Hybrid Embroidery Games: Playing with Materials, Machines, and People

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ABSTRACT

Our work centers on aspects of crafting creativity that are often overlooked in digital fabrication: playfulness, and possibilities for social engagement. We draw from precedents in both crafting (e.g. quilting bees) and gameplay (e.g. “Exquisite Corpse”) to inform the design of a set of turn-based collaborative games which center a computer-controlled embroidery machine as a “player” in games for one or more crafters. We prototype these games using our own computational input/output embroidery pipeline and observe how they can guide crafter-players to engage with physical, digital, and social affordances. We summarize our findings on how creative focus can shift over a playful experience of fabrication and how technology can mediate social crafting.

Authors Keywords

Embroidery, craft games, human-craft interaction

CSS Concepts

- Human-centered computing → Human computer interaction (HCI)

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Body part compositions showing a mix of hand and machine embroidery. Each body part is developed iteratively between human and machine participants.

INTRODUCTION

Fabrication can reconnect people to materiality: the act of patching a garment or making a clay pot can bring insights for designers, engineers, or anyone simply seeking to understand their world. Digital fabrication tools can scaffold advanced production methods and unlock design potential that would otherwise require advanced hand skills; interactive fabrication in particular can provide these outcomes in fluid and improvisational ways. However, many aspects of human making experiences are underexplored in digital fabrication research. Among these, we focus on material-based play and social interaction through a shared making experience.

To explore these aspects, we focus on computer-controlled (CNC) embroidery machines. These machines are relatively inexpensive—the cost of digital embroidery often comes from proprietary software, not the

hardware—but they are often overlooked as digital fabrication tools. While they are in some ways comparable to pen plotters, embroidery machines can also incorporate disparate soft materials [43], alter the texture of fabric [25], and even produce standalone objects [12]. Embroidery as a medium has a rich global history and complex connotations, from domesticity and mending to skilled luxury labor. Its particular graphic constraints have been studied as a graphics processing problem [22] and as a simplified domain suitable for teaching basic programming [42]; as a proxy for broader questions in computational design, it has been used for its ability to incorporate disparate materials [14] as well as its rich cultural associations [13]. These unique associations and affordances make machine embroidery an intriguing platform for digital material play.

We built an interactive “hybrid embroidery” system and used game design as a lens through which to explore

possibilities for playful interaction with this system. The system itself bridges analog and digital creativity: it can scan, process, and algorithmically respond through CNC embroidery. The games provide structure for interacting with the system: goals, prompts, and feedback. We deployed these games in two social contexts—an in-person workshop and an at-home variant—to observe how adjacent creation, shared goals, and light competition can deepen both crafting outcomes and social bonds.

In all, our work makes three contributions to current debates in computational design and interactive fabrication. First, it prototypes specific ways for people to interact with computational embroidery; second, it leverages a game design approach to mediate participant behavior in the making process; and finally, the system probes questions of social crafting alongside the digital world.

RELATED WORK

We align our hybrid embroidery games with work in both hybrid craft and game design.

Interactive Fabrication

Historically, computer-aided design and manufacturing (CAD/CAM) has focused on enabling efficient and reliable production. More recently, researchers have sought to develop new technologies which center the unique affordances of computational media while valuing human experience over production efficiency in mediating between makers and materials. Work in this space has explored, for example, how construction languages for CNC machines might enable open-ended design processes of “generative fabrication” [7]. At the same time, open source hardware and software toolkits have encouraged designers to build their own creative tools [3, 33], and to explore personal and even playful interactions with them [40]. With advanced personal fabrication tools becoming widespread, researchers can start to explore the potential of computational methods to enable situated, real-time exploration of materials [27]. These methods attempt to reconnect the human with the material world and support non-linear design iteration through a situated making process. Related studies on these methods include research on a real-time sculpting guidance system [44], a robotic modeling assistant empowered by augmented reality [34], and interactive laser cutting using a laser pointer as input [26].

Related efforts to develop “hybrid fabrication” systems have focused on leveraging computational systems and behaviors to support uniquely human capabilities, particularly in high-skill domains such as architectural plaster work [2]. Building on these hybrid practices, the realm of “hybrid craft” investigates various loci of meaning around and between human experience and machine agency; for example: re-configuring the roles of human and machine [9], considering taxonomies of craft skills through a computational lens [10], and embedding skills as computational artifacts [41].

