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# Reimagining Digital Fabrication as Performance Art

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*CHI'15 Extended Abstracts*, April 18 - 23, 2015, Seoul, Republic of Korea  
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ACM 978-1-4503-3146-3/15/04...\$15.00  
<http://dx.doi.org/10.1145/2702613.2732507>

**Abstract**

Within the HCI literature to date, digital fabrication systems are often oriented towards pre-determined goals and discussed in terms of the meaning of objects produced rather than the meanings of actions from which those objects emerged. This paper draws from contemporary performance art to inform fabrication system designs that frame meaningful actions as the primary product of fabrication activity. In doing so, we open up new generative ideas for HCI theory and practice, specifically in relation to posthumanist and research through design agendas.

**Author Keywords**

Performance art; digital fabrication; posthumanism.

**ACM Classification Keywords**

K.4.0 Computers in Society: general.

**Introduction**

Over the past decade, the development of small-scale collaborative manufacturing, perhaps best typified by the so-called 'maker movement,' has become a topic of mounting interest in HCI. As emerging sites of HCI innovation [20], hobbyist engineers have helped usher in new modes of digital fabrication, from easy-to-program microcontrollers to laser cutting and 3D printing. Inspired by these developments, HCI researchers have sought to open new 'hybrid' design spaces for digital-physical fabrication by turning to

more 'traditional' forms of craft-based production [37]. Others have anchored their work in the possibilities of emerging economies [35]. In growing this interest, HCI has reframed the user as maker [4] and broadened the scope of design practice from a functionalist to a posthumanist endeavor [16].

Alongside these developments, recent empirical and historical research has pointed to the symbolic underpinnings of computer engineering cultures and the legacies of performance art of the 1960s and 70s in their wake [1,33]. Otherwise known as Fluxus, action, anti-art, process art, guerilla theater, survival research and so on, this work has interwoven action with politics by advancing the body as material and the primacy of human subjects over objects [30]. In the decades since Silicon Valley's first computational innovations, such bohemian values and practices have helped define and legitimate emerging forms of technological innovation [32,33]. While these ties have sometimes lead to explicit anti-consumerist interventions in industry (e.g., IKEA hacking [25]), at other times histories of a counterculture only ripple beneath the surface of public events such as pop-up fixer collectives [26].

As the CHI community continues to grapple with the limits of production, it becomes ever more vital to cast an eye toward the artistic project-based practices that inform and support these sociotechnical shifts and the tools for 'making' and collaborative manufacturing they engender. In particular we ask how recognizing the performativity of digital fabrication might help us open up new generative ideas for HCI theory and practice? Here, we draw on a notion of performance wherein identities (e.g., gender for Butler [5]) get *done* through acts and iterations. This overturns a focus on objects

inscribed with meaning for an emphasis on meanings constituted through repetition. This turn also compels a related question of where acts of difference arise from when fabrication changes?

The paper that follows explores cases of performance art that present ideas for reimagining fabrication tools in HCI. This reimagining allows us to first contribute a reflexive perspective to HCI research on fabrication. As we will describe, the workings of performance art highlight digital fabrication as a means of technologically enacting a specific way of life. In this, objects not only become discursive phenomena (laden with particular social and political agendas) - but also harbingers of symbolic action rather than material 'solutions' [22] or instrumental ends. This work of envisioning new opportunities for fabrication also allows us to contribute design interventions that could extend how posthumanism is understood and enacted in HCI research. We detail this theoretical development and explore its extension of research through design approaches in HCI.

### **Tools for Making and Connecting**

Within the HCI literature, research on tools for making and connecting comprise two general thrusts: one exploring tools for augmenting social processes of handwork and the other investigating novel 3D fabrication tools for rapid product design. The former often uses smartphones and tablets to capture, access, and symbolically transform digital content. For example, projects such as AnyType [8] provoke surprise and wonder through customized images created using visual elements from the users' environment. Our work broadens previous approaches in that it takes seriously the relational nature of

creativity by examining and modeling creative activity in contextually rich environments.

In the domain of 3D fabrication, researchers have developed new tools to support children, amateur designers, and artists in creating, appropriating and reshaping specific kinds of objects and tools. Follmer et al. designed KidCAD [11] to enable children to use physical toys as inputs for 3D fabrication. The tool scans existing objects using a deformable interface to produce new 3D designs. Other research has examined the production of custom 3D shapes through 2D design and sketching. The designers of SketchChair [29] for example, provide an interface for laser-cut and CNC routed parts for chair assembly – enabling people to customize and virtually test the stability of chairs without 3D printing tools. Others focus on soft material constructions like 3D printing with yarn [15] and plush toy construction [21]. Lastly, Zoran and Paradiso [37] designed an interactive milling tool that pushes back while carving according to a pre-specified 3D file.

