Being the Machine: Exploring New Modes of Making

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Abstract
As making with digital fabricators becomes pervasive it is important to consider how the design of these technologies can suit the desires of diverse audiences. This paper presents two interactive craft activities where the actions of the user mimic the actions of algorithms that underlie digital fabrication technologies. Users are invited to perform the part of the making machine as they construct objects using everyday materials. In addition to suggesting new modes of making, interacting in this way may also provide closer and personally relevant understandings of the technologies and processes of digital fabrication.

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Computer-aided Design; Fabrication; Craft.

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
In 2005, Neil Gershenfeld wrote of the "coming revolution on your desktop" and made a claim that personal fabricators will become as commonplace as desktop printers [6]. This proclamation and growing enthusiasm for DIY making has piqued the interest of educators as a powerful way to support active,

Figure 1. G-Cake is an interactive application that uses 3D printing as a model for cake decoration

Figure 1. Mesh Mash is an application for making triangle meshes from everyday materials, such as balloons

hands-on learning approaches in and out of classrooms [2,4]. As making with digital fabricators becomes ubiquitous in culture and education, it is important to consider how designers can create technologies that support multiple pathways to entry into this promising future. This paper suggests a new mode of making that connects arts and crafts with the fundamental algorithms that underlie digital fabrication technology.

We present two design sketches, *G-Cake* and *Mesh Mash* in order to illustrate ways in which processes of making can be informed by algorithmic rules that are not explicitly specified by the user. Both designs are inspired by contemporary artworks that question the relationship between body and machine such as Janine Antoni's, *Slumber* [1]. G-Cake prompts a user to act like a 3D printer in producing cake decorations. Mesh Mash guides users through a process of combining found objects into physical instantiations of digital meshes. In both cases, we make an argument that mimicking machine processes allows for better understandings of those processes as well as opportunities to explore the environment and repurpose everyday materials in new and imaginative constructions.

Our intent is not to guide users along a fixed tutorial of how to build a given item. Rather, we aim to offer a closer and personal connection to processes that inform construction with digital fabricators in general. Papert uses the term "syntonic" to describe types of learning that connect abstract concepts to concrete experiences in the bodies and minds of individuals [8]. By physically performing the steps of an algorithm with everyday materials, we invite users to form tangible connections between the "needs" of a machine (paths, resources, etc.) and their own design needs (good resolution, structural stability, etc.).

The nature of the constraints in the system distinguishes this approach from other projects that combine computation and handcraft. FreeD is a project that explores a hybrid approach to combining physical and digital modes of production by using digital models to inform feedback on a hand-controlled milling machine [9]. In FreeD, the motions of the maker's hand remain relatively unconstrained, as she is free to choose her own paths. In G-Cake and Mesh Mash, the maker acts as a physical extension of an algorithm, performing actions in a way that a machine would. Additionally, in FreeD the computer intervenes when a potential mistake is going to be made. We see errors as an integral part of the learning process as well as a catalyst for creativity. Repair can be a productive aspect of the design process as a flaw in the model may give rise to creative design ideas [7]. Our previous work with AnyType also revealed ways in which challenge could provoke users to creatively appropriate everyday objects to fit their design objectives [3].

G-Cake

While humans might think of an object like a house in logical units (e.g. planar walls and a roof) 3D printers assemble a house by slicing it into layers and "drawing" it layer by layer. G-Cake looks to guide a user in conceptualizing models as layered slices by guiding their hand along the G-Code paths a 3D printer head would take.

Interaction with G-Cake begins with an individual constructing a 3D print model using any CAD application or downloading one from an online

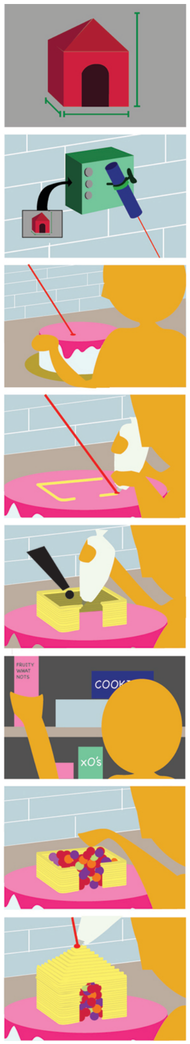

Figure 3. This storyboard depicts the process of interacting with G-Cake.

