Exquisite Fabrication

Exploring Turn-taking between Designers and Digital Fabrication Machines

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Figure 1: Detail of sample created in the project through a process of Exquisite Fabrication. The fabrication of this embroidery-based inflatable sample took four steps, done in three different machines: digital machine embroidery, a filament 3D printer and a custom Liquid Deposition Modeling (LDM) 3D printer. The steps were a) embroidering the substrate, b) 3D printing a mold on the embroidery, c) 3D printing the silicone and d) integrating the tubing through a couching stitch.

ABSTRACT

Digital fabrication and craftsmanship is entering into a new phase with increasing levels of complexity and a renewed desire for composites and cross-material experimentation. However, allowing work to travel from machine to machine, remains a challenge in terms of workflow, communication, orientation and material. Based on an exploration to combine embroidery and 3D printing in the pursuit of inflatable solutions, we propose the metaphor of the drawing game Exquisite Corpse to outline the three emerging concerns: turn taking, orientation and trade-offs. We propose a set of guidelines that suggest ways in which, we may allow different digital fabrication machines to be used in sequence, as a method

for adding complexity to the things we make and the ways our machines may talk to one another.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**.

KEYWORDS

Fabrication, Digital Craftsmanship, Turn-taking, Prototyping

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1 INTRODUCTION

The way we design and fabricate things is changing due to the growing adoption of digital fabrication technologies like 3D printing, laser cutting, and digital embroidery. The levels of reproducibility, accuracy and fidelity of finish of such technologies allow for new

possibilities that were not available with more traditional design processes, in which concept development preceded the inclusion of fabrication methods and material considerations into the process [18]. More specifically, these technologies enable designers in exploring real implications of production systems, supporting bottom-up approaches to design based on the capabilities and opportunities offered by the machines and materials [11]. We see this shift reflected both in research and industry by the growing interest in different methods of fabrication with companies such as Adidas, New Balance and others implementing 3D printing for mass manufacturing of shoe soles [21].

The close collaboration between designers and machines brings the experience of using digital manufacturing closer to that of traditional craftsmanship, where a constant dialog exists between the craftsman and the material [20]. To enhance this experience, researchers have been exploring the interaction between human-machine [7], digital craftsmanship [4, 6, 8], Interactive Fabrication [16, 24], digital manufacturing practices [23] and production systems for personalisation [17].

Although examples of designs based on digital fabrication techniques and systems abound [13], there is little cross-pollination between techniques. Some efforts in this direction combine several technologies into one machine, such as Popfab [19] and Jubilee [22]. Here, multiple technologies are combined into one, but in order to achieve this, compromises are needed to allow multiple technologies to work within the same machine. This limits each technology and narrows down the potential combinations to techniques that are similar. Combining a 3D printer and a CNC milling machine, for example, is much more feasible than bringing together a 3D printer with digital embroidery machine. In 3D printers and the CNC milling machines, the bed position is fixed and the nozzle or bit moves in the 3 axis. In the digital embroidery machine, the stitch is formed by interlocking top and bottom threads. As moving top and bottom would be unstable, the embroidery frame moves instead.

In this paper, we introduce an approach that encourages exploration, cross-pollination and improvisation in the fabrication process, which we refer to as Exquisite Fabrication. In this, we refer to the classic surrealist art game, Exquisite Corpse [5], where different people collaborate on a drawing in stages, knowing only the transition points of body parts such as the neck or legs (see example in figure 2). We propose that our contribution is the notion of the exquisite corpse as a cultural metaphor to facilitate a practical approach to working between multiple machine systems for fabrication. In this approach, each machine can remain itself, and instead the samples travel between various machines to get the advantages of combining multiple fabrication technologies. To take turns in the making process, only the transition or the starting point for the new process needs to be known. To make this work, we focus on supporting the alignment of the sample across different machines. In this way, the system of production available to the designer is flexible enough to include, exclude or replace machines. If a new digital machine comes on the market with new functionality, this machine can be incorporated into the workflow, without having to be fully compatible with the other machines.