Each of the projects above frames technology as an instrument or means to an end. For instance, SketchChair offers tools that novice users to create innovative chair designs and FreeD aims to provide an experience similar to freehand making. We engage performance art in order to frame printing technology as a conceptual framework through which self and culture are encountered and understood in new ways. The following section traces the history of performance art in an effort to articulate its continued attention to technology as a provocative concept rather than instrumental tool.

### **Contemporary Performance Art**

The Museum of Modern Art offers a broad definition of performance art as, “A term that emerged in the 1960s to describe a diverse range of live presentations by artists” [39]. While the term gained prominence in the 60’s, early 20<sup>th</sup> century Futurist performances are often cited as the first examples of performance art [13]. Mobilized through the Manifestos of F.T. Marinetti [24] a Futurist avant-garde sought to address the phenomena of everyday life rather than its matter by “explicitly acknowledging the total impact of machines in transforming performance environments into dynamic, sensory-technical apparatuses” [27]. The ability of performance to speak to the dynamic movements and sensations of everyday environments, and provoke a passive audience into action were particularly appealing to Futurists interested in waking up what they felt was a lifeless and sleeping culture [13,24]. Operating in the medium of performance, rather than paint or sculpture, allowed for social interactions and public life to be engaged directly by artists towards poetic and political ends.

The locus of “art” in this work is the lived experience of the artists and audience witnessing and/or participating in the performance. The central role experience plays in performance art makes questions of “difference” between self and other particularly salient [13]. In many cases, the “others” being explored or reacted to through performance art are technological machines. In an 1958 essay, celebrated literary critic Umberto Eco argued that if art is to speak to modern conditions that it should reflect the chaos that characterized modern life [10]. Drawing from Claude Shannon’s theory of information, he advocated for the integration of randomness as a means of increasing the amount of

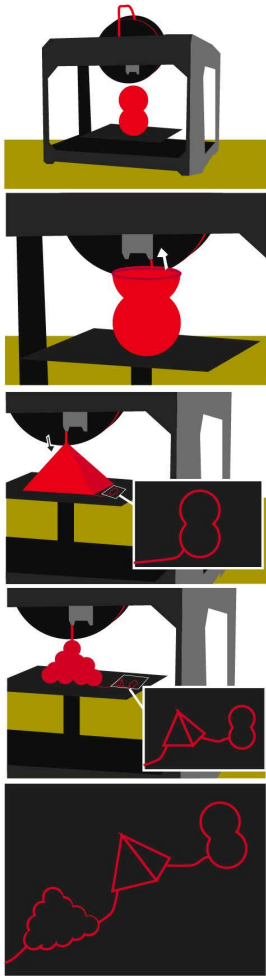


Figure 1: 3D Print Eraser: Doing as undoing with filament as historical record.

information present within those artworks. He described the mobiles of Alexander Calder as being “open” in terms of form since they change shape with the wind, and the writings of James Joyce being “open” to the semantic interpretation of the reader.

Performative techniques like audience participation became the method of choice for “opening” artworks in the period post-WW2 [9]. In a culture witnessing the growing presence of mass media, “smart” machines, and massively destructive war technologies like the atomic bomb, performance became a powerful way to speak to qualities of life seen as essentially human, unfettered, and non-commercial. American artist Allan Kaprow writes eloquently of this turn: *“Not satisfied with the suggestion through paint of our other senses, we shall utilize the specific substances of sight, sound, movements, people, odors, touch... [to] disclose entirely unheard-of happenings and events”* [18]. As we soon revisit through design scenarios, Kaprow underscores the need for new “concrete” art forms that speak directly to human experience and highlight sensory and reflective engagements in everyday life.

While our cursory overview of the history of performance art draws from a specific Western Futurist perspective, contemporary performance artists around the world continue to mutually engage humans and machine to provoke reflection and of what it means to be human, machine, and/or cyborg. For instance, the thrilling / terrifying machines created by Mark’s Pauline’s Survival Research Lab subject humans to the will of powerful, loud, and often fire-breathing machines to incite euphoric and adrenaline fueled human responses [31]. Other human-machine performances

focus on themes like labor [23,34], prosthesis [6,12], and maintenance [7,38,40].

