Why Fabricate?

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Abstract
Starting with the assumption that humanities research frequently renders three-dimensional objects two-dimensional for the sake of reference and communication, this essay articulates four research areas where humanities practitioners may wish to fabricate tactile objects as part of their work: 1) data physicalization, 2) remaking old technologies, 3) cultural studies of negotiated endurance, and 4) infrastructure studies by way of shared social concerns (as opposed to shared technical specifications). These four research areas are anchored in ongoing examinations of both the technical and cultural dimensions of digital fabrication, including methods for additive and subtractive manufacturing.

Keywords
Fabricate; Data physicalization; Old technologies; Negotiated endurance

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In the following paragraphs, I provide several responses to a single question: why, if ever, should humanities scholars fabricate tactile objects as part of their research? Under the umbrella of fabrication I am including additive as well as subtractive manufacturing (e.g., three-dimensional printing and computer-aided milling, respectively). But before I proceed I should admit the above question is subtended by a rather fragile warrant, namely that – for the purposes of scholarly communication – humanities research frequently renders three-dimensional (3-D) objects two-dimensional (2-D). Books, buildings, sculptures, environments, and innumerable others are flattened in the interests of reference. They become texts without texture or substance without substrate. From this perspective, Nick Montfort's (2004) "Continuous Paper" and Matthew Kirschenbaum's (2008) application of it in *Mechanisms* no doubt inform my line of inquiry.[1] Both scholars underscore the prevalence of screen-based treatments of new media, such as electronic text, which are too often deemed immaterial phenomena without any depth (Kirschenbaum 2008, p. 32). This essentializing flatland, if you will, corresponds with several concerns I have about digital fabrication's conceptualization in the humanities.

First and foremost, I worry that techniques such as 3-D printing are mostly whiz-bang for humanities research. For many, this concern is probably obvious. Desktop 3-D printing thrives largely on its wow factor. Yet in reality, it may be nothing more than a gadgety glue gun tethered to a computer. Echoing Elizabeth Losh, scholars have many good reasons to be skeptical of gadgets. In "Ten Principles for a Hacktivist Pedagogy," Losh (2014) writes:

> The advent of cheaper gadgets, such as Raspberry Pi, to teach programming is certainly exciting. A computer smaller than a pack of cards where the chip and circuits are laid bare seems a liberating device in that it avoids the appearance of the consumer electronics industry and the slick blackboxed technologies that it mass-markets. Yet Raspberry Pi is also a gadget, and like all devices intended to make the evangelical mission of disseminating technoculture easier, there is a complicated history of One-Laptop-Per-Child thinking. (n. p.)

In this excerpt, you could easily replace "Raspberry Pi" and its specifications with "MakerBot" and its features, and the quibbles would hold.

Most important, Losh's awareness of the evangelical missions of popular maker culture strikes me as incredibly compelling. With Raspberry Pi, MakerBot, and other maker-targeted technologies, there is a rush to get the gadget and see what it can do, often without consideration of relevance. The means can determine the modes, and wow can eclipse why. True, desire and novelty always play a role in technocultures, yet ignoring their force risks bypassing their importance. As Wendy Chun (2005) suggests in "Did Somebody Say New Media?," when talking about technologies we must consider what enables desire and novelty, from cultural biases and ideological motivations to how we are "entangled" (p. 9) within the actualities and experiences of platforms. After all, these entanglements really matter for humanities research, especially when our budgets and infrastructures are limited. Such, then, is the antinomy at hand: experimenting with gadgets is a luxury few humanities practitioners can afford; however, experimentation

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is fundamental to researching beyond wow and whiz-bang. Emerging technologies should be neither dismissed nor adopted too quickly.

My second concern borrows from a long legacy of demystification in cultural studies: Whiz-bang aside, how well does a given fabrication machine actually work? Beyond the polish and allure of industry advertising, what is the maintenance involved? What are the demands on practitioner time, resources, and labour? Although I am not asserting that technologies should always be user-friendly or conducive to productivity, I am highlighting the risk of considering computer-aided manufacturing (CAM) a plug-and-play process. As Jonathan Sterne (2003) notes on various occasions, including several key moments in *The Audible Past*, machines routinely need help from their operators. All is never automated. This operator assistance did not cease with the gear mechanisms and hand-cranked technologies of yore. Fabrication machines, including 3-D printers and computer-aided routers, demand quite a bit of attention, from machine assembly and file processing to debugging and extruder cleaning. By extension, they raise numerous questions about waste and eco-critical uses of new technologies: How are fabrication materials sourced, by whom, for whom, and where? How can existing materials be reused, repurposed, or recycled? When is rapid prototyping too conducive to a "print now, think later" culture? And what should we do with failed prints and discards? For now, effect- or impact-oriented observations that digital fabrication could reduce waste should be balanced with an attention to the labour involved in maintenance and reuse. Prints do not happen auto-magically, and the machines do not support (let alone replicate) themselves.

