Unmaking Digital Fabrication using Glitch and Upcycling

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Abstract

As physical objects change over time, they begin to need to be repaired, altered, augmented, re-designed, embellished, or otherwise unmade. However, many current fabrication systems "black-box" their processes and results, and in doing so, undermine a user's ability to make such changes after initial production. We argue for interaction techniques that support inventive repair around fabrication processes. We introduce two artifacts—*Glitch Gloves* and *IoT Stickers*—that illustrate destruction, modification, and reconfiguration in fabrication. We use these artifacts to raise questions for an inventive repair research agenda.

Introduction

A right to repair movement is on the rise as computing has entered everyday objects and begun to shape a new reality. Consumers are expressing concern that recent innovations—such as those encapsulated in the Internet of Things—undermine their ability to investigate, repair, and modify their own possessions such as cars, voice assistants, or phones [15]. This black-boxing of everyday objects frustrates a person's agency and ability to exercise control over their property, and displaces that person's skilled work and embodied knowledge.

If the right to repair is to be supported, computationally designed and fabricated objects must support the repair, deconstruction, and improvement that are the hallmarks of craft and artisanal processes [12, 21]. Folk modifications and embellishments are widely done for the sake of sustainability, adding value, or just plain enjoyment. For example, many craft processes have evolved from mending processes—for example, embroidery and appliqué have clear lineages from darning, reinforcing, and patching. Repair is less present in digital fabrication. Instead, it often strives to emulate a science fictional matter replicator: creating something from nothing; producing a whole-cloth object where previously none existed. This approach assumes the inputs to the system are predictable and uncomplicated, and the outputs are