Next, we draw on these legacies of performance art to examine possibilities for digital fabrication. Within HCI, digital fabrication has brought humans and machines together to complete and amplify the work of making [11,37]. Rather than use engineering to extend the limits of this amplification we use fabrication to inspire critical reflection on contemporary issues of technological change and its relation to alternate portrayals of the agency and historicity of the body.

### **Design Concepts**

The following design concepts build on works of performance art that exemplify commentary on present day culture and our relations with technology within it. In line with Blythe’s [3] recent positioning of a conference abstract as a work of speculative design fiction, we develop six design vignettes not as guidelines for production but speculative provocations for reimagining digital production and its reliance on these material histories. In addition to describing fabrication as performance, we intend for this collection of vignettes to describe how performance art can be engaged in the *design* of fabrication systems to open up new reflective and critical modes of production. Our selection of artworks stems from our interest in exploring themes of interference and tension rather than functionalist approaches to digital fabrication.

### **Erasure**

In 1951 Robert Rauschenberg shocked audiences with the debut of his White Paintings. In contrast to his celebrated combines, large-scale collages made from thickly layered paint and found objects, Rauschenberg’s

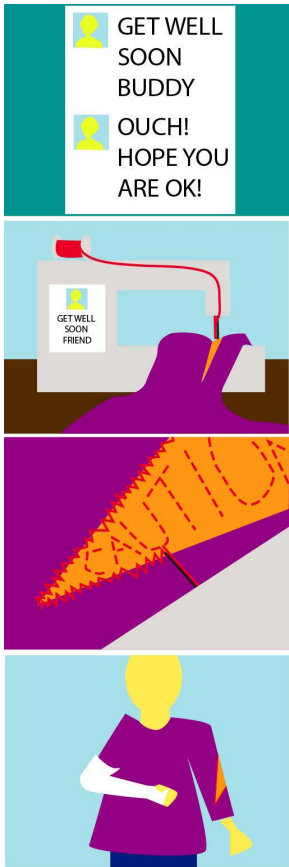


Figure 2: Sew-What: Mending as a Platform for Public Engagement.

new works consisted of large panels painted completely white. The works explored the tension between matter and phenomena by creating a space for the moving shadows cast upon the canvases stand as the content of the work. Further questioning the “content” of the painting, Rauschenberg produced “Erased de Kooning Drawing,” a drawing by renowned Dutch artist William de Kooning that he erased to create a similarly blank piece of paper. The work could be read as commentary on the locus of art: asking if art resides in an object or an idea. By taking a work that was once considered “art” and performing erasure, Rauschenberg commemorated his marks of erasure to reveal the magnitude of this undoing. In his own words, “It’s not a negation, it’s a celebration. It’s just the idea” [28]. The artwork highlighted material historicity - not located in the blank paper, but in the memory the paper and the title “erased de Kooning” evoked of the performance of erasing.

#### *3D Print Eraser: Filament as Historical Record*

Inspired by Rauschenberg’s act of erasure, we suggest the design of a 3D print eraser: a machine that takes as input a physical 3D printed object and systematically converts it back into filament (Figure 1). The project extends the original metaphor of material historicity with a present day commentary on the culture of 3D printing as wasteful and consumerist [41]. The mechanical labor of production is matched by the labor of erasing and highlights the ease with which forms come into and out of being. With this design we ask what kinds of alternate entanglements between an idea and thing might emerge from fabrication? If the existence of 3D printed objects were temporary, would more sustainable and reflective modes of 3D printing ensue?

A critical component of Rauschenberg’s work is the title “Erased de Kooning Drawing.” The title serves as an entry point into the drawing’s history, recalling the actions of erasure. Accordingly, our 3D print eraser could embody previous forms created with the printed material in the filament itself. For example, the filament could encode each erased object with each new print, visualizing a small “icon” or single layer outline of the previously printed object. As more and more prints are generated and erased, a longer chain of outlined objects would surround the base layer of the 3D printed model, calling into memory the past lives of this filament and the records contained within them. A system like this could lead to playful engagements with 3D printed objects. 3D printer filament could become a timeless media, like yarn to be raveled and unraveled and shared with others. The histories within the filament could contain secret messages to be encoded by one person and revealed by another. The 3D printer eraser could provoke reflection on the nature of material historicity through printing while serving as a long term record, or diary, of previous engagements.