In aligning ourselves with this “hybrid craft” framing, we draw on craft values in our computational setting:

materiality as a basis of creativity, experience as a valuable outcome, and craft itself as a way of working toward external goals such as strengthening social ties.

Game as Creative Approach

Additionally, we consider material exploration and collaboration (both social and computational) as fruitful territory for game design. This is not an unnatural fit. Gaming and crafting share common properties of being playful, improvisational, and often collective [39]. Within design practice, games are often used in participatory approaches to organize participants and communicate affordances for exploration [5]. Games can also serve as research instruments: the production of a game can force its designers to articulate underlying systemic assumptions [28]. Within art, games can be engines for productive defamiliarization; for example, the Surrealist party game “Exquisite Corpse” serves to frame and then re-frame the players view over the course of play [18]. Improvisational theatre games work as prompts for creativity and social bonding [24].

In combination with digital fabrication, gameplay can produce physical outcomes. For example, a 3D printer can produce player trophies or pieces to modify existing board games [4], and a laser cutter’s dual capacities for creation and destruction can create real-world stakes [11]. In the textile craft domain, Threadstading [1] and eBee [32] combine board game mechanics with CNC embroidery and e-textiles, respectively; Loominary [38] combines interactive narrative with weaving. Our approach draws specifically on social gameplay, encouraging looser, more interpretive rules as well as blending competition with cooperation. Notably, our gameplay rules are not enforced computationally: they are constructed as a social overlay onto algorithmic pattern generation.

Social Crafting

Collective activity abounds in handcrafts, particularly in textiles, from knitting circles and quilting bees to sew-alongs and fiber arts guilds with varying levels of formality. Craft projects can draw people together to form a powerful community; for a large-scale example,

the AIDS Memorial Quilt project [17] gathered a grieving community in panel-making workshops over a decade-long project from 1980 to 1990, highlighting the potential of needlework as an accessible medium for marginalized voices. Social crafting has been studied in the social sciences as a specific lens on community formation and duration [30], as an indication of social hierarchy [29], and even to suggest ways of supporting graceful aging [37]. Crafting together is a dialectic process [6, 37], and it makes technical competence into a sociable experience, bolstering crafting skills for individuals and the community overall [15].

Within HCI, the social element of crafting has been explored through analysis of online crafting communities [19] and as an opportunity for technical systems to encode personal reflections and social intent [35]. Our research focuses on shaping a social space for collective craft creativity.

GAME DESIGN FOR PLAYFUL FABRICATION

Game design aims to structure an experience through rules. The experiential goals of our hybrid fabrication games were improvisation, social engagement, and material exploration, and in our context, we saw plenty of existing rules: social norms and etiquette, physical possibilities of materials, and the algorithms of computer vision and shape generation. We decided our game should be a fairly lightweight overlay: a turn-based cycle and a set of player goals to clarify the possibilities at each time point.

In developing the specific game rules, we decided to merge two existing activities: 1) the Surrealist party game Exquisite Corpse, in which participants draw separate sections of a fantastic character body without seeing one another’s work until a final reveal, and 2) quilting bees, in which participants gather to communally complete one participant’s quilting project. These activities share the element of cooperative creation, though Exquisite Corpse typically features more surprise and humor, whereas quilting bees are typically longer in duration and feature more iteration and overlapping contributions.

INITIAL GAME DESIGN

We initially designed our game to take place as part of a workshop in our lab. As in *Exquisite Corpse*, our game begins with each player receiving instructions to produce “a head,” “a torso,” or “legs” within a pre-defined canvas. Marks on the connecting edge[s] of the canvas show where each design is expected to join continuously with the other body sections. At the end of the game, players gather all the pieces and assemble them into full “bodies.”

Drawing from the tradition of quilting bees, and diverging from classic *Exquisite Corpse*, players collaborate *within* a body segment in teams of three: two human players and the computational system.

The process of making the body sections is itself iterative, with the members of the team taking turns adding new elements to the section. For this version of the game, we provided drawing sets, embroidery kits, and a variety of soft materials. We encouraged players to edit their canvases for as many iterations as they liked and to exchange ideas with other players both in their own teams and otherwise.

