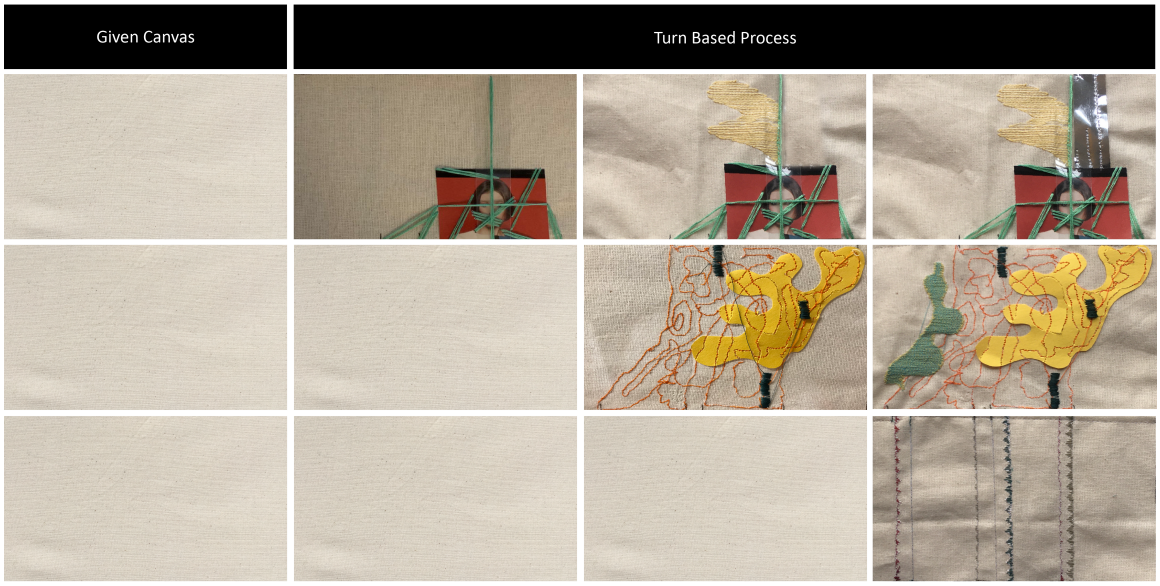


Figure 7.1 *The image shows the collective pieces done by three authors in CodeLab, Carnegie Mellon University.*

Social Engagement Observation

During the making process, most of the conversation were about debugging the sewing machine and some people asked about how to handle machines. Some asked questions such as concerning the attachment of plastic to canvas, how to separate embroidery floss, or how to switch the sewing mode from 2 to 14. The more skillful user usually offered help while others encountered trouble by talking with the other player. On the other hand, when it comes to personal design, users do not often comment on each other's work or asking for a suggestion. Some comment from users:

> "I wanted to talk to other people when I had technical issues. I didn't want to get insights from others as I want to have higher originality of the work."

> "I want to focus on my own work. Because there are a lot of materials, patterns, tools that I want to explore for the first time, so I did not spend much time talking to the others."

> " By sewing all the corpse together, I feel interested when seeing very body's work, but at the same time, I feel a distance with the final product as it does not have a direct connection to my creation intention, rather it became an independent work. "

In the preliminary experiment, there are not enough people to contribute to the corpse; therefore, there are not many combinations for users to try out. They just sew three pieces up as it should be without much discussion and negotiation. Most of the conversation is about daily chatting.

7.2.2 Play-by-Mail

Under the COVID-19 pandemic situation, many social science related research cannot collect research data, which frustrated people. However, it did raise a new question about how social fabrication can carry on and keep bounding together the members in the group. There are some precedents in the knitting community. For example, the online platform "Ravelry" used to host the knitting competition or games online, and the participant could work on individual work at home and share the object by the mailing system. The activity showed the need of social interaction among the hobbyist group and how technology could mediate the interaction. The COVID-19 situation provides a chance for this research to explore the remote working potential of the interactive system.

To respond to these challenges, the research launched a play-by-mail version of the Collaborative Exquisite Corspse by inviting six people in the Pittsburgh area to participate in this remote game. Each player will get an embroidery toolkit and instructions to start the game (figure 7.2). In the first-round of play-by-mail Collaborative Exquisite Corpse, people received a plain canvas with assigned body section like the head, torso, or leg and material instructions. To achieve the element of social interaction, participants pass the box with notes that assign the specific material characteristic for the next player to find and use on the design. Based on the result (Figure 7.3), the assigned texture and color did influence the design a lot. For example, in one of the instructions, it mentioned pink and/or feather, which led to the result of flamingo. On the other hand, assigned material also opened up people's imagination on how their daily material could be used in artmaking.