#### **Maintenance**

In 1969, feminist artist Mierle Laderman Ukeles published the “Maintenance Art” manifesto, a document contesting the time and effort women invested in domestic, service-related labor [7]. Instead, Ukeles positioned herself as a “maintenance artist,” a concept that seeded upcoming projects such as “Touch Sanitation” (1978-80), which invited New York’s sanitation workers to shake hands with Ukeles. Developing this idea of maintenance, today Bay Area artists Michael Swaine and Miriam Dym use the work of textile mending to produce similar interventions in public life. In “Reap What you Sow,” Swaine pushes a

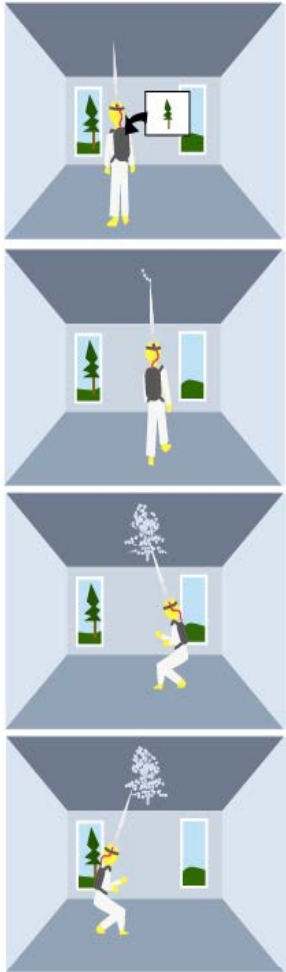


Figure 3: Unicorn Extrusion: Engaging Body, Context and Movement in Printing.

sewing machine mounted food cart through San Francisco offering to repair damaged clothing [38]. In her “Logo Removal Service,” Dym re-imagines textiles by replacing industrially branded elements of low-quality mass-produced clothing with handcrafted patches [40].

*Sew-What: Mending as a Platform for Public Engagement*  
 Inspired by these interventions, we envision how mending might behave as a medium for social critique and engagement. Mending of material, discourse and the body might happen in union – emerging through new forms of understanding and participation in public life. The Sew-What platform could investigate such engagement catalyzed by the integration of mending and collaborative media. The machine would mend clothing according to patterns of messages sent and received via social media (Figure 2). Imagine someone hit by a drunk driver while riding a bike and tearing their favorite sweater. Upon repairing the sweater with Sew-What the machine could produce a “get well” message from a friend or a public message urging people to look out for bikers on the road. The system enables the recognition of traditionally hidden work of mending by blending public conversation with discarded textiles.

### Prosthetics

Over the last few years, a growing community of ‘makers’ has used 3D printing technologies to produce and share customizable prosthetic designs. Body augmentation and the use of technology as a prosthetic brings body and machine into a highly intimate bodily experience. The use of prosthetics allows the boundary between body and machine to be blurred, opening a space for posthuman reflections on body as machine and machine as body. Prosthetic devices are used in

performance art to not only explore a body-machine relationship, but also the relationship between the body-machine and physical space. Oskar Schlemmer’s *Stick Dance* (1926) explores the relationship of body and space by attaching many long sticks at two points on the dancer’s body. As the dancer moves, the sticks jut out into all directions in space, breaking spatial planes and extending the geometry of the body within the stage. The structure of the space itself dictates the movements within it. Contemporary work by Rebecca Horn offers another perspective on the theme of prosthetics, body, and space [6]. In a 1974 performance, she attaches long claw-like apparatuses to her hands so that as she stands in the center of the room and extends her arms, the tips of the mechanical “fingers” just touch the wall. As she methodically walks back and forth, her arms scrape the walls of the room creating both sonic and visual textures within it. An interesting aspect of Horn’s performance is the way in which her prosthetics bring her within reach of objects while simultaneously enforcing distance, provoking reflection on the dual nature of technology as enabling and distancing.