In order to facilitate this approach, we designed a machine operation alignment system (referred to as MOAS), a system created to

Figure 2: Example of a Exquisite Corpse drawing. Photo by Alan Levine, 2012, CC BY 2.0 via Wikimedia Commons ([https://commons.wikimedia.org/wiki/File:Exquisite_Corpse_Art_\(7356894034\).jpg](https://commons.wikimedia.org/wiki/File:Exquisite_Corpse_Art_(7356894034).jpg))

support the alignment between different digital fabrication tools. In this paper, we provide a description of an example design process, that focuses on maintaining the designerly and collaborative qualities of the work, while providing a simple system that facilitates interoperability of two existing fabrication systems. This example is the detailed process of implementing MOAS to develop an inflatable actuation sample (see figure 1), fabricated by combining digital machine embroidery and 3D printing techniques, as a design test case. While the design focus of the process is the creation of an embroidered inflatable, this paper is entered on the broader possibilities for exploring turn-taking between disparate systems and distant collaborators. We propose the metaphor of the Exquisite Corpse to outline the ways in which we may allow different machines for fabrications to be used in sequence, as a method for adding complexity to the things we make and in turn new ways for our machines to talk to each other.

2 RESEARCH CONTEXT

The project was started with the explicit aim to explore the possibilities and implications of transporting samples across the machines in a lab. Inspired by the challenges found in previous work in the area of actuation in soft wearables [12], we used the Embroidered Inflatables as a design case of combining 3D printing, digital embroidery and silicone casting to create textile-integrated inflatable actuators. The Embroidered Inflatables already combined the processes of digital machine embroidery and manual silicone casting. We expected that by automatizing the casting process and creating a system for transporting the sample across machines, we would not only solve a technical issue (interoperability) but also develop an approach and a working metaphor (Exquisite Fabrication) to support different crossovers between skill sets and distinct machines.

As silicone adheres only to itself, combining it with other materials requires an open structure or a porous surface, it can sink into. In our test case, we aimed to create self-supporting substrates by using digital embroidery as an open structure to facilitate integration of the silicone with textiles (see figure 3). The material qualities of the substrates and, consequently, the interactive possibilities of the final inflatables can be changed depending on the sewing attributes or layering of the embroidered designs. While the advantage of this fabrication method is shifting the complexity of fabrication from the casting mold towards the embroidery, which is more reproducible, the casting is still crucial. Manually placing the mold and manual pouring of the silicone hinders the reproducibility and control of the actuators. Even slight tilts of the mold or small differences between the amount of silicone in each pour can cause the inflatable actuators to behave differently from each other.

For the purpose of this exploration, we decided to approach the casting process through two kinds of 3D printing, one for creating the molds and the other for pouring the silicone, and create a system to facilitate the transition between the machines. As previous work has shown [10, 11] it is possible to use an embroidery frame as a fixed device that travels between machines. However, we wanted to overcome the limitations of the maximum operation areas of the machines involved as well as to remove the need of retrofitting machines with compatible hardware. In the following, we detail the design process of the system and we report on the implementation and outcomes.

3 INTRODUCING THE MACHINE OPERATION ALIGNMENT SYSTEM

In order to support the creation of multiple-machine samples, we designed a Machine Operation Alignment System (MOAS). The system was developed recognizing the value of leveraging the capabilities of each machine, as well as the expertise of each maker. As such, instead of creating a multi-purpose machine, our goal was to allow separate digital fabrication machines to interact as a system without changing how they normally operate.

We realised that the game of Exquisite Corpse could be used as an effective metaphor for how each process builds on top of each other, making turn taking between machines the core concept of MOAS. Rather than designing and envisioning all steps upfront, the work practice we propose leans towards exploration and improvisation. Each new machine does not need to know all that happened before. Rather, it only needs to know where to start the new process. As such, the design of MOAS took into account the following factors: 1) The operations done by a machine should align with the operations done by the other machines; 2) The system should support decisions to be made on the fly; and 3) MOAS should intervene as little as possible on the regular use of each fabrication machine, allowing easy and rapid implementation of a machine into the system.