Consequently, humanities practitioners interested in fabrication likely have much to learn from human-computer interaction and social computing scholars, such as Daniela K. Rosner (2014), Morgan G. Ames (2014), Stephen J. Jackson (2014), and Laewoo Kang (2014), who are collectively interested in maintenance and repair. For example, Rosner and Ames's (2014) notion of "negotiated endurance," or how the lifecycles of devices are negotiated over time (not somehow determined or prebaked into machines), may prove quite informative for laboratories, makerspaces, and research teams considering how to build and sustain scholarly infrastructures over time and across distances. As I suggest below, negotiated endurance prompts practitioners to complicate what I call the "make-break binary," where technologies are either new or obsolete, constructed or deconstructed, created or destroyed. Concepts and practices such as maintenance, care, negotiation, and even versioning, stress process over product as well as iteration over event, and they may also help us better address Debbie Chachra's (2015) concerns about the eclipsing of care in "Why I Am Not a Maker." In the humanities, the maintenance and care of projects are usually performed in the labs, libraries, offices, and centres central to our research yet so difficult to trace through our publications and other scholarly communications. This everyday labour is rarely recognized (let alone considered scholarship), and it is increasingly integrated into contingent positions, with – for one example among many – the percentage of part-time modern language faculty increasing from 22.2 percent in 1970 to 50 percent in 2011 (MLA, 2014).

Finally, my third and fourth concerns more or less assume an awareness of the first two (i.e., techno-evangelism and maintenance): To what degree is fabrication actually relevant to research in the humanities? And what should humanities scholars know in order to fabricate persuasively? In "Dear Academy: Where's the Fab?" Katherine Goertz and Danielle Morgan (2014) of the Maker Lab in the Humanities at the University of Victoria share an environmental scan of digital fabrication research happening on campuses across Canada and the United States. From that scan, they learned that arguably no computer-aided manufacturing (CAM) research space in those two countries is based in the humanities.[2] This observation suggests at least two things: that digital fabrication is not, in fact, relevant to humanities research, and that, even if it is relevant, humanities scholars do not have the requisite training for it. Before we accept either possibility, more research might be conducted on when and why humanities work insists on studying its primary sources in a 3-D state. Or, to frame this claim as a series of questions: When does scholarship most effectively resist a flatland for reference and communication? For which methodologies do tactility and texture especially matter? When are screen-based examinations of media clearly insufficient? When is scholarly communication most persuasive off the screen?

Once these methodologies and research areas are identified, a humanities survey of how digital fabrication happens across machines and sites may be in order. Although additive manufacturing via desktop 3-D printers is most often the subject of popular media, those popular representations only scratch the surface of how fabrication actually happens. Or they mystify the processes, not to mention the maintenance and materials, at work in computer-aided manufacturing. Not only do the machines and techniques vary widely; the substances do, too. In short, for most research projects (not to mention industry or private sector initiatives), digital fabrication involves far more than a MakerBot, some PLA or ABS plastic, and downloading STL files from Thingiverse. Significant infrastructure, training, trial-and-error experimentation, and post-production (including manual labour) are involved.

If humanities researchers are interested in more than a MakerBot, then they may wish to learn from, support, and collaborate with existing scholars of digital fabrication, including practitioners in design, engineering, sculpture, and architecture who work in makerspaces both on and off academic campuses. These sorts of cross-disciplinary partnerships may allow curious researchers to better identify what (if any) fabrication techniques are both relevant and feasible for their research and to then proceed accordingly, articulating their research or research-creation aims with the infrastructures and technocultures they want to see in the world. In the humanities, we already have several examples of this work being done by Kari Kraus (2011), Kim A. Knight (2011), Bethany Nowviskie (2013), and William J. Turkel (2005), among others.

With these concerns in mind, below are some very brief responses to my initial question: *why, if ever, should humanities practitioners fabricate tactile objects as part of their research?* Two responses are about methods. Another is about rhetoric, ontology, epistemology, and materials design. And the last one is about infrastructure and collaboration. To be sure, the list is far from complete, and it will not appeal to all areas of humanities research, especially since digital fabrication does not appeal to all areas of humanities research. Still, I offer these responses as potential areas for future work.

