GripFab: Summer Research Experience at UMBC

Megan Hofmann
Colorado State University
hofmann.megan@gmail.com

Dr. Amy Hurst
University of Maryland,
Baltimore County

Erin Buehler
University of Maryland,
Baltimore County

ABSTRACT

The influx of consumer-grade 3D printers has changed the potential user base for computer-aided drafting (CAD) software. No longer are 3D models solely the work of engineers and animators. We now see hobbyists, educators, and even children generating 3D-printed objects, however, there is a significant skill gap between the novice 3D printer user and the expert designer. Filling that gap is a growing number of novice-targeted software tools. This study presents one such tool targeted to a specific subset of novice users: occupational therapists. GripFab is 3D modeling software that automates the generation of 3D-printed assistive hand grips to aid in the use of everyday objects such as styluses, art supplies, and eating utensils. We developed the GripFab prototype in collaboration with several Physical and Occupational therapists who serve students with motor impairments at a high school. In this paper, we describe the motivation for a specialized tool, the development and testing of GripFab with therapists, and future work and considerations for similar design software.

INTRODUCTION

The rising use of 3D printers in homes and schools has brought hobbyists, educators, and children to the three-dimensional design space. These new users frequently lack the advanced design skills that those familiar with computer-aided drafting (CAD) software have acquired with years of training and practice. There is a growing body of tools targeted specifically for novice users; however, these tools frequently lack the features or intuitive affordances necessary for a novice to create practical, novel designs. Our study explores the creation of a highly targeted tool designed for occupational therapists (OTs) using 3D printers.

As part of a 9-month long study exploring 3D printing at a special education school, we identified several opportunities for the use of 3D printed objects as both learning aids and assistive devices. Assistive devices are often costly, limited in selection, and lacking in customization. In some cases, these problems can be mitigated with 3D printing which offers the ability to generate low-cost, durable, and highly customized solutions to accessibility issues. Our initial interviews with faculty and support staff at this investigation site uncovered one such assistive design project. We worked in collaboration with two onsite occupational therapists in the creation of a customized stylus grip for a student with limited hand mobility. The OTs had already tested a variety of ergonomic styluses and pencil grips, but they found that the

Figure 1. A 3D printed assistive hand grip for a spoon.

student continued to struggle with writing and accessing items on touchscreens. After multiple rounds of prototyping and revision, we were able to create a 3D-printed hand grip that could accommodate styluses and pens, allowing the student to write and utilize touchscreens with less fatigue. This initial case study served as the motivation to create an automated design tool that would allow therapists to create custom 3D printed hand grips without any CAD training.

The resulting tool, named “GripFab”, is described in this paper. We will first discuss relevant work in 3D modeling for novices and 3D printing assistive or therapeutic devices. Next, we list the specifications unique to this software with respect to the end-users and the objects generated. We will describe the prototyping and design process involved in the tool’s development. Finally, we present the feedback offered by the therapists, planned features and modifications for future iterations of GripFab, and considerations for the design of similar highly customized design tools for novice 3D designers.

GRIPFAB DESIGN AND DEVELOPMENT

After a long-term study at a special education school, we identified a need for a 3D printed intervention for an accessibility problem. The resulting collaboration with occupational therapists to design that solution in combination with interviews and observations led us to the development for a design tool for the therapists at our investigation site. We will discuss the motivation for this tool briefly before elaborating on the software design process.

Motivation

We conducted interviews and observations at a special education facility over the course of 9-months. The goal of the initial research was to explore the applications of and obstacles to 3D printing in special education. Among those interviewed were two onsite occupational therapists who thought 3D printing might help them with an accessible technology problem. The OTs had been trying to find the right ergonomic grip set up for a student with a hand mobility impairment. Having already purchased and tested several products, the OTs state that the student still had difficulty grasping styluses and pencils which led to hand fatigue.

For two months we worked closely with the OTs to help model a custom hand grip solution for this student. The OTs made several clay impressions of the student's natural hand grip which we scanned and converted into a smoothed 3D model using a Makerbot Digitizer[4] and two novice 3D design tools, Tinkercad and MeshMixer[5]. We then returned the printed grip to the therapists for user testing. The OTs identified changes necessary to make the grip more comfortable and to accommodate a change in the student's stylus type, so the process of clay models and digital refinement was iterated two more times before arriving at a satisfactory grip.

Even though the tools involved were open source and largely targeted to novice 3D designers, the therapists did not feel comfortable creating the hand grip themselves. The primary concerns the OTs had were time and training. They perceived 3D modeling as a time consuming task and a skill that would take extensive training before they could generate a practical design. Even though the 3D printed grip had value it was not enough for the OTs to overcome the perceived and actual challenges of 3D modeling to leverage the technology. This discovery served as our motivation for creating a more automated tool for designing 3D-printable objects.