The result is an open system that consists of the digital fabrication machines and software tools designed to facilitate turn-taking between them. These software tools aim to create a common language between machines that may function very differently from one another, enabling design researchers to combine techniques by adding, removing or replacing machines from the subsystem

used in a given project. This language is mediated by a main software tool, the MOAS sticker designer (MOAS SD), which generates markers to help position a sample into a new machine. While some machines allow positioning the file in the working area through an interface, others need this process to be done via software. For such cases, we designed a second software tool, which we called MOAS Translation Tool (MOAS TT), to give the needed X and Y positions of the operation as well as rotation.

As a design case, we combined digital machine embroidery and two kinds of 3D printing through MOAS. Through the design process of creating an embroidered inflatable sample, we experienced through a first person perspective the challenges of combining techniques and of turn taking, not only between machines but also between designers. Based on this experience, in the following we articulate our findings about multi-machine collaborations. We introduce a new method for design researchers to work with digital manufacturing, not as isolated technologies but as a larger system.

4 KNOWING WHERE TO START

Every digital fabrication machine carries with it its own coordinate system, i.e. it knows its own zero position. Every operation needs to be aligned based on this reference frame. MOAS uses this principle as a basis for alignment. By finding points in the reference frame of the machine, the location and rotation of an operation can be calculated with simple trigonometry. To place an operation in the machine, a sticker is made with the MOAS SD software. Each sticker contains a number of markers. The amount and shape of the markers may differ per machine. The machine is aligned to the marker in a way that works with the standard operation of the machine (see figure 4).

Different kinds of machines as well as different models of machines have features that pose different implications when using them with MOAS for alignment. These differences may include access to the working area of the machine, work envelope and interfaces. Some machines, like digital embroidery machines, allow for positioning an operation through the interface of the machine itself. In such cases, the markers on the MOAS sticker are used to find the offset and rotation within the machine.

Machines like 3D printers, on the other hand, do not offer the ability to change the location of an operation once it is prepared for printing. For such machines a second piece of software is needed to calculate the position of the operation so it can be placed in the right position before slicing. In this case, the stickers feature two markers. The X and Y locations of these markers are used by the translation tool to calculate the position of the sticker within the machine. This piece of software gives the coordinates of the operation and its rotation. These values are then used to position the model or file in the software of the machine. To participate in Exquisite Fabrication, each following operation needs a starting point. Through the stickers, MOAS provides this starting point to the machine. Independently of the machine, MOAS is used for alignment of each new operation that is done. New machines can be added to the process seamlessly due to the starting point provided by MOAS.

When making multiple versions of the same sample, machines can be replaced when another machine can be used to achieve a

Figure 3: Sample created in our process of Exquisite Fabrication being actuated

similar outcome, or machines can be removed when their operation is no longer needed or easily substituted. As a result, Exquisite Fabrication turns all machines and people in a design or research lab into collaborators. Where previously each machine was used individually, they can now work together to create a shared outcome. Different designers can each apply their expertise and combine techniques to create new artifacts that would not exist without the cross-pollination between technologies and makers.

4.1 Stickers and translations

Two pieces of software were created to support Exquisite Fabrication: the MOAS sticker designer (MOAS SD) and the MOAS Translation Tool (MOAS TT) (figure 5). Both tools were created using Processing [2] and can be run as standalone applications.¹

The sticker designer is the backbone of MOAS. It creates the stickers that are used for alignment. The stickers serve as placeholders for operations within a machine and feature a set of markers that the machine can align to. The amount of markers and their shape depends on the machine. All types of machines work a little bit differently and, for that reason, the markers are tailored to work best with a specific machine.