Data phys

At dataphys.org, Pierre Dragicevic and Yvonne Jansen (2014) have compiled a list of over 180 "data physicalizations." Well over a majority of them are dated 2000 or after, and each entry is categorized (e.g., "passive physical visualization") and tagged (e.g., "3-D printing," "paper," "knitting," and "arduino"). Even if data phys – like data viz – is not new, it is being remediated in striking ways through algorithms, physical computing, and real-time data gathering techniques. At first glance, this remediation may be reduced to mere re-presentation: whatever is on screen is now in hand, on the wall, or the like. As such, researchers might be inclined to compare data phys to printing a Word document or spreadsheet. However, the humanities may learn a significant amount about transmedia design by constructing or gathering data intended explicitly for tactile interaction, to not only stress the limits of the screen but also develop projects for public display and interaction. David J. Staley's (2013) *FHQ III* is one example of such work, which operates across history and design. Recent research by the Data Viz Experiments group (2014-2015), including Leanne Elias and Denton Fredrickson, at the University of Lethbridge is also compelling. This research brings data off the screen, into the everyday places people inhabit, often with contemporary social and cultural issues in mind.

With data phys we may ask when "humanities data" should be situated in a specific place and time, when algorithms need texture, or when people need a tactile snapshot of real-time culture, which moves quickly, just out of reach. True, such questions are largely about data aesthetics and data rhetoric, but both of these areas (though often marginalized in the humanities) matter when making arguments about how literature, language, history, and culture are experienced and embodied today. What is more, they could make the often abstract and overwhelming aspects of data visualization more tangible for interpretation, not to mention more accessible by a broad range of audiences. For instance, in some cases data physicalizations may be more legible than screen-based data visualizations, especially dynamic data visualizations that express a lot information in a small amount of space. They may also be conducive to universal or inclusive design in data-oriented fields, and (as demonstrated by David J. Staley [2013] as well as Data Viz Experiments at Lethbridge) they may spark experimental articulations of arts, humanities, and science research that do not assume data's sole function is to prove or rationalize something. Indeed, by shifting the interface from a screen to a geographic site of installation, physicalizations may exhibit data's cultural function – how it works, how it behaves, what it affords, where it begins, where it ends, and how it prompts interactions – across the disciplines. On this topic, recent writing by Wendy Chun (2011), Alexander Galloway (2012), and McKenzie Wark (2015) is informative. While these three authors do not interpret interfaces under the same assumptions, they all point readers to how visualizations are value-laden and entangled in culture as instruments, allegories, and labour, respectively.

Remaking old technologies

Material culture studies, as well as media, science, and technology studies, are rife with scholarship on how this became that (e.g., how sounds were inscribed onto wax). Rarely, if ever, does this scholarship naively assume that we can reproduce history exactly as it was then. It also tends to avoid the vulgar reduction of technologies to their physical particulars. Instead, it may be about what we do not know or cannot access. For example, when an old technology is neither in the archive nor ready to hand, how do we learn how it was manufactured? How and by whom it was used? How and for whom it failed? How and under what assumptions it was deemed obsolete and discarded? Digital fabrication may help researchers address questions such as these, even if the answers will never be certain. Not only do additive and subtractive manufacturing facilitate the construction of old technologies across digital and analogue materials; they also facilitate thinking through primary objects of historical study. They are at once means and modes.

Informed especially by Devon Elliott, Robert MacDougall, and William J. Turkel in "New Old Things" (2012), which argues for remixing history through physical computing and fabrication, I have written elsewhere about the relevance of "remaking" media and technologies (Sayers, 2014). Here, I simply want to emphasize that fabricating historical artefacts in the present affords an awareness of transduction in the past, especially when those artefacts are not accessible (e.g., they cannot be viewed, heard, handled, or digitized). As a technique, remaking usually requires deconstructing or exploding objects into their component parts, as well as examining documentation such as laboratory notebooks, patents, and photographs. The workflow includes 3-D scanning, modelling, editing, fabricating, assembling, finishing, and then distributing objects both online and off. Conducting this research in 3-D – with tactile media fabricated in materials such as wood, acrylic, metal, paper, and plastic – gives researchers a sense of what is lost and gained by any flattening, either onto a screen or into text, images, or a series of surfaces. Research in 3-D also expands how primary objects can be perceived, allowing researchers to stitch together evidence into historically unique models and prototypes.

But to reiterate, the gesture toward digital fabrication need not fall back on claims for authenticity, such as: "3-D representation is more like being there. It is closer to real history. It is a perfect replica." Instead, digitizing, modelling, and fabricating the component parts of the past multiply – and thus complicate and enrich – how scholars interpret history with technologies as technologies become available. Put this way, increasing the presence of digital fabrication beyond science and engineering raises some exciting possibilities for modelling and prototyping the past.

