Designing Interactions for Mixed-Initiative Machines: Balancing Automation and Craftsmanship

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ABSTRACT

We believe that creative work can be intrinsically enjoyable. Our work investigates how automation can be applied to support users of fabrication machines during the making process without taking away benefits that come with the experience of craftsmanship. In this position paper, we share some of our ongoing exploratory work in interaction design for mixed-initiative fabrication machines for creatives. We discuss three examples of interaction vignettes, and welcome feedback and input from the human-robot interaction community and beyond.

KEYWORDS

interaction design, mixed-initiative interaction, creativity, human-machine interfaces

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1 INTRODUCTION

> “Most enjoyable activities are not natural; they demand an effort that initially one is reluctant to make. But once the interaction starts to provide feedback to the person’s skills, it usually begins to be intrinsically rewarding." – Mihaly Csikszentmihalyi, *Flow*, p.68 [4].

Under the right set of circumstances, creative work can be intrinsically enjoyable. Fabrication work involves the learning and mastery of a craft. There is a sense of satisfaction and pride that can come from making something. This sense of satisfaction can be coupled with physical experiences of having used the body in the process of making. Working at a physical product can be a grounding experience in which a user experiences a sense of ’flow’; accomplishment; increase in skill; job satisfaction; a feeling of being physically tired, yet feeling accomplished. Some recent works have described this value of effort and (physical) creation, which has also been the topic of popular books such as Sennett’s *The Craftsman* [16], Csikszentmihalyi’s *Flow*[4], and Graeber’s *Bullshit Jobs*[9].

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In our recent work, we interviewed maker entrepreneurs – that is, makers of physical goods who derive income from the sale of these physical goods – and found, among other things, that the joy of making was a key motivator for the maker entrepreneurs to pursue this type of work [7]. Yet, makers also experience problems related to the physical strain their work places on their bodies. Thus, There is a balance to strike between manual work and technological support to arrive at an optimal state of (dis)comfort.

Tools and machines can augment the making process in order to meet different requirements, such as increased technical capabilities and increased efficiency. Machines used in creative tasks can become tools that play a very personal role in the user’s life. The user does not merely use the machine to achieve a productive and efficient outcome through a pleasant process, but the machine directly enables self-expression within the user. The rapid advances in the development of generative artificial intelligence highlight the potential of increasingly intelligent and initiative-rich machines.

Automation always brings along the question of how it will change the experience of users performing tasks. In the case of fabrication work, automation has the potential to enhance the experience of makers, or it could lead to a similar fate as to how the introduction of assembly lines changed the experiences of workers [18]. Our work investigates the design of mixed-initiative machines for creatives, following the vision of mixed-initiative interaction as presented by Horvitz [11]. We are aiming to achieve a balance between automated support and the preservation of craftsmanship and task immersion. In this position paper, we will share our process so far and plans for future work.

2 PAST WORK

To approach the research topic of collaborative machines for creatives, we took an exploratory approach, borrowing methods from different disciplines. We took the stance that a collaborative machine is, in essence, a non-anthropomorphic robot. Our exploratory body of work provided us with insights that will be taken forward into our further design process. We focused specifically on the AxiDraw pen plotter [15].

2.1 Studying Tic-Tac-Toe to understand paper-based interactions

We first familiarized ourselves with the AxiDraw by trying out various typical workflows with the machine (see [2, 3]). Then, we simplified the problem of collaborative drawing to the game of Tic-Tac-Toe and built a simple system around an AxiDraw pen plotter, which allowed for a participant to play Tic-Tac-Toe against the machine [5, 6]. This work highlighted the potential of using the AxiDraw as a research platform and confirmed insights regarding the social actors paradigm [14]; however, the controlled game of Tic-Tac-Toe provided limited insights regarding how people would experience collaborating in the context of *making*.