Switching to Play-by-Mail

Our planned workshop sessions were interrupted by local COVID-19 lockdowns. We decided to use this opportunity to adapt a “play-by-mail” variant of our game, inspired by historical practices of correspondence chess and mail-based games of the late 20th century [23]. For a physical game, playing by mail meant we needed to assemble kits of parts for the participants. Although we hand-delivered these packages instead of using literal mail, the transit time still meant that this activity would necessarily unfold over a much longer timescale than our workshop games. We decided to limit each player’s turn to one full day (24 hours).

We modified the computational turn-taking to just two scenarios: in one, the player would receive their canvas with machine embroidery already on it; in the other, the machine embroidery would be applied after the player’s turn. To re-introduce the within-section human collaborative aspect of our game, we added an additional rule: each player should author a “material task”: a set of material-based requirements for the next player to follow. Thus each section would be a synthesis of the previous player’s task ideas with the current player’s execution of those ideas.

HARDWARE DESIGN

Our hybrid system includes hardware and software components. The hardware setup centers around a custom-built swatch scanner and a CNC embroidery machine (Singer Quantum Futura CE-100), both of which connect to a laptop via USB. The swatch scanner enclosure contains: 1) a fixed-distance camera, 2) an LED light, and 3) fiducial markers for image localization. The embroidery machine reconnects computational processing to the physical project. While sewing time depends on the complexity of the shape, it generally takes the machine 10-20 minutes to finish an embroidery task within our canvas size. The machine does not support multiple simultaneous thread colors; within the hybrid embroidery system, we encourage the user to select a thread color of their choice.

The hardware setup, including the embroidery machine, laptop, and swatch scanner.

Sequence of drawing, aligning, and scanning.

SOFTWARE SUPPORT

The custom software has several components coordinated within a Rhino/Grasshopper program. Sub-components include the scripts that generate an initial canvas layout, analyze the human handwork, generate machine feedback, and finally stream the generated pattern data to the embroidery machine [20]. We explore a variety of machine feedback modalities and describe our geometric algorithms in the SIGGRAPH Art Paper “Hybrid embroidery: exploring interactive fabrication in handcrafts” [21].

(a) A player sketches within embroidered canvas boundaries. Markers show the player how their design will connect to others’.

(b) The swatch scanner camera captures the sketch.

(c) A Python script extracts the visible features.

(d) Image processing, including sampling, clustering, and sorting, derives a representation of the input as a sequence of drawing strokes.

(e) Closed, filled shapes are generated to relate to the provided input.

(f) These shapes are then converted to the continuous line paths necessary for CNC embroidery.

In Person	Play-by-mail
Workshop in our lab	Kits sent to homes
Two players per body section	One player per body section
Finish during workshop	24 hours to take turn
Multiple iterations with machine	One iteration with prompt <i>or</i> feedback from machine
Provided materials	Using own materials

WORKSHOP SETUP

We initially studied our game in a small-group workshop setting. In order to observe how the game could mediate casual social interaction, we recruited participants who were already friends with at least one other participant. In this setting, we provided all materials and technical assistance, so we did not choose participants on the basis of textile expertise.

When we switched to the play-by-mail variant, we selected participants with some background in needlework to offset the lack of technical support while they were working. Overall, we had ten participants: five in the shared space setting and five in play-by-mail. In both settings, players were given canvases and instructed to create an embroidery composition corresponding to an assigned body part (head/torso/legs).

In the workshop version, the researchers were on hand to give instructions, answer questions, and provide technical assistance. In the play by mail version, the rules were provided in written form inside the game kit.

We observed participants' interactions during the game and conducted informal interviews during (workshop condition) and after (both conditions) the game. Prompts in the interview included: how participants felt about the machine working directly on their creation, their design strategies, and how they perceived themselves in the collective creation. We also recorded the embroidered artifacts at the end of each turn and in their final forms for visual analysis.

Above left: in-person workshop materials; right: the flow of swatches and tasks, and summary of participant skill demographics, in the play-by-mail version. Below: provided material “kit” for the play-by-mail version.

DISCUSSION

In our observations, we were initially surprised by the lack of obviously “social” behavior amongst the participants: during the making process, most of the conversation was about the machine. Some participants asked for technical assistance (such as attaching the embroidery frame, separating embroidery floss, or switching the stitching mode on the sewing machine) and the more skillful users usually offered help with these tasks. However, the participants did not often comment on either their own or each other’s personal creative work.

