Speculating the Possibilities for Remote Collaborative Design Research. The Experimentations of a Drawing Robot

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Abstract: Technology has influenced the field of design throughout history, transforming the making process and the tools used to generate artifacts. We are two design researchers who have worked remotely for the past three years, practicing a critical and speculative approach. Our research uses present technologies to speculate future possibilities for remote design collaboration, where interactions and exchanges are limited to those mediated by technological devices. This paper covers the process, findings, and trajectory of design research, exploring the means through which collaborative making can expand beyond digital platforms, into a physical environment, and produce collaboratively drawn artifacts off the screen. By speculating a future where all collaborative experiences are initiated, explored, and implemented through this robot, this paper challenges the standard remote-collaborative experience in the design process.

Keywords: Remote Design Collaboration, Drawing Robot, Critical Design, Technical Tools

1. Introduction

Technology has influenced the field of design throughout history, transforming the making process and the tools used to generate artifacts. Research in design should explore processes that extend beyond the expectations of present applications for technological tools, taking an active role in shifting and advancing technological innovations in the field.

As two design researchers, who practice nearly 730 miles away from each other, we have worked remotely for the past three years—practicing a critical and speculative approach to design making and research. Our inquiry investigates present technologies to speculate future possibilities for remote design collaboration, where interactions and exchanges are limited to those mediated by technological devices.
Together, we have built and tested multiple robots to function as additional technical tools in augmenting the remote-collaborative making process. These robots perform as drawing instruments, which are controlled in real-time through an online interface. Drawing with the robots is a way of learning the limitations and abilities of the tool; with each use, a range of opportunities for future development surfaces. The processes and logistics for drawing with the robot are prioritized over the outcomes by utilizing prompts that challenge the abilities of the tool and operate under unexpectedness, surprise, and discovery.

Conclusions from the research to date expand on ways the tool can impact the remote-collaborative experience by fostering new ways of making, forming online connections through elements of play and experimentation, altering the way we implement and use communication tools, and reconstructing technologies to increase technical literacy.

2. Collaboration, The Design Process, and Challenges of Proximity

With the advances in technology, a new level of complexity, and yet possibility, is brought forward within the systems that designers work. With this complexity, technology opens up communication and information sharing beyond the traditional workflow to include more collaborative processes in the design field. This enables designers to work and collaborate with other designers and those outside of the design field with more ease and fluidity.

Collaborations in design research take on many forms of interactions and exchanges between the contributors involved. For example, participants may contribute research, writing, planning, project management, brainstorming, evaluation, presentation, and, to a certain extent, making and experimentation. Successful collaborations require contributions at several levels and phases of the design process, often facilitated to produce work within a broad scope. Collaboration is critical in sharing, expanding, and developing ideas, as the collaborative process draws from the multiple perspectives and expertise of the contributors. Sharon Helmer Poggenpohl (2004) writes in the article, Practicing Collaboration in Design: “collaborative work is marked by shared decision making, the give and take of ideas exchanged and explored, the integration of multiple perspectives and a synthesis that integrates hitherto isolated ideas” (p. 144).

The contexts where collaborative design research takes place can dictate the degree of “collaborativeness” involved in the actual working process, making it complex and dynamic. The spaces and time of collaboration can span both digital and physical environments and “real-time” versus “hand-off” exchanges. We define “real-time” as a live, continuous workflow, whereas a “hand-off” scenario passes activities from one collaborator to the next. When collaborating remotely, issues may arise when contributors are isolated by proximity, most often limiting real-time exchanges in a physical environment. In order to identify these limitations and uncover opportunities for future development, we conducted a survey of the technical tools currently available.

3. Survey of Technical Tools in Remote Collaboration

Current technical tools enable some aspects of the design process to occur through various platforms, expanding the notion of what it means to engage in remote-collaborative design research. These tools can offer specific benefits to collaborative working methods, but when it comes to doing certain activities in design research, there are limitations. From a survey of technology used in
remote-collaborative experiences, we examined the capabilities and limitations of various platforms, including video conferencing tools, project management tools, and live-editing tools.