Negotiated endurance: Beyond make and break

With the material turn in media studies (see especially Kirschenbaum, 2008), much has now been written about how the digital is also physical. It is stored somewhere, it degrades and rots, it is intertwined with actuality, and it is embodied. In many ways, digital fabrication foregrounds these claims, or – better yet – it exhibits a sort of digital/analogue convergence. Scholars such as Neil Gershenfeld (2005) and Steven E. Jones (2014) have written rather extensively about this convergence. Borrowing from the work of William Gibson, Jones details the "eversion," where the Internet is turned inside out. It is no longer virtual or elsewhere; it is distributed across programmable environments. Meanwhile, Gershenfeld writes about student theses at the Massachusetts Institute of Technology (MIT) as both bits and atoms. They are computer files that should also walk out of 3-D printers. However this convergence is articulated or exemplified, the processes of digital fabrication demonstrate how media are in constant iteration, undergoing shifts from objects in hand (e.g., as wood or metal) to objects on screen (e.g., G-code in one window, and an OBJ file in another) to objects in hand again (e.g., as acrylic or foam). Here, the variability of Lev Manovich's new media (2001) is instantiated in ways he may not have anticipated during the early 2000s. It complicates neat distinctions between analogue, digital, print, electronic, static, and dynamic. Through a paradigm of variability, we may look for stress points along a continuum of material change, or points where remaking, remediating, repurposing, modifying, altering, layering, repairing, warping, morphing, transforming, versioning, or bending occur. Taken together, these stress points highlight the negotiated endurance of material culture: how, to be clear, the lifecycles of materials are negotiated over time, not somehow determined or prebaked into machines. To reiterate a previously made point, this negotiated endurance is seemingly resistant, if not antithetical, to a make-break binary, where technologies are either new or obsolete, constructed or deconstructed, created or destroyed.

While negotiated endurance is less conducive than the make-break binary to grand narratives of creation and disruption, it best reflects the actualities of our platforms and their persistence over time. It is also not unique to digital fabrication. Still, digital fabrication lends itself to studying such continuum-based ontologies and epistemologies, especially if they are situated in the context of prototyping. Borrowing for a moment from the work of Alan Galey and Stan Ruecker (2010), with a given prototype we can ask whether there is an identifiable trajectory across a recognizable continuum of material change, and if so, what it is. By treating objects as processes, trajectory identification can help practitioners better understand how those objects express arguments, correspond with specific labour practices, solidify biases over time, and ultimately favour certain interactions. In the case of digital fabrication and prototyping, some working knowledge of materials design is central to this identification and can also enrich an awareness of how historical artefacts were sourced, developed, and discarded. Perhaps most important, materials design beyond the make-break binary can work to unravel the cultural implications of a now ubiquitous twist on the material turn: that, since the physical world is now programmable, its common substrate is code, which is easy to manipulate and control.

Critiques of this twist might be most persuasive when done immanently, that is, through (rather than about) digital fabrication techniques. Returning for a moment to Elizabeth Losh's remarks about gadgets: composing scholarship through emerging technologies may give researchers the best sense of whether those technologies warrant enthusiasm, skepticism, or – most likely – something in between. Where digital fabrication is concerned, experience with 3-D models as both code and tactile objects fosters an awareness of what Bethany Nowviskie (2013), by way of William Morris, calls "resistance in the materials" (n.p.). Even if more materials are becoming programmable today, they are not becoming so without friction. Often, a fabricated object does not manifest exactly as it appears on screen. Hiccups occur in the machine, the additive material does not stick to the printer bed, the subtractive material burns or splinters, or component parts cannot be assembled as planned. With digital fabrication, turning this into that is indeed a process of iterative change and constant negotiation, which is never reducible to code in the last instance.