Identifying Requirements

From our interviews and design work with the OTs, we came up with basic set of requirements for a minimal design tool. Even though the hand grip was explicitly created for one student, the therapists indicated that multiple students could benefit from a custom grip modification for an array of objects. We opted to create a piece of software specifically for creating more of these grips.

Another important consideration for our interface design was based on a recurring theme from not only the therapists but other onsite staff asking for a design repository. While our participants were made aware of online design sharing sites such as Thingiverse, they expressed that these sites lacked the specificity and privacy for the nature of the designs they would want to create for their students. We incorporated a grip model library and a grip profile system to emulate the desired repository functionality.

Finally, to remove the intimidation factor behind the mouse-drive design software, we abstracted the model generation down to numeric and option-selection settings. The next section details the development of these features.

Tool Development

In evaluating the stylus grip design process, we noted that there were few steps that required expert understanding of engineering or CAD tools. The biggest barrier to the OTs completing this project on their own was the time and lack of training. The OT's felt that they could master novice design software, but they simply did not have time to learn the process of 3D modelling. Instead they would prefer a simple form based program that allowed them extensive control of the features they understood and hid the technical information. The OT's wanted a program they could get in and out of quickly and be used for a variety of students and tools.

To facilitate more grip design at the investigation site we have begun developing GripFab (See Figure 2), a simplified modeling program that allows the user to easily alter a grip so that it will support a variety of tools. One of our design goals is to obscure the complexity of the design process from the OT's and end users so they can print their own custom grips.

Simplified modeling programs exist such as: Tinkercad and the Thingiverse Customizer. However, these programs do not meet the specific needs of this population. Tinkercad is a simplified version of traditional 3D modeling software. It is intended to allow the user to create anything, but the options are overwhelming to a population that only wants to create grips. Customizer, on the other hand, is too limited. Only one model can be customized limiting the number of grips needed. This demographic wants a simple program to design a variety of grips. In response, we developed GripFab.

Many common grip positions are included in the GripFab library; we believe that, as the program is used, more corner cases will be added to the program. Boundary values (maximum and minimum dimensions) will depend on the grip; for example a built up grip may hold objects of greater diameters than universal cuffs. These boundaries are hardcoded in for each new grip. Currently, new Grips are added by program designers.

So that the user can adjust their grips for new tools or to maximize comfort, a user profile system is included in the software. The user opens their profile to alter the appropriate settings. The profiles are created by writing a formatted text document. Each variable from the GripFab

[4] http://store.makerbot.com/digitizer/.

[5] http://meshmixer.com/.

form is listed in order; this order is then read back into the application when a profile is opened.

To break up the design process, GripFab has a tabbed structure. In initial testing phases, users were confused about the relationship between the various settings and the final grip. The tabbed interface separates these settings, connecting them to smaller aspects of the final design. This made the relationship between settings and the final product clearer. As the user submits new settings on each tab, they are allowed to progress to a new section. The tabs are broken into a hole design (Figure 2) and barrel design. The hole tab creates a tight hole for the object to slide into. The barrel tab allows the user to design a custom barrel to support and alter the direction of the object.

As settings are altered, GripFab shows static 2D diagrams to help the user visualize the final product. To increase the speed of the program, diagrams were chosen, rather than 3D rendering. 3D renders of the current model would delay the program. This may lead the user to assume they have broken the program.

In the backend of the software, settings are loaded into a private java class that renders the model as an stl. OpenScad code is generated by calling methods linked to changes in the settings from the application form. The OpenScad code either alters base models, such as the contracture grip, or adds onto the model. Then, the program and base model are loaded into a user defined file location then removed when the stl is fully rendered. This masks the rendering process from the user, leaving a clean stl file for printing.

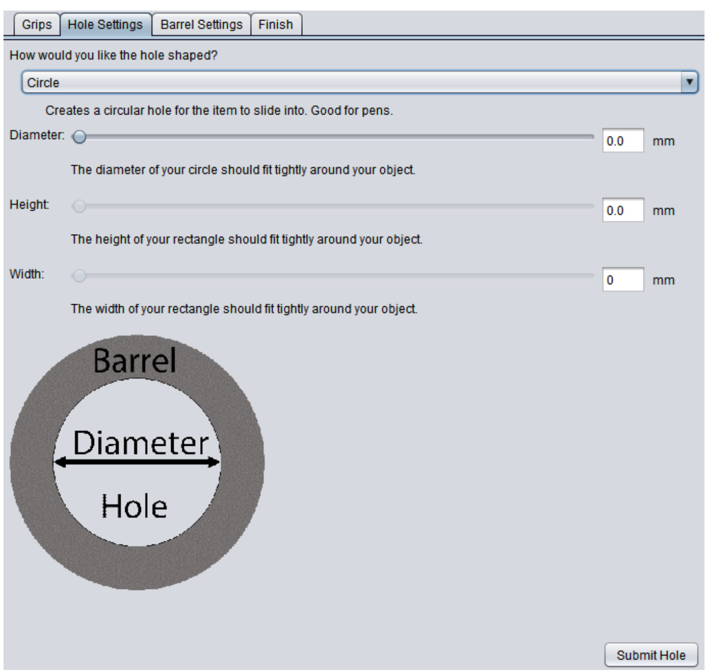

Figure 2. Screenshot of GripFab creating a hole for a cylindrical object .