Video conferencing tools\(^1\) resolve issues of communication, allowing remote collaborators to engage and plan projects, brainstorm, generate ideas, and share development. They offer a platform for real-time exchanges but offer few solutions for experimentation and making, which are important components of the design process and an integral aspect of design collaboration. Project management tools\(^2\) provide an understanding of project development as a whole and foster the organization of workflow, planning, assigning, sharing, and documentation of tasks. They assist with hand-off and anytime exchanges, operating well in digital spaces; however, they offer little in regard to experimentation, particularly in real-time exchanges that may foster collaborative making. In contrast, live editing tools\(^3\) offer an environment that is malleable for many situations in real-time exchanges. These tools assist in writing, editing, and, to a certain extent, making and experimenting, but primarily in the form of digital artifacts. When it comes to making analog artifacts off the screen in a physical space, these tools fall short.

Further research into technical tools brought about another category of interest: drawing machines. These tools are particularly interesting in design collaboration because they offer functions and capabilities that the aforementioned tools do not, making analog artifacts. Often generating abstracted drawn artifacts, drawing machines are mechanical devices that respond to human interaction or programmed algorithms. These tools offer an alternative way of making in the physical environment, yet the limitations of working with these tools from remote locations has yet to be explored and challenged. They are limited to certain users within proximity, causing issues of accessibility. Remote collaborations mediated by drawing machines (and robots in general) have yet to explore the human-machine relationship.

4. Speculative Design

Advances in technology continue to push the ways in which people communicate and exchange information. In the field of design, these advancements are changing the ways of making by providing technical tools that enable anyone to produce artifacts. Sharon Helmer Poggenpohl (2016) explains in her recent essay, *Communities of Practice in Design Research* that design is changing and much of this change is due to technology. She states, “sophisticated production tools are available to anyone with the time and patience to learn to use them” (p. 46). Consequently, this change directly impacts the current roles and responsibilities of the designer in the design process, implicating a need for design research to practice alternative approaches to making, discovered by working speculatively with these tools.

In Christopher Jones’ (1970) oft-cited book, *Design Methods*, he argues that “to design is no longer to increase the stability of the man-made world [...] the instability of the present, under the influence of technological change planned in the past and coming about in the future, is perhaps the hardest thing to get used to” (p.33). Jones suggests, with the influence of technology and the instability in the design field that it creates, designers must acknowledge technological change as a consistent

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\(^1\) Video conferencing tools are communication systems that mimic face-to-face meetings from any location with WiFi accessibility.

\(^2\) Project management tools are technology systems that maintain, organize, and implement a workflow across collaborators from any location with WiFi accessibility.

\(^3\) Live editing tools are web application systems that provide a way to create and edit content in a shared workspace from any location with WiFi accessibility.
variable in the field. And, although this may present challenges to the designer, if one can be flexible and adapt to this instability, then one may be more comfortable with the evolving field. With this comes an inherent responsibility for designers to work critically and speculatively from what will be and can be possible in the future. Critical design, a term coined by Anthony Dunne and Fiona Raby (2013) in the mid-nineties, is defined as an approach to design that “uses speculative design proposals to challenge narrow assumptions, preconceptions, and gives new roles products play in everyday life... its opposite is affirmative design: design that reinforces the status quo” (p. 34). Practicing a speculative design approach can uncover the possibilities of present technical tools in shifting and advancing technological systems that facilitate connections, reconstruct knowledge generation, and alter the ways in which we implement and use these technical tools in design.

5. Process and Approach: Our Methods

With a stronger understanding of design collaboration, the design process, and the technical tools that enable such interactions and exchanges, we inquired:

- How can the use of present technologies speculate future possibilities for remote design collaboration, where interactions and exchanges are limited to those mediated by technological devices? Further, how can the use of present technologies support remote-collaborative making that takes place off the screen and occurs in the physical environment?