Using the MOAS SD works as follows. The outline of the operation is exported as an .SVG file. This can be derived from the file used for embroidery or an export of the bottom of a 3D model. The machine the sticker is for is selected, and based on the width and height of the file, the software determines the placement of the markers. A new .SVG can be exported that includes both the outline as well as the markers.

In some cases, a machine cannot be aligned to the sticker directly e.g. a 3D printer. For this the MOAS TT was created. MOAS TT is auxiliary software that takes the coordinates of two markers on a sticker and provides the center point and orientation of the sticker i.e. operation, within the machine. This information can be used to position the operation in the software of the machine.

4.2 What the machine knew already

Digital fabrication machines usually come with proprietary software. This software is used to prepare digital files compatible with the machine. For 3D printers, this software is the slicer, which converts three-dimensional models into code for the machine. For embroidery machines, embroidery digitizing software is used to program the sewing order and sewing attributes of embroidery patterns. Final adjustments, including size, position and rotation can be added on the machine via its screen interface. Other software, such as CAD (e.g. Solidworks) or a vector graphic editor (e.g. Adobe Illustrator) can be used in the design phase. MOAS works alongside the existing software for a machine instead of replacing it. This way, MOAS has a minimal impact on the operation of a machine. The digital file of the new part of the sample is created as the design researcher normally would, using the appropriate proprietary software. From the design file, an alignment sticker is created by the MOAS SD. This sticker is used for alignment, either directly through the interface of the machine or with use of the MOAS TT. MOAS TT works in conjunction with the machine's own software by providing the coordinates and orientation of the model.

5 FABRICATING EMBROIDERED INFLATABLES THROUGH MOAS

Based on the Embroidered Inflatables [12] as a design case, MOAS was developed to combine digital embroidery with 3D printing. The differences between the two techniques supported us in designing a software tool that is flexible to adapt to how each machine operates. 3D printing and digital machine embroidery have been combined on several occasions. The paper Combining Strings & Fibers details the use of digital embroidery to embed wires into 3D printed objects [3]. With this approach, the yarn embedded in the 3D printed parts adds functionality that cannot be achieved otherwise. FabriClick combines the 3D printing of soft materials with embroidery on stretched fabrics to create textile pushbuttons [10]. The FabriClick jigs build on the embroidery frame to allow the fabric to remain under tension when changing machines and keep the alignment between machines. From these implementations it

¹The codes of the MOAS tools are available on github.com/JorivdKolk/MOAS

Figure 4: Workflow of 3D printing a thin mold on top of the embroidered sample: (a) Received embroidered samples. (b) Preparing 3D model. (c) Making sticker in MOAS SD based on an SVG from the 3D model. (d) Placing sample in the 3D printer. (e) Placing stickers. (f) Recording marker coordinates. (g) Removing sticker. (h) Positioning file with MOAS TT. (i) 3D printing mold.

became apparent that a system can be created to let samples travel between machines where each machine can add something to the final outcome. In the case of FabriClick the jigs only work with machines that are modified to work with the jigs. A solution that does not rely on these kinds of modifications would make the process of transporting samples between machines much easier to implement and not limited to certain technologies or work envelopes of machines. The Embroidered Inflatables [12] demonstrated that one possible fabrication process for soft actuators is a hybrid of digital machine embroidery and silicone casting. Laser cut acrylic molds can be used for the casting, but performing the casting manually

can result in errors and low repeatability as both the placement of the mold and the quantities of silicone in each pour are hard to control. In using MOAS, the goal was to improve such casting by 3D printing the mold onto the embroidery and using a custom 3D printer to deposit silicone when and where needed. For this action to be successful, the 3D printers need to be able to print in the right location.

Because of the isolation measures against the spread of the coronavirus, the 3D printers and embroidery machines were located in different cities. Due to this physical separation each type of

Figure 5: Screenshots of MOAS applications. (a) MOAS SD creates the stickers with markers that support the alignment of the sample in different machines. (b) For machines that do not have an interface that allows changing the alignment, like in 3D printers, MOAS TT takes the coordinates of the markers to give the center point and rotation for input in the proprietary software of the machine.

machine was operated by a different researcher. Therefore, the material samples travelled through mail back and forth between the two designers involved in the fabrication process. MOAS facilitated this collaboration by allowing each design researcher to draw from their own expertise using the machine in question to fulfill the next step in the fabrication process.