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```
for (var f = 0; f<numFingers; f++) {
  var fingerWidth = randomBetween(widthMin, widthMax);
  var fingerHeight = randomBetween(heightMin, heightMax);
  if (f>0 && Math.random() < thumbChance)
    glove = addThumb(glove, fingerWidth, fingerHeight, yarn);
  }
  else {
    glove = addFinger(glove, fingerWidth, fingerHeight, yarn);
  }
}
glove = addCuff(glove, yarn);
```

Figure 1: Glitch gloves and the central logic loop to construct them.

interchangeable—it's easier to print another than to modify what is made. These assumptions fail to address varying contextual needs over an object's lifespan and prevent the user from engaging creatively with fabrication as part of a cyclic or ongoing process.

We call this creative engagement process *inventive repair*. To illustrate how fabrication might better support inventive repair, we describe two artifacts that make use of glitch and upcyling to realize alternative ways of computationally designing and fabricating objects.

Related Work

We provide a brief review of related work on embodied fabrication and unmaking.

Commitment in Destruction

Patterns of interaction manifest on existing physical objects as damage or wear; patterns of intent manifest in new physical objects as the embodied knowledge of their creator[12]. When direct manipulation was introduced as an interaction paradigm, it allowed the object of a user's interest and its responses to be continuously visible [12, 18]. Interaction techniques that couple a system's output to the user's actions commit the user to a course of action [10, 16]. For example, "destructive games" incur irreversible physical damage during gameplay [8]. Furthering user control over destructive processes, FreeD is a purely subtractive tool that allows the user to override the system to remove extra material [23].

Making Fabrication Hands On by Modifying Existing Objects

Craft approaches to fabrication introduce a human in the loop to shape outcomes according a desired aesthetic and to enable embodied engagement with the creation and construction process. For example, drafting techniques were inserted into a lasercutting process to create a closer coupling between drawing and shape creation [14]. Augmenting and modifying existing objects has been explored in processes of patching [20] and embedding [5, 17]. Hands-on fabrication and remixing of modular embellishments has been further investigated using sticker sets to construct circuitry on the fly [9, 22]. Central to these approaches is a desire to unmake manufacturing processes to insert a person's inventive hand.

Inventive Repair

Repairing black-boxed systems has become a site of invention and ingenuity. Caught in a *control paradox* over their home network in which families increasingly feel their control erode as the network's complexity grows, a set of *Digital-Do-It-Yourselfers* has emerged who approach their home network as an ongoing project and recreational learning opportunity in an attempt to regain control over its configuration [4, 6, 13]. This has never been more present than when the online retailer Amazon released a set of web-enabled buttons (the "Dash Button") that automate home purchasing of consumer goods with a commercial depicting "the dream of domestic life as a perfectly calibrated, automated system" [7]. In reaction, a burgeoning online community developed around hacking the button to subvert it for their own purposes [3]. In the initial Dash Button hack, a parent widely publicized his methods to redirect the

Figure 2: IoT Stickers support upcycling everyday objects with computing capabilities by attaching stickers.

button's automated logging to record his child's developmental markers [3]. Indeed, Do-It-Yourself approaches may offer end users greater discretion and control over how new technologies are woven into their lives and relationships [2, 4]. Far from viewing this work as a burden, opportunities for unmaking black-boxed systems may support creative repair of misguided designs.

Unmaking Artifacts

Glitched Gloves

Glitch is a process of interrogating a system by introducing errors—selective destruction can surface the underlying logic of a system by pushing it just past the edge of its expected use without disintegrating it completely [11]. In this project, a Knitout [1] algorithm is written to carefully replicate the logic of an industrial glove-knitting program which would typically produce very inexpensive mass-market gloves. However, the Knitout version of the code is structured in clear modules such as "addThumb()" so that it can be easily modified to create an arbitrary glove. Instead of running this algorithm with the usual inputs—four fingers of normal lengths and widths, and a thumb to match—it is randomized and biased to produce more than the usual number of fingers and thumbs, Fig. 1. The resulting objects would *need* to be heavily modified to return to usability, but the design (more than enough fingers) leaves open this possibility.

Upcycling with Stickers

Objects may be given a second life through a process of upcycling, wherein they are converted into an object of greater value or quality [19]. IoT Stickers is a project that introduces computing artifacts into the environment by enabling a person to modify their everyday objects by attaching stickers to them. In a participatory design study working with 10 households over the course of 7 days, we found that new computing artifacts pose costs beyond financial investment. For example, our participants used objects to negotiate their relationships with others, to experiment with material and social constraints, and to make progress on their aspirational home. At times, participants were wary of the disruptive costs of new computing capabilities such as displacing their routines, discarding perfectly functioning items, or rendering their current skill sets obsolete. In response to these findings, IoT Stickers is designed to support users in upcycling their existing objects to gain control over which object properties will be modified, and thus how disruptive the modification will be.

By upcycling a social group's existing objects, IoT Stickers supports group members in reconfiguring social roles and challenging shared norms. By augmenting existing objects that are entrenched in group norms, upcycling can support group members in stretching their expectations and experimenting with alternative social dynamics through reconfiguring the shared object itself. We are currently designing the IoT Sticker set to support user reflection on the group dynamics around shared objects. During this upcycling process, IoT Stickers scaffolds considerations of what to discard and displace as well as what to augment and enhance. In doing so, IoT Stickers helps groups craft new dynamics and repair past breakdowns inherited from historical norms.

Implications for Inventive Repair

Glitch and upcycling show ways that fabrication tools and processes can support inventive repair by allowing uncertain intervention and by supporting modular reconfiguration of ill-fitting design norms.

- **Critiquing Normative Assumptions** Fabrication models make assumptions about the world that may not hold in fact. Inventive repair provides an avenue for users to augment and modify these assumptions to adjust the models to their context. How do we develop a craft approach to fabrication in support of incremental and sustainable change from uncertain inputs?
- **Agency and the Ability to Repair** As needs change, people must be able to modify their built environment. Taking cues from the ideas of "right to repair," we insist that it must both be *possible* to modify a production system as well as *discoverable*. Seamful design can help users discover axes of modification in a system, and possibly result in takeaways/lessons for other systems. How can we incorporate ideas from "the right to repair" into tools/systems design, not just end objects?
- **Process and Joy** Going beyond "possible" and "discoverable," the flexibility and modifiability of fabrication systems might even be designed to foreground the ongoing process of making and re-making. For example, a fabrication system might be *playful*—that is: primarily emphasizing exploration and enjoyment, and only secondarily promoting specific outcomes. How do we build tools that support the lifespans of physical objects as ongoing, re-visitable processes, with their own emotional and experiential states, not just as end results?

Conclusion

We make a case for unmaking digital fabrication using techniques of inventive repair. We illustrate example techniques of this sort using glitch and upcycling in our projects *Glitch Gloves* and *IoT Stickers*. These artifacts raise questions for how inventive impair techniques could be incorporated in the fabrication pipeline. Specifically, they show how such techniques could be incorporated at various points in the design and fabrication process, either at fabrication time or by leaving artifacts necessarily incomplete to await the owner's intervening hand. We outline several questions for inventive repair work going forward.

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