Our research methods for investigation included the development of multiple robots created to augment the remote-collaborative making process. By drawing from existing technologies across multiple categories of tools discussed in the survey, including live video streaming, live editing tools, and drawing machines, these robots alter the experiences of remote collaborations. Through experimental making activities that prioritized a collaborative process over outcomes, the discoveries reflect on ways that we might collaborate in future spaces of design, where interactions and exchanges are conducted solely through these robots.

5.1 Our Tool, The Collaborative Drawing Robots

We developed a pilot robot (April 2015) from a Roomba that could move in various ways. The initial investigation allowed a user to access the robot from an outside network and drive in a remote space with live-video capability. The web browser interface included navigational buttons and video streaming for maneuvering the robot in the physical space.

After some basic understanding of accessibility and movement, we built the second (August 2015) and third model (May 2016) of the robot to enhance its usability features and experiment with drawing capabilities in our respective locations through collaborative making activities (Figure 1). The remote-collaborative drawing robots included a body type or chassis with wheels, raspberry pi computer, battery pack and charger, camera, and mark-making tools. The battery pack powered the motors, controlled by the raspberry pi computer, which initiated movement of the device from python script. The charger powered the raspberry pi computer and the camera. The web interface, built from HTML, served as the user interface, which connected remote collaborators with the robot.
The ability to drive the robot via the web interface in a remote location with live-video streaming of the physical space and drawing surface, enabled drawing to take place in the remote location. The mark-making tools and canvases were interchangeable, allowing for a wide range of collaborative-making activities.

With the tools augmenting the remote-collaborative experience, we set up a configuration for working in our respective locations (Figure 2). The web interface (which connected the researchers in real-time) provided a portal into each other’s physical spaces. Within this working configuration, it became evident that each researcher had distinctly different roles in working with the tool. Researcher A became the “driver” of the robot from the web interface (Figure 3) while Researcher B acted as the “facilitator” by managing the collaborative-making experience in the physical space (Figure 4). The robot was placed on the floor where the facilitator, who controlled variables such as canvas type and the robot’s mark-making tools, set up a large canvas. The driver, the facilitator, and the robot worked together over a duration of time to create a process-driven artifact. This particular configuration of working was developed and applied in both locations.

Figure 1. Robot Model 2 (left image); Robot Model 3 (right image)
Figure 2. Diagram of Current Working Configuration

Figure 3. Location #1, Researcher A becomes the “driver” of the robot from the web interface. She is connected to the physical location via WiFi in real-time to draw with the robot in Location #2.

Figure 4. Location #2, Researcher B acts as the “facilitator” by managing the collaborative-making experience in the physical space; she sets up the space and guides decisions on mark-making tools.
5.2 Process, Experimentation, Play

The artifacts created from the robots are a direct result of the collaborative process that was defined at the beginning of our experimentations. With this process, we collaborated in real-time to produce drawn artifacts; each working session typically ran for two hours, although durations of time for the collaborative-making process were varied.

We outlined the process as:

1. Facilitator prepares the physical space—setting up mark-making tools (paint and brush, ink, markers, graphite, chalk, etc.), adhering a canvas type (paper, fabric, colors, etc.) to the floor, and initializing the robot for making.
2. Driver logs into the digital environment (web browser interface).
3. Both the Facilitator and Driver select a mark-making tool, which is then inserted into the drawing robot by the Facilitator.
4. Driver controls the robot, ultimately making the decisions for where the robot will draw on the canvas.
5. Repeat steps 2-4 until artifact is completed.

To provide more direction and set common goals in the working sessions, we introduced prompts to our experimentations and play. Prompts functioned as catalysts to our drawing activities and sometimes consisted of one or more work sessions. The prompts allowed for us to remain focused on the task at hand, narrowing our processes in ways that allowed for specified scrutiny on the robot and/or the making process.