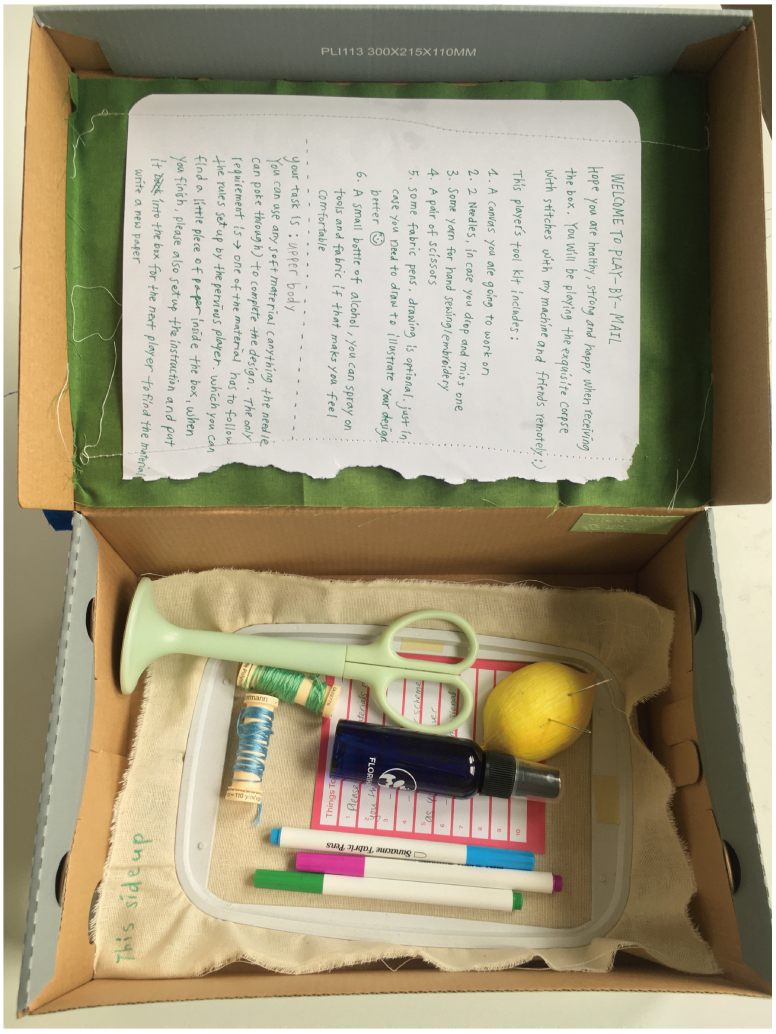


Figure 7.2 *Toolkit sent for each participant in play-by-mail.*

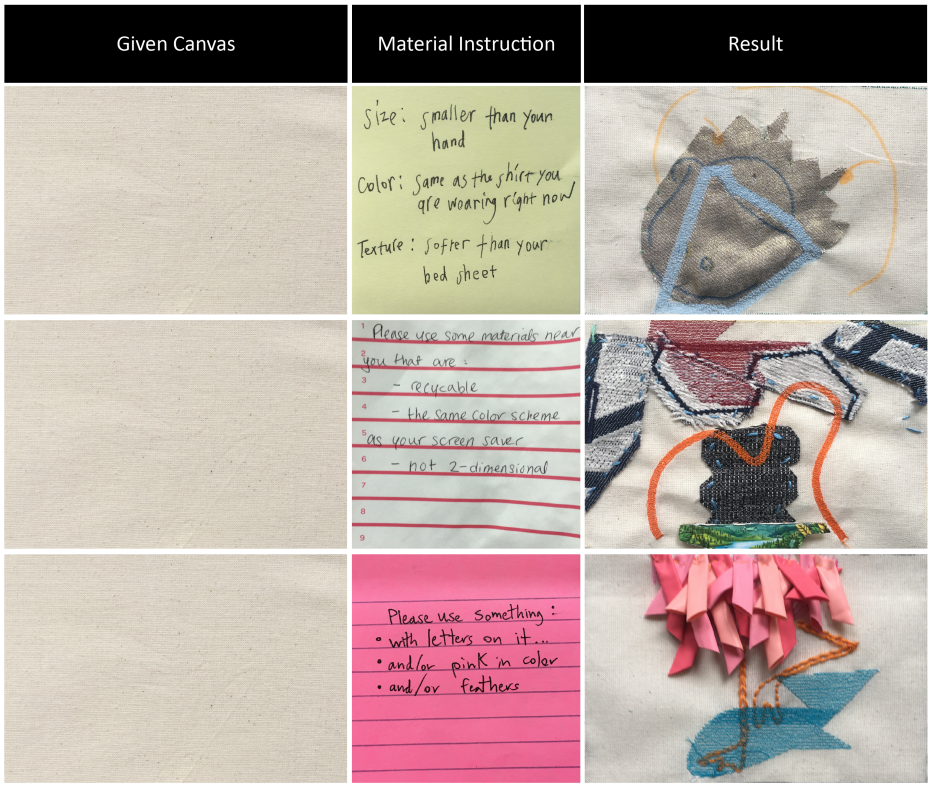


Figure 7.3 *Embroidery exquisite corpse Play-by-Mail version. Round 1, starting with plain Canvas.*

In the second-round of play-by-mail (Figure 7.4), each participant received the canvas that already has the computational output as prompt. In this side project, the research wants to see how the player will respond to the starter. According to the result, when starting with plain canvas, human control the whole style, and the design is more understandable. In other words, it is easy to we see the human or animal feature in the design. On the other hand, the existing prompt on the canvas triggered more abstract results. In this case, people had less control over the composition.

In the informal interviews, one of the participants said that receiving the note and giving the note make him nervous because he does not want to become the burden of the group. In another case, a player said she feels connected to others