6 THE DESIGN AND FABRICATION PROCESS OF THE SAMPLE

The design process of the new Embroidered Inflatable sample was done in four fabrication steps (figure 6): embroidering the substrate, 3D printing a mold on the embroidery, 3D printing the silicone, and couch stitching the tubing via digital machine embroidery.

The main aim of each step was predetermined. The research team agreed on which fabrication processes would be combined and what would be done in each step (substrate, mold, casting, tubing integration). However, we allowed opportunities to emerge when deciding on how to proceed with each process, including which technical specifications would be used in the design of each part. The embroidery steps were carried out by one design researcher and the 3D printing steps by another. This meant that turn-taking happened not only between machines, but also between collaborators and techniques.

The first fabrication step was straightforward. A free-standing substrate was embroidered including the outline of the inflatable, a support pad and appliquéing [1] an extra layer of the water soluble stabilizer that will create the pocket to create a unilateral inflation (similar to the design of Interaction Mode 3, described by Goveia et al [12]). The sample was removed from the embroidery frame and sent by mail to the other design researcher. MOAS SD was used to create an alignment sticker for the 3D printers. Since the 3D printing of the mold and the silicone had the same general shape and they would happen in the same area of the sample, this sticker could be used for both 3D printing fabrication steps. The sample was attached to the bed of the 3D printer and the sticker was placed

over the outline of the inflatable. Using the MOAS TT and the 3D printer's software, the digital file was aligned to the position of the sticker. The digital model is raised slightly from the bed of the printer to account for the thickness of the sample. The sample with the mold was then transferred to the silicone printer and the same steps of placing the sticker, aligning and printing were executed.

To support our understanding the implications of different machine features to alignment through MOAS, we also used two different digital embroidery machines to compare experiences. For that, we did one last embroidery step, couch stitching the tubing, on both a domestic embroidery machine (Brother Innov-is 750e) and a professional one (Brother PR1050X). The latter has a built-in camera that supports precise alignment of designs. The camera is also already meant to support alignment by scanning a specific sticker design, which we incorporated into the MOAS SD. The domestic machine we used, on the other hand, had no LED pointer or any other indicator of the precise position of the needle on the frame. To check whether the position is correct, the needle had to be lowered into the fabric. Typically, the process of precisely positioning the design onto the frame can be done in two methods that can be combined. The first method of precisely positioning the design is making sure the material onto which the design will be embroidered is aligned with the center of the embroidery frame while setting the fabric (or stabilizer) in the embroidery frame. The second method is to adjust the position and rotation of the design on the display of the machine. For this machine, we used nine markers on the MOAS sticker to skip the first method.

7 WHAT DID WE LEARN

Our design case allowed us to experience through first person perspective some of the implications of engaging with multi-machine and multi-maker collaborations. In this process, we experienced the making like a game of Exquisite Corpse, each action was followed by the next until we arrived at a result that was more than the sum of its parts. This had implications in different aspects: turn taking, improvisation and trade-offs.

7.1 Turn taking

While an obvious aspect of a system designed to move work from one machine to another, turn taking emerged as a much more complex and personal aspect of the work. As makers we found ourselves not just aligning our samples and materials, but also our dedication to the process and our individual making ethos. We were forced to share our craft and machines in closer ways than we had expected.