Thus, any given participant’s focus was sometimes on their own work, sometimes on the technical system, and sometimes on other participants, but rarely on combinations of these: the craft process acted as a bridge between crafter and the other three foci (material, machine, and other people), but sequentially, not simultaneously.

In light of this observation, the turn-taking aspect of our game design became especially crucial: with this lens, the game itself choreographs players’ focus on each crafting aspect in sequence. In each “mode,” different concerns are brought to the foreground. This is particularly pronounced in the “play by mail” version of the game, in which the turns are quite separate temporally:

1. Focus on *material*: Crafter must collect and find creative potential in materials around their house and write a “task” to focus another crafter’s attention in the same way.
2. then *machine*: crafter observes their own work through the lens of the machine’s enhancements
3. and finally *people*: crafter sees other participants’ results, including the ones from the task they authored, and has opportunities for humor and discussion.

In all, the distinct stages of the play-by-mail version served to tease apart these experiential threads and could serve as inspiration for future in-person sessions. In the following pages, we discuss game design tactics that shaped the participants’ focus in each mode.

Material

Our focus on hybrid craft, and specifically on embroidery, was motivated in part by the richness of material possibility and variety of techniques within textile practice. Because we saw many participants in the workshops choosing to simply use marker drawing instead of a broader range of materials, we decided to alter the rules for play-by-mail to underscore the possibilities of embroidery, to encourage the use of unusual materials, and perhaps to highlight the contrasting capabilities of hands and machines. Two main rule changes affected the material outcomes. First, the turns took place over a very different time scale. In the play-by-mail version of the game, players were given a full day (24 hours) to complete their task. This is much slower than the workshop version—the speed of marker drawing no longer gave any kind of creative “advantage”—but it is also short enough that, in pandemic lockdown conditions, crafters would be required to use materials in their own homes. Second, our play-by-mail rules included a specific material-based task designed by a previous player: for example, the material must be “the same color scheme as your screen saver.”

These tasks had twofold outcomes on the material aspects of the game. First, the constraints pushed the crafters to consider the materials in their own environment beyond what they may have initially considered in scope. Ultimately, we did see a variety of material creativity in these at-home results, ranging from the addition of latex balloons to magazine cut-outs. In reviewing the objects generated from these tasks, the framing of the task could be seen influencing the results beyond the material usage: for example, the embroidery response to “letters, pink, or feathers” ended up containing feathers as a motif but not literal ones.

Second, the act of writing a task for the next participant served as a materials-focused creative project in itself, encouraging the crafter to consider their own relationships to materiality and project them onto another. The task also served as a bridge to the “other people” aspect of the game, which was a connection that was otherwise very attenuated under lockdown.

MACHINE

Machine elements can encourage improvisation through adding generative elements for the crafter to work with: providing even a random “prompt” on an otherwise blank slate can spur creativity [8]. However, algorithmic systems can also support creativity through feedback: by responding to the crafter’s input, the machine can highlight, support, or undermine aspects of the work that the crafter may not have even noticed.

In initial tests of the hybrid embroidery hardware setup, we observed these aspects as part of an iterative, improvisational cycle, with the primary action being semantic interpretation. For example, **above**, the person sees the first pink output as a nose and responds with a mustache; in the following turn, the green shape is interpreted as cucumber in need of a hand to hold it.

In our play-by-mail trials, the number of iterations between human and machine was necessarily limited, so we were curious to see each of these effects (“prompt” and “feedback”) in isolation.

We thus had two simple conditions:

1. the crafter was given a blank swatch, and the machine’s embroidery was generated in response to theirs
2. the crafter was given a fabric swatch which had already been marked with machine embroidery

We observed that the “blank slate” compositions were more figural: they featured human or animal figures, and the compositions were more centered in the frame. The machine’s later additions could be semantically rationalized—as an extra garment, or as a pool of water. In the “random input” swatches, even though the basic “Exquisite Corpse” prompt remained the same, the results were more abstract and the composition more dynamic, with the hand-crafted contributions echoing the colors and shapes of the initial machine contribution.

swatches which were marked by the human first

swatches which were marked by the machine first

People

While neither the workshop nor play-by-mail participants exhibited the “obviously social” chatting or unprompted collaboration behaviors we initially hoped for, both experiences incorporated subtler social aspects.