Prompt #1: Make marks on the canvas to explore motion and control of the robot

This prompt challenged us to draw geometric shapes—a series of lines and circles and a combination of both—on the canvas. The collaboration was an experiment in working with the robot, navigating the physical space, and working with the robot’s mark-making tools on canvas (Figure 5).

![Figure 5: Details: One two-hour work session, Robot tool: Pilot test, markers, drawing paper](image)

Prompt #2: Informed by the robot’s movement, draw letterforms, symbols, and marks

This prompt challenged us to create a series of symbols or marks that were less expressive and more concrete. We designed a typeface informed by the movement and capabilities of the robot. Experimenting with multiple mark-making tools, the letterforms took on a range of forms (Figure 6).
Prompt #3: Make a process-driven artifact by layering multiple drawing instruments

This prompt challenged us to work over a longer period of time, over multiple work sessions, to create a process-driven artifact. During the collaboration, mark-making tools were changed often, creating a final artifact with multiple colors and types of drawing instruments (Figure 7).

Prompt #4: Add transparent masks to the drawing canvas

This prompt challenged us to screen off portions of the canvas while layering marks. The facilitator created a series of six-inch diameter circle masks out of adhesive, transparent vinyl and adhered them to the canvas. After layering marks on the canvas, the screens were removed, creating an artifact of the mask on canvas and additionally, the screens themselves (Figure 8).
6. Learnings From Working with the Robot

The process and outcomes from our investigation with the robot led us to critically reflect on the remote-collaborative experience, mediated by the robot. By challenging standard models for interaction and exchange in design research, specifically in the design making process, we uncovered underlying insights from our working sessions with the robot.

6.1 Insights on Remote-Collaborative Making

During our activities, we often transitioned between multiple roles—facilitator, driver, or other—in order to make an artifact. Both collaborators were open to exchanging and negotiating roles and responsibilities as needed. This challenged the role of designer as maker, as both collaborators are makers, and not, simultaneously. By using the robot as a technical tool for making, the collaborators, in some ways, had to relinquish control of the made artifacts and embrace the ambiguity of the process. In order for a collaboration to be successful, flexibility was needed in the roles and responsibilities, as well as in agreement of goals and purpose within the development of the process.

Additionally, the design process was open, relying on choices made by each collaborator, and not one individual. Although a set process was agreed upon, openness in the process allows for variables to occur, such as which mark-making tool is chosen and which directional cue is sent to the robot. These variables allowed for experimentation and playfulness in the design process, making each integral to the remote-collaborative experience. Without each collaborator contributing to the variables, the process would have been incomplete. Important questions arose from these activities such as: who is the real maker—the facilitator, driver, or the robot itself? And, if all were the makers in the collaboration, what happens if collaborators (robot included) worked across different times and for different durations in their respective locations? Additionally, what were the affordances of collaborating in real-time in a physical space?

Finally, through our understanding of the prompts, we recognized that the collaborative process was the content of the final outcome: an artifact created as a record of the experience between collaborators. It represented a captured moment in time where the collaborators worked together to create something, from the first mark to the last mark on the page. The artifact visualized the experience, and it became documentation of the making-process that fostered new ways of thinking and experimenting. Further, disruptions and mistakes often became interesting aspects of the process, becoming a catalyst for new prompts and activities. By focusing on the process, the robot
fostered an opportunity to learn about technology and collaboration, where the outcomes were unexpected, providing insights into future remote-collaborative making scenarios.

6.2 The Robot as Maker, Technical Adjustments

Technical adjustments came into contemplation when considering the possibilities for future collaborative configurations. Refining the robot’s camera, expanding on recording options, adding multiple arm attachments, and improving the robot’s mobility were ongoing pursuits in our design research. An altered camera could expand the user’s capability to control the zoom feature, enable night vision versus color, and shift the camera perspective. The addition of recording options, such as video recording and code recording, could produce new digital artifacts that visualize and document the design process. The ability to control multiple arms on the robot could foster multiple collaborators to work simultaneously. And, expanding the navigational functions on the robot could provide users with new ways of maneuvering in the physical space, increasing notions for prompts and activities. From these technical insights, we can explore methods for expanding on the design artifacts created through the collaborators’ making experience, which may improve the user’s ability to understand the overall space in a more sophisticated manner, as well as create interesting comparisons of designed artifacts from the analog to the digital.