From shared specifications to shared concerns

Maintained by MIT's Center for Bits and Atoms (n.d.), the open Fab Lab hardware specification[3] has been crucial to the development of digital fabrication research across the world. Tested, annotated, and routinely revised, this inventory gives practitioners a shared infrastructure, which is especially useful for people who are new to digital fabrication and want to start their own fab labs. Although the existence of – and perhaps interest in – fab labs in the arts and humanities across North America remains rare, the very idea of shared infrastructure may nudge those of us in humanities labs and centres to speak more openly about the physical composition and everyday practices of our research spaces, not to standardize them, but rather to discuss how infrastructure shapes our habits and values. In media studies, models for this sort of inquiry already exist, and they are explained in collections such as *Signal Traffic: Critical Studies of Media Infrastructures*, edited by Lisa Parks and Nicole Starosielski (2015). But researchers can also draw from personal experience. For example, while conducting my own fabrication work, I have determined that collaborating with visual artists, especially artists with experience in sculpture, is an absolute necessity. Not only are visual artists well versed in the transduction of materials; they are also knowledgeable about the features, aesthetics, interoperability, maintenance, and exhibition of those materials. Each of these areas is largely unfamiliar territory to me; however, I am learning more about them through collaboration based in shared infrastructure: how we use the same machines similarly and differently, and how those uses resonate and diverge from uses by fellow researchers in other settings and disciplines.

Framed as such, digital fabrication infrastructures are tangible opportunities to spark conversations about the social relations at play in our research settings. These infrastructures are not merely things, and they are not simply means, either. They are processes shaping the commonalities and boundaries of research practices as work. Discussions about infrastructure may not be anchored in wow or whiz-bang, and their focus may be the quotidian. But the banal character of infrastructure is a productive site for grounding comparative analyses, including analyses across disciplines. It is also a starting point for transitioning from shared specifications, such as the Fab Lab hardware specification, into what we might call "shared concerns," or the social and cultural matters that, in this case, are intertwined with matters of hardware and other technologies.[4]

On this topic, Miriam Posner (2014) has written about committing to digital humanities people (not just digital humanities projects), with "a long-term investment in scholarly growth" (n. p.). Elsewhere, in *Digital Humanities in the Anthropocene,* Bethany Nowviskie (2014) asserts: "We need systems of reward that don't just value the new, but find nobility in activities like metadata enhancement, project maintenance, and forward migration—and therefore prompt us to attend to the working conditions of our colleagues in cultural heritage institutions and those who steward DH software and systems" (n. p.). These two positions stress how entangled practitioners are with their technologies and systems, and they also point to quotidian work that is all too often ignored, buried somewhere in a change log or notebook. True, this entanglement and this work are not at all unique to digital fabrication. Yet, given its nascent state in the arts and humanities, not to mention the fact that physical computing and fabrication research are often invested in "open-source hardware" (i.e., rendering the design information of objects and systems publicly available for reuse and modification), digital fabrication is an area where humanities practitioners could contribute examples of experimental approaches steeped in values design. Among these values could be considerations of how to steward fabrication systems, source and care for projects, collaborate around CAM technologies across disciplines, test prototypes, share metadata and models, and – echoing Posner and Nowviskie – understand infrastructure as a way to commit to shared concerns, including the working conditions and scholarly growth we want to endure in our research settings.

Even if fabricating tactile objects is about adding depth to the flatland of scholarly communication, it need not be object-oriented. It can account for the various agents, relations, and conditions involved in turning this into that.

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Notes

1. In "Continuous Paper," Montfort (2004) writes:

   > By looking back to early new media and examining the role of paper (in both punning senses) we can correct the 'screen essentialist' assumption about computing and understand better the materiality of the computer text. While our understanding of 'materiality' may not be limited to the physical substance on which the text appears, that substance is certainly part of a work's material nature, so it makes sense to comment on that substance. (n. p.)

   Building explicitly on Montfort's work, Kirschenbaum (2008) argues the following in Mechanisms:

   > Nick Montfort has coined the term 'screen essentialism' to refer to the prevailing bias in new media studies toward display technologies that would have been unknown to most computer users before the mid-1970s (the teletype being the then-dominant output device). One result, as Montfort discusses, is that an essential dimension of the materiality of early electronic literary productions like ELIZA and ADVENTURE is elided, since these works were historically experienced as printed texts on rolls of paper rather than as characters on video screens. Thus one does not always need to look at screens to study new media, or to learn useful things about the textual practices that accumulate in and around computation. (p. 31)

2. Goertz and Morgan conducted this scan as researchers for the Maker Lab in the Humanities at the University of Victoria. The results of their scan supported arguments for the University's new Digital Fabrication Lab (DFL), a partnership

between the departments of English and Visual Arts. The DFL is arguably the first fabrication lab in North America that is based in the humanities. In the interests of transparency, I should note that I direct both the Maker Lab and the DFL.

3. URL: http://fab.cba.mit.edu/about/fab/inv.html.

4. For more on shared concerns, or "matters of concern," see Latour (2004). For more on the relevance of shared concerns to fabrication and making, see Ratto (2011). For more on the entanglement of matter and meaning, see Barad (2007).

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