In the process of making, designers gain intimate knowledge of the materials, techniques and tools they use. We learn how the machine works so that we can encode and decode potential errors or interesting effects based on our understanding of the process. The turn taking between design researchers brought interesting dynamics to our collaboration and our relationship with the process of making. In our process, whenever one maker gave the sample away for the other one to continue on, this next maker had to play a game of Exquisite Corpse in order to be able to build on top of what was already done. Each maker became attached to the sample

Figure 6: The sample was transported between three machines to perform four fabrication steps: (a) embroidering the substrate, (b) 3D printing a mold on the embroidery, (c) 3D printing the silicone, and (d) couch stitching the tubing via digital machine embroidery.

in turn and, as such, the sample encoded a piece of each maker and how they each approached their craft.

Our experience was that this turn taking between makers was a close and instinctive exchange and quite different than more traditional co-creating. When co-creating, all parties involved stay in control of the creative process and can negotiate the compromises to be made. Sharing a sample with someone else to let them take a turn in making meant sharing a part of ourselves through the sample and letting go of the control over the outcome. We had to trust that the other person would treat the sample with the same level of care and dedication we did.

Next to building trust in each other, we learned that to enter this type of collaboration, we had to accept the shared risks and ownership of the process (Figure 7). Every time the sample changed hands (and machines), the risk of something going wrong increased. Likewise, the lucky chance of one of us receiving the sample with a positive unexpected result was also part of turn taking. Accepting these risks required a strong feeling of shared ownership and shared responsibility.

Although the turn taking between people facilitates the letting go of control over the design to allow opportunities to emerge, we believe that Exquisite Fabrication can also be carried out by the same maker engaging with machines. In our experience, the turn taking between machines may also be an interesting dynamic as the order of operations and nature of each machine/technique

affect the opportunities for future steps. To make our inflatable, for example, the first step in the process is to embroider the free standing embroidery that served as the base of the sample. As the embroidery is relatively flat, it enabled the 3D printer to add the walls of the mold without problems. Inverting the order of processes would not have allowed us to execute the same sample. Different opportunities would have to be explored. This shows that the order of operations may open up different kinds of opportunities for next steps of Exquisite Fabrication. In future work, in this direction, exploring the other paths inverting operation orders or types of machines would be an interesting way of further exploring what it means to design bottom-up, from the sample one has at hand.

7.2 Improvising & understanding machines

While the system we devised was designed to make a complex process easy and less prone to error, we found that even with these new guidelines a certain level of improvisation was required in order to micro adjust each turn. There are a number of aspects to this, one is the inherent tolerance in each machine and how they may amplify each other, another is a simple inherent precision of the hand. Micro adjustments and improvisations remained important aspects of the way we worked.

The initial vision for the system was that it would provide a technological solution to the transfer of work-in-progress between machines. In our experience, however, we found that each step

Figure 7: To engage in this kind of making, we had to accept the shared risks and ownership of the process. The last step was high risk because it was the most experimental. This step consisted of integrating tubing through couch stitching. The tube had to be manually arranged as the machine stitched.

required some level of improvisation on how to implement MOAS to transport the sample between machines. This moment of picking up the sample to think "what now?" created anchoring points or seams [9] in the process that pushed us into investigating the possibilities of the machine and the material.

The MOAS application allowed us the simple flexibility to replace the marker designs and the number of markers on stickers to adjust to each machine/process. To check the alignment of the last step with the marker in the domestic embroidery machine, the position of the needle needed to be lowered into the sample. However, lowering the needle into the silicone would damage the inflatable. To increase the chances of there being two or more markers that could be used for alignment, the stickers for embroidery contained nine markers. Their positions around the outline of the part match points the machine can move to when the starting point key is pressed on the display.

The markers were adapted differently when testing the system using the professional machine with a built-in camera. The central marker was changed to match a design that the machine could automatically recognise through its scanning feature. The machine correctly recognized the marker and aligned the file accordingly. A visual check and some final adjustments were necessary to achieve the best alignment. The rotation was usually off by one or two degrees. As such, we found that to engage in Exquisite Fabrication, improvisation worked together with exploring and understanding how the machines we use work to make the best use of the capabilities of each machine. Rather than pushing towards the technological solution, the tool is used as much as it is needed.