7. Conclusions and Further Speculation

The following conclusions expand on ways the robot can impact the remote-collaborative experience by expanding new ways of making, forming online connections through elements of play and experimentation, altering the way we implement and use communication tools, and reconstructing technologies to increase technical literacy.

7.1. Expand on new ways of making artifacts

After collaborating remotely in the design process with the robot, new ways to make artifacts from our existing activities and configurations expands exponentially. Visual evidence of the design process could be realized across new physical and digital media, or a combination of both.

This concept expands on the current making activities of the robot by adding new capabilities to the robot and interface. This scenario would enable researchers to create digital artifacts of the design making process simultaneously as the physical artifacts are being created. Additionally, live-video stream footage and the code stream of the activities could be collected. Layering of artifacts could happen across analog and digital artifacts, and reproductions of the collaborative design making experience could occur. Between better control of the robot in the physical space, combined with better capabilities for recording digital artifacts, the possibilities for creating a larger range of designed artifacts with multiple remote users at the same time may increase.

7.2. Forming online connections through elements of play and experimentation

By altering the way in which we collaborate, the perceptions of the design process are challenged by the robot. Where a traditional design process might include a linear development of phases, the design process with the robot tool includes variables that rely on the collaborator’s ability to experiment and play with the tool. It also relies on the transparency of roles between collaborators and the exchange and negotiation of responsibilities.
A possibility for creating a configuration for online connections to be made through elements of play and experimentation includes opening the process to new collaborators. In this scenario, a third location would provide a venue for new users to contribute to the process. This process could happen in real-time with new users driving a single robot; the “mistakes” made as a result of disruptions that occur in the drawing process as well as the introduction of new, inexperienced collaborator(s) make the experimentation unique and unpredictable (Figure 9).

![Figure 9. Concept Diagram: Inviting new collaborators into the drawing process, all collaborators contribute to one process-driven artifact, which may be located in a new remote location.](image)

### 7.3. Altering the way we implement and use communication tools

After working with the robot tool primarily for making activities, new opportunities for use in other areas of the design process emerge. Combined with challenging the definitions of collaboration and real-time production, we believe the robot tool may be used for communication in a hand-off scenario, challenging other digital forms of communication across remote locations.

This concept tests the communication capabilities of the robot by having interactions happen at the will of an individual user, versus in a collaborative, planned setting. This scenario would enable the researchers to experiment with communicating to each other solely through the marks made by the robot, augmenting the communication and collaborative exchange. Possibilities for how the driver interacts with the robot are to be considered. For example, what if specific behaviors or voice commands activate sensors placed in the physical environment of location #1, which prompt the robot in location #2 to respond by drawing a preset mark? How is the driver actually “driving” the robot, beyond interaction with the web interface (Figure 10)?
7.4. Reconstruct technologies to increase technical literacy

Opportunities to empower individuals to reconstruct present technical tools as a means to foster a collaborative design making experience have surfaced throughout the duration of the research. In order to better understand the entire process, collaborators have the opportunity to learn the technical tools, including the basics of hardware/robotics, software/programming, and digital communication tools available via the Internet. By making the technology transparent for understanding and knowledge consumption, this experience supports a societal movement away from over-consumption, supports design democracy, and enables citizens to make and fix things, as seen in organizations like repair cafe (https://repaircafe.org/en/).