### *Unicorn Extrusion: Engaging Body, Context and Movement in 3D Printing*

With Horn’s performance in mind, we consider how a 3D printer might account for its context. Specifically, how the situation of use might influence the printer’s movement while simultaneously (dis)connecting the body within a space. Drawing from another of Horn’s performances, *Unicorn* (1971), a piece where she reflects on self exposure by attaching a single long spire to her head and wanders through an open field, we envision a 3D printing system that consists of a single location aware extruder extending out from the top of the maker’s head (Figure 3). The concept of a unicorn

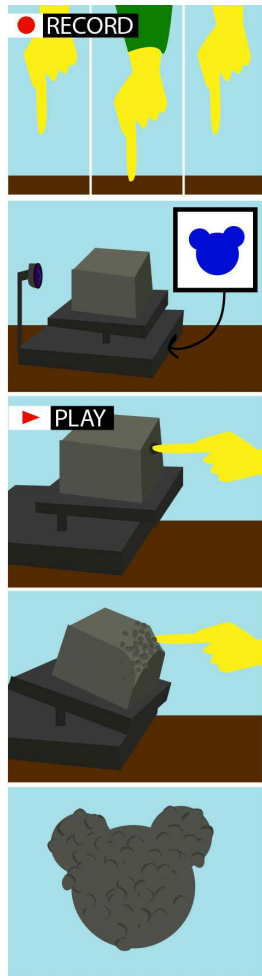


Figure 4: Repetitive Motion Machine: Prompting Reflections on Labor through Repetitive Actions.

seems particularly interesting because it speaks to a contemporary notion of a unicorn as “a woman who is being exceptionalised: i.e. treated as the first or only woman geek ever” [42].

To fabricate with the Unicorn Extruder, a user would upload her model to the system, place the horn/extruder on her head and adjust it to reach the exact height of the ceiling. As she wanders throughout the space, the horn extrudes a single drop of material on the ceiling in locations that match the paths of the digital model. As material accumulates, hanging down from the ceiling, she must move the horn to dodge the material so as not to knock it down and position her body to extrude material exactly atop the preceding layer.

The bodily motion required to move the horn and place it in various locations enforces the relationship to the space as well as the structure modifying the space. The choice of digital model might shift from an object of interest to an attention to what movements that object could produce through interaction: how could an object alter the way in which the space is experienced? Additionally, the spectacle of printing in this fashion invites an audience, prompting the maker to call the meaning of the objects, movements, and feminist reflections on exposure into question.

### Labor

The vivid contrast between the rote and repetitive labor of factory work and the skilled workmanship attributed to small-scale artisanal production has remained central to popular accounts of manufacturing and their critique. Such critique is explored in Revital Cohen and Tuur Van

Balen’s *75 Watt*, where they used the structure of an object to choreograph human actions of assembly line workers in China, showcasing assembly as a stylized dance. The performance “invokes a geopolitical commentary on industrialism and a critique of both global and local sociocultural ramifications of capitalist consumerism, while at the same time celebrating the human spirit of ingenuity and innovation” [23].

### *Repetitive Motion Machine: Prompting Reflections on Labor Economies through Repetitive Actions*

Drawing on this concern for manufacturing as choreography, we imagine an interface for fabrication that foregrounds the action of sculpting the material over the resulting form. Once activated, the system scans gestural movements for a short period (Figure 4). The user can then employ the same gestures as repetitive motions to produce an object. Rather than the hands moving to shape a malleable material, a material would move around the hands according to a digital model. For example, the system might record the gesture of a finger poke and then move a malleable form around the hand to produce an object textured by the poking movement. By moving bodies in a particular configuration, the system produces an intimate performance-lead production. In this scenario, the roles of human and machine are flipped as the machine takes on the more animated movements of humans and the human acts in the fashion of manufacturing machines. In light of this role reversal, one may be prompted to consider what it means to be skilled or deskilled and how this particular interaction reflects of broader notions of technology producing passivity.

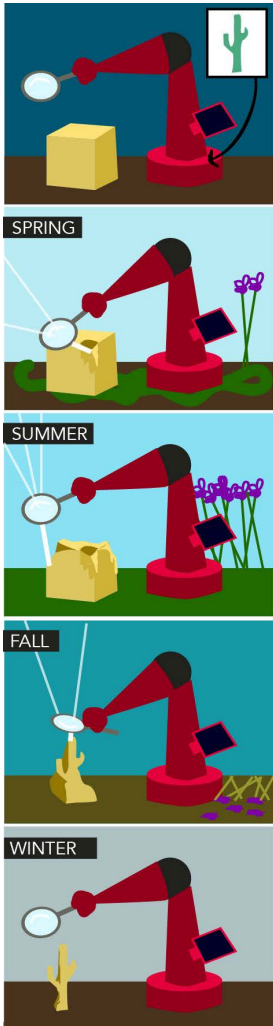


Figure 5: Melt: Exploring Decay as a Means for Subtractive Manufacturing.