The area or volume in which each machine can operate is different and machines treat their work envelope differently. 3D printers are rather straightforward in this regard, they have a set volume they can work in, always building up in layers from bottom to top. Scaling up the size of a printed object can be achieved through strategies like modularity. Digital embroidery machines present different challenges. While they are limited to a maximum sewing area, it is possible to reposition the material in the embroidery

frame to overcome this limitation. When deciding on doing an operation with a machine, you must work within its workable area or seek viable strategies to overcome its limitations. In Exquisite Fabrication, this also means you have to investigate what your material sample is/does to inform what you want to make next.

7.3 Trade-offs

Every engagement with a tool, a machine or a collaborator comes with its own risks and promises. The trade-offs inherent in every system is the one aspect we as designers appear unable to anticipate. The MOAS system generated a number of trade-offs between efficiency and flexibility and precision and in turn offer suggestions for best-practise.

Our proposal of Exquisite Fabrication aims to foster exploration and cross pollination of techniques. This proposal builds on ideas of corresponding with the materials/tools [14] and intentionally drifting in the design process [15]. We propose using the moments of turn-taking between machines or people to be anchoring points to enable drift. Steps should not be fully planned in advance, but instead, be open to emerging opportunities and improvisation. This way, the concrete possibilities of a step can inform the possibilities for the next.

While working with MOAS, we found the process of being open with the sample and the machine to be a trade-off between precision and flexibility. When aiming for precision, the whole process needs to be thought through. The result might be the most accurate and polished. However, the process is carried out with the expectation of a specific result as a measure of success, leaving little chance for the possibilities that arise along the way to be taken into account.

When engaging with Exquisite Fabrication, the results of every step can become the starting point for consideration for new directions. To allow this process to happen, design researchers also trade control over their outcomes for discovery by letting others and machines offer new opportunities and starting points, like in the game of Exquisite Corpse. To add something to a sample the only thing a maker or machine needs to know is where to start. What comes after is not of importance for the current step, decisions can be made on the fly. We found this to still be true in our design case, even though we pre-determined which actions we would perform.

In our case, we wanted to be as precise as possible about the alignment of steps to make a functional actuator that would be more reproducible than those poured by hand. The planning ahead of how each step would be carried out was not important. Each maker had the freedom to choose which machine they would use and how they would incorporate MOAS in its use, letting the sample, the software and the machine inform the way.

8 CONCLUSION

With this project, we have attempted to create a common language between machines and makers to practice turn taking, while playing a game of designerly Exquisite Corpse. The resulting process allows each machine and maker to take turns by building on the actions done before. This aims to foster collaborative exploration and cross pollination by deliberately breaking up the process between machines/makers. As we have described here, the collaboration between people and systems are both technical and cultural in nature.

This means that alongside the design and distribution of a system for the technical coordination of work, it is of equal importance to provide a cultural narrative for these collaborations. A distant collaborator does not only need to know what work must be done, but also perceive that the turn taking is explicit, meaning that the potential risk and outcomes are shared and understood. As such, we aim for these systems to allow a shared understanding of “what is at hand”. Rather than imagining a full plan of operation and executing it, the breaks of each turn should invite makers to ask the sample material and the machines they are using, what kinds of processes can be done next. We experienced and explored this first hand through the making of our soft-inflatable sample as a design case. To complete this Embroidered Inflatable, we moved the sample between three different machines to complete four steps of fabrication. Through this process we showed the possibilities that arise when allowing turn-taking between machines while letting each machine be itself. We discussed the trade-off between precision and exploration as well as the implications of collaborating with multiple machines and makers on the same sample. Entering this kind of process in collaboration with other makers required building trust in the expertise of each other, which supported us in letting go of control over the outcomes during the turn taking process. Based on our experience, we believe that engaging in Exquisite Fabrication can be a fruitful exercise or approach for designing bottom-up processes, allowing decisions to be made based on the real implications of the production systems we have at hand and facilitating the creation flexible systems of production.

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