2.2 Exploratory system design: bringing visual algorithms to paper

With ShadeBot (Figure 1), we took a different approach and expanded the context of the application beyond games and to the richer context of drawing. We wanted to see for ourselves what the process could be like if a shade-generating algorithm was implemented onto paper – in a way similar to the practice of reflection-in-action [13]. We developed a system to run a digital algorithm to generate shading for line images and apply it to work using hand-drawn lines as an input and outputting the shading by controlling the AxiDraw. In this application, there is a shared initiative between the user, who draws, and the machine, who shades with a certain degree of freedom. However, as this application involved an actual implementation of a working algorithm, our interaction experiments were limited to the capabilities of the system. We next adopted the Wizard-of-Oz method, allowing for interaction exploration beyond the confines of technical capability.

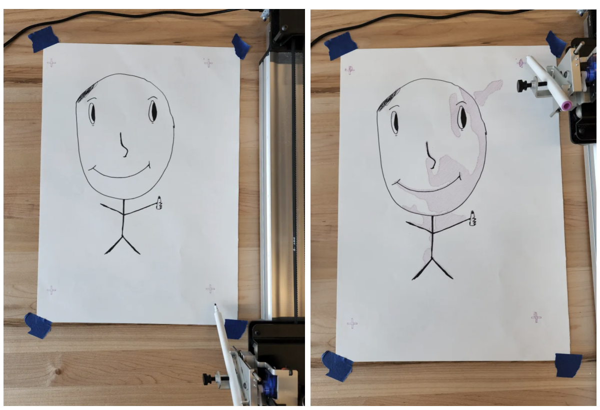

Figure 1: ShadeBot explores a physical implementation of a digital shading algorithm.

2.3 Wizard-of-Oz for richer explorations of collaborative drawing

We built three iterations of Wizard-of-Oz systems for co-creative drawing beyond the context of Tic-Tac-Toe. These systems follow a research tradition of table-top based Wizard-of-Oz systems for collaborative tasks, such as [1, 8, 12, 17]. The first system consisted of an iPad interface controlling the AxiDraw remotely in real-time. Due to lagging issues, we explored the possibility of using pre-designed paths in the second version of this Wizarding system. The third system was fully operable from a remote room. It involved mostly pre-designed paths, thus overcoming the lag problem of system 1 and adding remote controllability to system 2 (see Figure 2)).

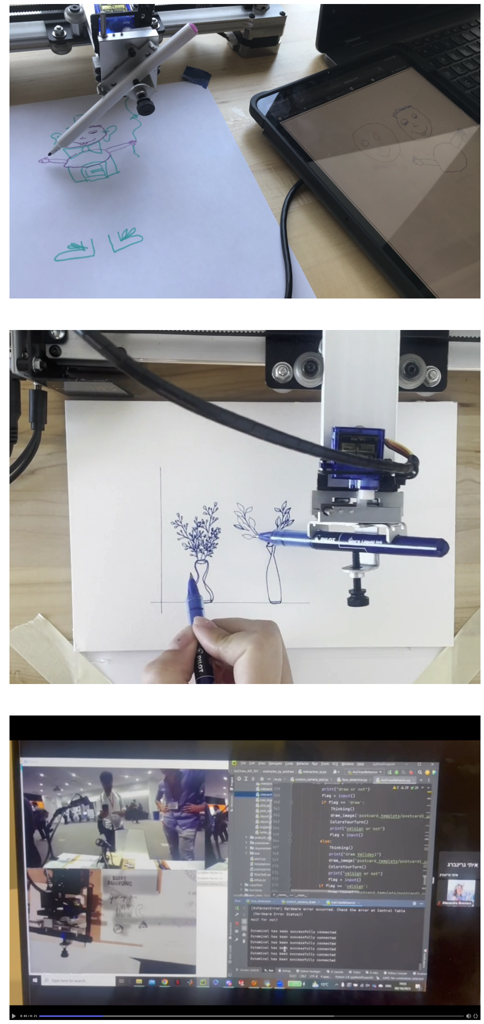

Figure 2: Three iterations of Wizard-of-Oz systems that allow for studying and observing human interactions with mixed-initiative machines.