This scenario introduces multiple drivers controlling multiple robots via a singular interface. Physical locations such as a classroom or museum would open up the collaborative making experience to others in an environment suitable for learning. Design researchers, collaborating as drivers, could publish video tutorials for new users to begin to create their own robots for collaboration, further investigating the reconstruction of technologies in order to increase technical literacy. Possibilities for expanding a controlled recording of the drawing experience and enabling a memory recall of code could lead to a collaborative library of symbols that is collectively built through the multiple interactions with the robots. This could, in fact, lead to the strongest expansion of the project (Figure 11).
8. Conclusion

The collaborative process is complex and dynamic, with interactions occurring across both digital and physical spaces and exchanges taking place anytime. Advances in technology add to this complexity, yet offer new opportunities for remote collaborations in the design process. After a survey of the current technical tools, we found that limitations exist when collaborative activities extend to making artifacts. Through speculative investigation we inquired how the use of present technologies support remote-collaborative making that takes place off the screen and occurs in the physical environment. The implementation of drawing robots enabled us to challenge the standard remote-collaborative experience. Multiple working sessions led by experimentation and prompts uncovered a collaborative process that was prioritized over the final outcome. This led to multiple possibilities of future configurations where all collaborative experiences are initiated, explored, and implemented through this robot.

From our insights, we can expand on the ways in which we understand the process, while implementing the robot in remote design collaborations. Considerations of roles, variables, time, location, and configurations could be adjusted in ways that would alter the collaborative experience. Our conclusions reveal a range of new opportunities to develop and expand the research, speculating on new configurations and processes for working, as well as opening experimentations to new collaborators. Our investigation examines who, what, how and for what purpose the robots are controlled, creating an interesting and evolving platform for designers to consider, not only the role that technology plays in the design process, but also how engagement with new tools in remote collaborations fosters new ways of thinking and making between collaborators.
References

Bardzell, J. & Bardzell, S. (2013). What is critical about critical design? [conference paper]. Retrieved March 16, 2016 from ResearchGate, DOI: 10.1145/2470654.2466451

Dunne, A., and Raby, F. (2013). Speculative Everything. Cambridge, MA: MIT Press.

Dunne, A., and Raby, F. (2001). Design Noir: The Secret Life of Electronic Objects. Switzerland: Birkhäuser.

Faste, H. (2015). Posthuman-centered Design. In Armstrong, H. (Ed.), Digital Design Theory: Readings from the Field. (pp. 134-144). New York: Princeton Architectural Press.

Jones, C. (1970). Design Methods, New York: John Wiley & Sons Ltd.

Middleton, M. (1967). Group Practice in Design. London: Architectural Press.

Noble, I. & Bestley, R. (2005). Visual Research, Switzerland: AVA Publishing SA.

Peart, R. (2016, October 25). Automation Threatens to Make Graphic Designers Obsolete. AIGA. Retrieved October 25, 2016 from https://eyeondesign.aiga.org/automation-threatens-to-make-graphic-designers-obsolete/

Pisano, G. & Verganti, R. (2008). Which Kind of Collaboration Is Right for You. Harvard Business Review. Retrieved November 5, 2013 from http://tinyurl.com/okn975y

Poggenpohl, S. (2004). Practicing Collaboration in Design. Visible Language 38, (pp. 138-158). Providence: Rhode Island School of Design.

Poggenpohl, S. (2015). Communities of Practice in Design Research. She Ji: The Journal of Design, Economics, and Innovation. 1(1), 44-57. Tongji: Tongji University and Tongji University Press. Retrieved December 25, 2016 from http://dx.doi.org/10.1016/j.sheji.2015.07.002

Ratto, M. (2011, May 27). Critical Making. In van Abel, B., Klaassen, R., Evers, L. & Troxler, P. (Eds.), Open Design Now: Why Design cannot remain Exclusive. Netherlands: BIS Publishers. Retrieved from http://opendesignnow.org/index.html%3Fp=434.html

Tufekci, Z. (2015, April 18). The Machines are Coming. The New York Times. Retrieved December 10, 2016 from http://www.nytimes.com/2015/04/19/opinion/sunday/the-machines-are-coming.html

Zimmerman, J., Forlizzi, J., & Evason, S. (2007). Research through design as a method for interaction design research in HCI. In Proc. of CHI '07. Chicago: ACM Press.

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