EVALUATION

The current version of GripFab is informed by a series of pilot studies and a group user evaluation conducted at our target site. We have been working for eight months with the OT's in this environment.

Pilot Testing

We conducted ten pilot trials with interns in our lab. In these tests we asked the user to design a grip for a pen. We observed as they progressed through the program without focusing on the actual data they entered. Difficulties with visualizing how each setting related to the grip lead to the tabbed design and the 2D diagrams.

Onsite Demonstration and Testing with Therapists

We conducted one hour-long focus group at the investigation site with four OTs, including the two involved in the original hand grip design project. The session included a brief introduction to 3D printing and the hand grip project for the other two OTs who were unfamiliar with our prior work. Once all the participants understood the motivation and goals for the software, we continued with a set of semi-structure questions regarding the OTs' current experiences with hand motor impairments and their current practices for devising solutions for accessibility challenges.

Participants were then shown an example grip designed to hold a fork before receiving a high-level walk-through of the features available in GripFab. We then asked the OTs to complete a grip design for a large highlighter. One participant controlled the software while the other three provided suggestions and feedback on the usability of the application. If questions or problems arose, the participants were invited to ask the investigators for help.

After the task was completed, the participants were asked to reflect on the usability of GripFab and encouraged to suggest desired features and alternative applications of this tool design. The session was audio-recorded and transcribed for further analysis.

Open coding was performed on the transcribed document by two investigators. Common themes were identified and discussed, yielding feedback on multiple aspects of GripFab and other potential novice software tools.

FINDINGS

Our analysis provided us with detailed requests for improvements to GripFab, as well as ideas for similar 3D-printed assistive objects. We have also identified considerations for novice tool designers.

Changes to GripFab

The most advocated change to GripFab was an interchangeable attachment option. The OTs suggested that rather than printing a new grip for each object a student uses, there should be a base grip unique to the student's grasping ability that has a mounting for each accessory barrel. In this way, for example, an art classroom could keep a collection of specialized attachments for paintbrush, stamps, and other related objects that the students could snap in-and-out of their personal grip.

Other requested changes included adding models to the grip library to accommodate different types of ability. The OTs indicated several types of disabilities and disability related symptoms that could benefit from a custom grip, including limited or spastic movements, tremors, or missing parts of the hand. The participants also stated that while some grips users would see the most benefit from a highly customized grip base, there were several situations were users would benefit from a generic exaggerated handle or t-shaped rocker grip with customized attachments.

Lastly, GripFab is still in its early stages of development, but the evaluation provided by the OTs has given us several points of improvement for future iterations. This included providing colorful and dynamic visualizations to help the user conceptualize the adjustments that they are making to a given model. A labeled physical model was also mentioned as an alternative to a dynamic visualization. The OTs also suggested refining the interface labels to a less technical vocabulary. A 3D dimensional rendering of a design was deemed unnecessary, providing that the other interface changes were put into place.

Alternative AT Designs and Tools for 3D Printed Objects

With GripFab as an example, the OTs came up with a few alternative applications of 3D printing and specialized design tools. Among these designs were exaggerated grips for everyday electronics cords, custom fit assistive hand or wrist cuffs printed with flexible materials, and findings and/or mounts for attaching objects to wheelchairs. Participants felt each idea matched the GripFab model, in which a library of basic designs and customizable features can be manipulated with the user providing metric details rather than manually manipulating a 3D design.

Considerations for Targeted 3D Modeling Tools

Despite several suggestions for changes and improvements, GripFab was still well received. Based on the enthusiasm and feedback from our participants, we believe there is great potential for similar customized tools. In creating such modeling applications, we recommend future designers consider the following:

- Identify the existing level of expertise for end-users, not their potential expertise;
- Find out the level of detail needed to generate a practical design outcome;
- Ensure that features and labeling are in keeping with the domain expertise of the end-user;
- Abstract away complexity where possible.

CONCLUSION AND FUTURE WORK

We have presented GripFab, a specialized piece of modeling software for the creation of 3D-printable assistive hand grips. Based on our testing and user feedback, we feel that task-targeted novice 3D design tools are an important next step in the democratizing of 3D printing technology. [More feelings?]

In the future, we hope to expand upon GripFab to incorporate as many of the recommended features as possible, as well as creating and testing similar tools to help facilitate the use of 3D printing in all environments.