2.4 Brain- and body storming the role of movement for collaborative machines

Through our wizarding platforms and the piloting of these, we realized increasingly the importance of movements in how people responded to the robot. We brought in dancers and animators, who are movement experts, to consider the design of movements for the AxiDraw during collaborative drawing. These movements were used in [10] (Figure 3).

3 INTERACTION VIGNETTES

Following the work above, we approached people who engaged in various types of physical making and spoke with them to gain an understanding of their work, the most fun and most frustrating parts of making, and how a machine could help them with this. Here, we present three interaction vignettes that arose from our

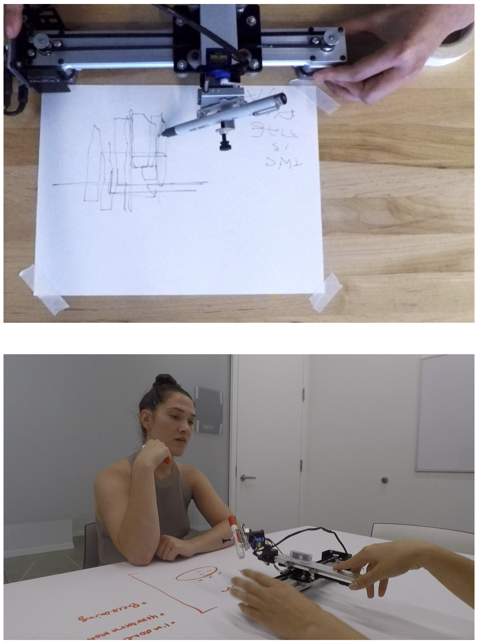

Figure 3: We involved animators and dancers to consider the movements involved in a drawing machine. (Partially published in [10].)

interviewee’s experiences and our own exploratory design work. Each of these three vignettes describes a different role that a mixed-initiative fabrication machine could take in the making process.

3.1 Machine as a guide

First, there is an asymmetry of skill between the human and the machine. When implemented correctly, the machine could support and guide the user so that they can focus on what they want to do and what they want to improve on.

To illustrate this, one interviewee mentioned her frustration with learning how to throw pottery on a wheel. Whereas the process itself was fun, the initial step of centering the clay on the wheel was something that she struggled with and would usually ask for others to help her with. She mentioned that having supportive rails, like bumpers in bowling, would have been nice:

> “You know how in bowling there’s bumpers? I wish there were that for throwing, to make it so I didn’t mess up so much because I felt like I spent so many hours trying to learn it."

We can imagine a machine that takes a role almost like a guide (Figure 4). For instance, you might want to draw a still life of a fruit basket, but instead of worrying about proportions, the plotter provides helpful guidelines so that your proportions will be right. A plotter could achieve this by observing a real object with a camera and generating support based on the outlines of the object to be drawn. The machine could offer corrective feedback if, later in the drawing, your proportions are off again.

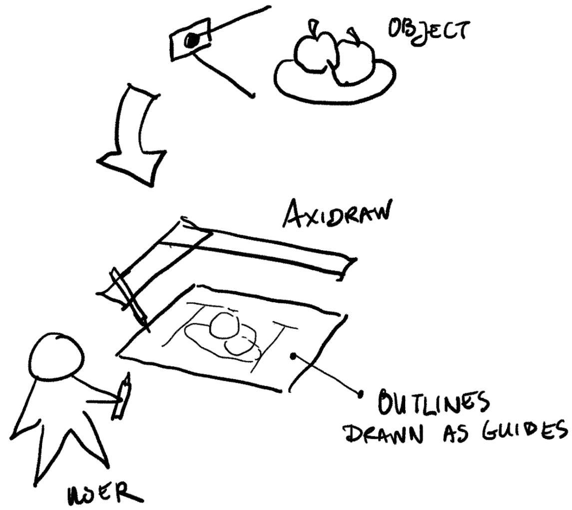

Figure 4: The machine guides you.

3.2 Machine as a presence

Another interaction that we think of is doodling and fidgeting; the joy of being immersed in the activity of making, and engagement with the material. One interviewee discussed this aspect of his experience while crocheting:

> “A lot of people, when they feel fidgety, pick up knitting or crochet because it’s something they can do with their hands and help them [calm down]."