when she received the note and expected to see what the next play will do with her instruction. This feedback indicates that the user are aware they are part of the bigger work.

The Play-By-Mail version of Collaborative Exquisite Corpse with embroidery is a small step toward exploring the potential of the interactive system in the remote scenario. Although the social setting (communicating through notes), is different from the shared space scenario, the results still provide valuable insight. We can observe how people perceive value and how computational prompts influence the users' decision. In the early stage, people only act on the canvas once, due to the limitation of the mailing system, but if time permits, we can allow each player to interact with the system multiple times, like the original turn-based setting. The result from play-by-mail inspires how we might implement the system in the future.

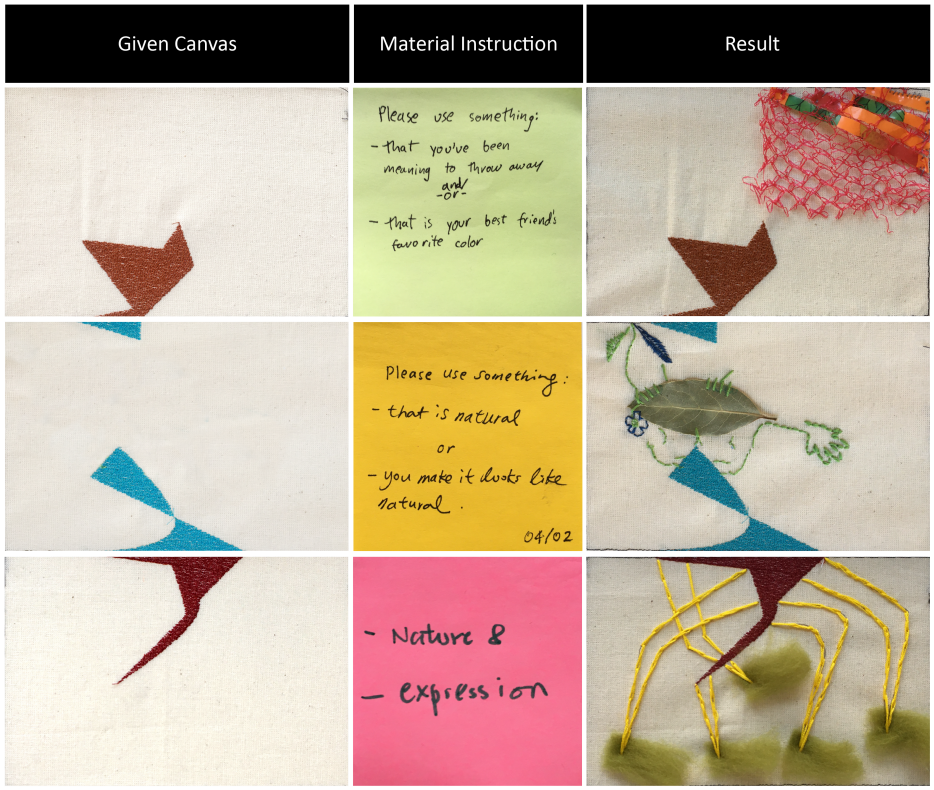


Figure 7.4 *Embroidery exquisite corpse Play-by-Mail version. Round 2, starting with the computational prompt on Canvas.*