collection like thingaverse.com. The user sends the model to a networked laser guide with 2-axis and can physically "calibrate" the position of the laser by moving the cake. Once positioned correctly, the user presses a "Go" button follows with a tube of frosting in hand, laying down the first layer of her 3D print decoration. The user hits "Next" to advance the program and update the path for the next layer. As the process continues, the user might confront one of the following problems. First, she could realize that her model uses too much frosting (i.e. her model is solid) and might opt to redesign the model to use less material (i.e. make it hollow). Second, she might come to a place where her model needs scaffolding in order to remain structurally sound. In this case, the user can hunt around her environment in search the ideal scaffolding material to support her construction. Once her model is complete, she can decorate it with other food objects or add candles, give it as a gift or impressing friends with her new sculptural cake decorations. While this example uses frosting, many other materials that could be arranged along a layered path would work, like gumdrops, licorice ropes, bubble tape, or spaghetti, which leads to a great variety of possible outcomes and flavor profiles.

This process has opportunities for users to form personal connections with various aspects of 3D printing. First, they gain a physical, body syntonic, understanding of layered printing method that may improve the way they create models for printing. Second, they gain insights into resource demands in printing, something they might not get from sending a model to thingaverse.com to print. Third, as they experiment with different materials, they may explore the idea of "resolution" of a printer. For example, they may discover that a small thin material yields a more contoured model than one using thick tubes of frosting.

Mesh Mash

Meshing algorithms are central to 3D modeling, as they are responsible for connecting a set of points into an accurate 3D representation of an object. Knowledge of meshing algorithms is generally limited to computational geometers and computer graphics practitioners but the visual appeal created through meshing is gaining prominence in art and design as evidenced in many alternative mesh creation approaches [5]. This project looks to connect users to these beautiful algorithms by letting them manually construct objects in a mesh, triangle by triangle.

The storyboard on the next page depicts the process of interacting with *Mesh Mash*. Like G-Cake, interaction begins when a user constructs or imports a 3D model into the Mesh Mash application on their laptop or mobile device. The software internally converts the model into a Delaunay surface mesh and prompts the user to find a set of objects that vary by length to use as "edges" in the mesh. The user can explore her environment for such objects and choose to use a specific type of object (like the balloons tied to different lengths in the example) or a heterogeneous mix of objects. The interface asks the user to layout all objects in a specific orientation, organized by length, in order to ease construction and give an opportunity for the user to reflect on the number of objects and relative sizes of the pieces needed to make her model. This allows her to change their model before she gets too deep into building. The software then shows her the pieces to connect, triangle-by-triangle, until her model is complete. The method of joining pieces is left up to

Figure 2. This storyboard depicts the process of interacting with Mesh Mash

the user to make the best of with their resources. As the user attaches triangles to the model, the on screen model continually updates to match the progress of the user and allows for rotation and adjustments to ease a model.

In Mesh Mash, users gain first hand understandings of mesh structures and the way in which different materials interact in a structure. They might find that rigid materials (like branches) create better structures but require additional accuracy in joinery and edge lengths to produce well-formed closed models. Additionally, in playing with the properties of materials, they may arrive at unexpected configurations and new ideas. For instance, a mesh made of string can become a new and interesting wearable when placed over the body and animated with the arms.

Conclusion
Typical accounts of CAD place the software in a servile relationship to the user. The user tells the software to "do" something using automated actions or writing code to specify particular paths to explore. Making the user to *play* the role of algorithm, taking orders from machines, may provide a guided experience that encourages individuals to break out of their existing ways of thinking and doing by constraining them to construct based on simple and specific rules. While the hand is constrained the choice of materials is not. As common materials are connected into uncommon arrangements users will find that each material lends its own characteristic voice to the resulting artifact, influencing how both the creator and audience might relate to it and what they might read from it. This shift could be influential in supporting makers who may be less interested in thinking about *what* can be made and more concerned with *why* we make and *what meaning* digital fabricated objects carry.

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