In this case, we can imagine that it would not be desirable to completely take over the aspect of material handling from the person. Rather, the machine could be a presence, humming and doodling along without disrupting your fidgety fun. This could be envisioned by picturing a drawing robot that enhances your doodles through procedurally generated patterns, as depicted in Figure 5. Here, the focus of the work is not the outcome of the drawing but the process of drawing itself.

3.3 Machine as a co-creator

One of our interviewees worked professionally with extruders printing polymers and clay and expressed her frustration with polymers not allowing her to intervene halfway through a design:

> “I truly hate not being able to intervene. That’s not something I had with clay. I think that many people working in the world of clay now realize that there is value in being able to intervene mid-print. [...] [I see] something I could easily intervene in and save the whole print. But I can’t do that because it’s not in the code or embedded in the jet – it’s not like I can take it out, play with it a little, put it back, and continue."

In this case, we can imagine an interaction with a clay printer, where both the user and the printer react to each other by observing each other, observing the object that is being made, and acting upon the object as the process goes along (Figure 6).

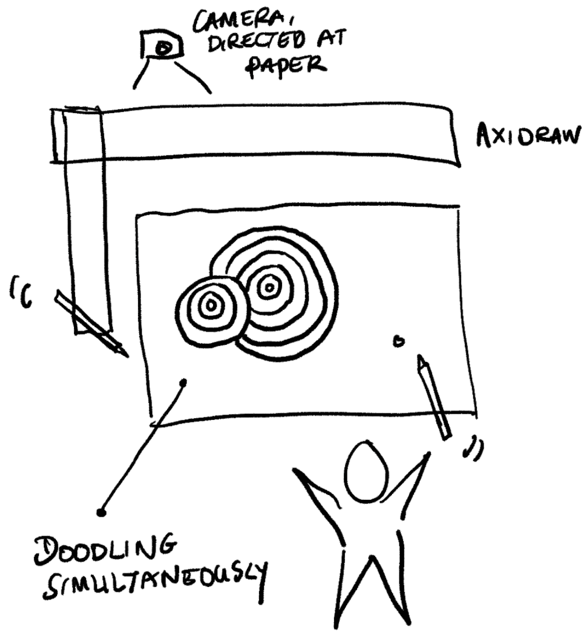

Figure 5: The machine doodles along with you.

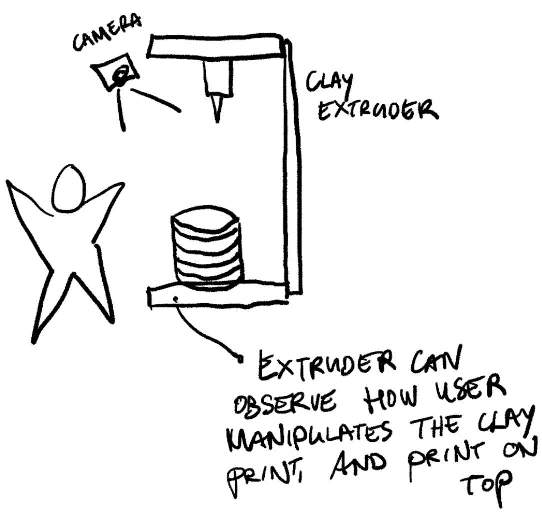

Figure 6: The machine adapts to your interventions.

4 DISCUSSION AND FUTURE WORK

We will continue the iterative exploration of designs based on insights gathered throughout our research so far. To start, we will expand the work of the three vignettes above. Then, we will use our Wizard-of-Oz methods to instrument machines to elicit user interactions during collaborative drawing approaches and collect data to model and understand these interactions.

We welcome discussion from the HRI community and beyond to join efforts in designing interactions for mixed-initiative machines that balance automation and craftsmanship. Our work links most to the workshop themes of values-based design as well as methodological approaches for HRI. As is common with design research, our work is inherently transdisciplinary and will benefit from the integration of varied perspectives including ethnography, sociology, engineering and industrial design.

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