In a workshop trial with two participants working together with the machine, we observed a “polite turn-taking” behavior: participants would tend to leave more room for ambiguity when they knew that their human collaborator still had additions to make. If they knew they were making the final move, participants would finish the design, e.g. by adding smaller details, whereas participants working on earlier stages would intentionally “do less” to leave space for others.

Participants also incorporated humor or cultural references, both in the compositions and in their discussions of them. For example, one participant modified the machine-added blue area to look like a weapon from the cartoon television show RWBY [31]; the same participant referred to a final (machine-generated) addition as “a fart.”

In the play-by-mail game, the primary channel of social contact was the material task: complying with the given task, then authoring a new one. We saw similar patterns of sportsmanship and humor here. Several themes emerged in the authoring of material tasks: some were reasonably straightforward descriptors of the material itself (“pink,” “natural”), whereas some played with object and context associations (“the same color as your screen saver,” “softer than your bedsheet,” “that you’ve been meaning to throw away”). Throughout, we saw a high degree of interpretability—we called these “tasks,” but players positioned them as somewhere between a prompt and a challenge. They seemed to want to not over-constrain other players, leaving room for creative interpretation (e.g. “natural, or, you make it look natural”).

The final move of the game is to assemble the embroidered swatches into the full “Exquisite Corpse” composition. This allows all participants to see their work in its intended context, but it’s also a moment of evaluation. In this step, we observed participants using language of cooperative competition: one participant immediately pointed out another’s work as “better,” and wanted to see all the material tasks so she could “do a better job next time.”

Gameplay to Mediate Materials, Machines, and People

The results of this work are directly related to our positioning of the embroidery experience as a game. We have used “crafter” and “player” somewhat interchangeably in this work, and indeed we see the participants’ roles frequently in flux between the two.

We see the gameplay framing as an essential component of our work, as it mediates the material, machine, and social aspects of the experience. The game acts as a “magic circle”—a place with its own norms and expectations [16]—to support creative risks and extract a buy-in of effort that participants may not otherwise have committed to. Additionally, the norms of gameplay itself allow for tasks that might otherwise seem absurd (such as drawing disembodied legs), and provide a gentle buffer against disappointing results. We found that some participants were initially uneasy with having their work altered, either by machine or by another participant, but the lowered stakes of the game convinced them to try it out.

The social compact of gameplay can be quite strong: one participant changed her clothes because her material task required her to use material “the same color as what you are wearing,” and she disliked the idea of using that color creatively. While she could have simply cheated—after all, in the play-by-mail game, she was working alone in her own home—she felt that changing her clothing was a more satisfying solution.

FUTURE WORK

The current interactive system is a working prototype designed with our workshop in mind; as such, technical improvements might include efficiency, scanning accuracy, and the machine operator interface. Design iteration might widen the points of contact with computational mediation, such as more synchronous remote collaboration with the machine or other players, or even “social media” interventions like crowdsourcing task notes or hosting post-game debrief chatter. Positioning our work as a game gave us some helpful precedent for adjusting from in-person to play-by-mail modes; that same precedent includes numerous potential case studies for a qualitative study of pacing, e.g. between correspondence chess and tightly-timed “bullet chess.” How does hybrid embroidery adapt across time scales and communication bandwidth?

Besides these, we see opportunities to use hybrid embroidery as a testbed for broader questions in computational creativity. The unique constraints of embroidery influenced the aesthetics of both the machine algorithms of computer vision and geometric output, as well as the human algorithms of gameplay; how might we iterate on these aesthetics, with an eye toward both the affordances of fabric and the opportunities of digital fabrication?

CONCLUSION

In this work, we use computational embroidery and computer vision algorithms to facilitate a set of playful creative interactions. We see these interactions as drawing from the richness of material practice, machine input and feedback, and social discourse; however, we observe that these elements have shifting relevance over the course of the creative process. We document our process and results to illustrate how our hybrid embroidery system leverages turn-based game rules to script a path through these three foci over time. Broadly, we highlight the value of material and collaborative crafting in HCI; methodologically, we hope to inspire other researchers to use gameplay and iterative game design as ways to interrogate existing and potential relationships in human-computer-material interaction.

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