## Decay

The celebration of cracks and decay emblematic of wabi sabi, the Japanese philosophy rooted in imperfection and transience, or Kintsugi, the art of fixing broken pots with gold dusted resin, fueled the work of Japanese painter Jiro Yoshihara. In 1956, Yoshihara developed the first Gutai Manifesto, which proclaimed his embracing of attrition and change: "Gutai art does not change the material but brings it to life. [... T]he novel beauty to be found in works of art and architecture of the past which have changed their appearance due to the damage of time or destruction by disasters in the course of the centuries. This is described as the beauty of decay, but is it not perhaps that beauty which material assumes when it is freed from artificial make-up and reveals its original characteristics?" [17]

### *Melt: Exploring Decay as a Means of Manufacturing*

Yoshihara and other artists active in the Gutai group viewed the process of decay as a material's life exposing itself. The artwork developed from an examination of the material and how it might call the material "to life" [17]. Accordingly, we imagined a fabrication system where environmental decay is the means for revealing computational models. The system would take a mass of raw material, like wax, and use a lens to focus the sun's rays to melt the wax in specific regions (Figure 5). Technically, the system could work much like Kayser's Solar Sinter [19], a site-specific 3D printer that uses desert sands as fabrication material. We envisioned our system operating slowly, revealing a single form over the course of the year or longer. The long-term production cycle and eventual decay of the form itself would frame the system as one of many animate objects within a garden or other natural setting. As one tends to their plants or passes by the system in the park each morning

on the way to work, one witnesses an object decaying into and out of form. While these interactions are more passive than engaging in making directly, they could foster reflection on the categories of 'artificial' and 'natural' and their relation in the printing process.

## Discussion

So far we have discussed examples of performance art as a means of bringing a reflexive perspective to HCI research on fabrication. On the one hand, we see the workings of performance art as advancing progressive and person-centered ideals through technology. On the other hand, we find material artifacts reveal themselves as not only discursive phenomena, but also a crucial means of recognizing performativity: characterizing the primacy of what they perform over what they materially produce. For digital fabrication, artifacts are not seen as stable entities but as (intra-)active forms always underway.

For HCI, this work points to two central implications. First, it suggests design opportunities by surfacing new forms of expressivity and engagement through fabrication. By foregrounded action (as opposed to object) as the locus of meaning we consider how histories, public spaces, time, environments, audiences, and gestures can be meaningfully enacted in fabrication activities. Second, we figure fabrication as a tool for social inquiry that extends and refocuses methods of research through design [3,36]. In particular, our design proposals begin to sketch out research programs for using design interventions to ask questions of the work of 'making' and restructure dominant theoretical frameworks in HCI.



This work presents a counter-narrative to systems that aim to work like magic and frame technology as a way to extend the technical reach of human abilities. Our examples are precisely concerned with *limitations* of materials, bodies, and conceptualize fabrication systems as a means of revealing, probing, questioning, and experiencing those boundaries in action. In this way, a performance art perspective on fabrication systems design offered an especially useful tool for understanding fabrication as a posthumanist endeavor.

Posthumanist perspectives argue against an essentialist view of life and its material instantiation. Beyond decentering the human, they trouble the “givenness” of an ontological separation of “human” and “nonhuman” by acknowledging the actions through which those categories get produced, legitimated, or undermined [2]. In the domain of material fabrication, a resulting object becomes a side effect of action, or what literary critic Katherine Hayles refers to as an, “accident of history” [14] The body and prosthesis are one and the same, and the intelligent machine extends this human body [14]. In the words of Katherine Hayles: “[...] my dream is a version of the posthuman that embraces the possibilities of information technologies without being seduced by fantasies of unlimited power and disembodied immortality, that recognizes and celebrates finitude as a condition of human being, and that understands human life is embedded in a material world of great complexity, one on which we depend for our continued survival.”

This paper has begun to take up Hayles’ vision in the domain of digital fabrication. We offered visions of fabrication activity that entangled categories of human and machine to reveal their material historicity. Moving forward, we hope these fabrication scenarios help us

reimagine the body’s active role in the workings of fabrication and account for the forms of power it enacts. Furthermore, we suggest that designs for ‘making’ can address a much broader set of concerns than what’s made.

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