3D Etch-a-Sketch: a tangible interface for playful interactive fabrication

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ABSTRACT
This paper presents 3D Etch-a-Sketch, a tangible interface for interactive fabrication. 3D Etch-a-Sketch presents users with an opportunity to playfully explore 3D printer hardware. The interface enables users to control position of the X and Y axes, extrude filament, and increment the Z axis, through a physical controller. The interface helps ground thinking for future work weaving together play and digital fabrication; educational design and machine control; and alternative interfaces for digital fabrication.

Author Keywords
3D printing; casual makers; digital fabrication; interactive fabrication.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): User interfaces: Prototyping.

MOTIVATION
New casual users have increased opportunities to explore digital fabrication [1,5]. Often, introductory experiences in digital fabrication are designed to be creative, playful, and beginner friendly. While there are a range of tools for casual users to explore the software based design tools used in digital fabrication (e.g., Computer Aided Design (CAD) and 3D modeling), the physical hardware often is not as open, and opportunities for novice users to explore the physical processes of digital fabrication are limited. This project is a move towards opening digital fabrication machines themselves, specifically 3D printers, to playful exploration.

BACKGROUND
Software. There are a number of different software platforms where new users can engage, explore, and play with 3D design and CAD (e.g., *TinkerCAD, Meshmixer, Solidworks Apps for Kids, Beetleblocks*) [3,4,14]. These software environments have low barriers to entry, intuitive and easy to use interfaces, and can be used to create more complex designs. Though these software tools are typically intended for students and casual users, they often still require guidance or instruction from more experienced users [5].

Hardware. A broad range of work has focused on exposing new and casual users to digital fabrication and prototyping processes, such as Computer Numerically Controlled Machining (CNC) [6,11,12], electronics [8,10,14], 3D printing [7], and e-textiles [13]. Designs focused on making hardware more accessible typically either present a new tool, or focus on teaching new skills. Though often designed with beginners in mind, new tools are sometimes tested with more experienced users [5]. Skill based projects focus on outcomes or progress along a learning pathway. Fewer projects are interested in creating experiences of open ended or playful exploration with digital manufacturing.

3D ETCH-A-SKETCH
3D Etch-a-Sketch is a tangible interface for 3D printing and machine control. Users control the motion of the X and Y axes, the extruder motor, and can increment the Z-axis, in real time. The emphasis on real time control of the 3D printer buildings on work on interactive fabrication [16].

Building the 3D Etch-a-Sketch posed two challenges; control and communication.

Control

Our interface is made of two physical controllers and a base station. Both controllers have three functions; control of the X or Y axes, speed control, and extrusion.

X and Y Control. Axis position is controlled by two large arcade style push buttons (left and right, forward and backward). We chose large push buttons common to games and controllers. They are a familiar invitation to play. Our intention was to signal to new and casual users this was a device to be explored and played with.

Speed Control. The motor speed is set by a potentiometer surrounded by a ring of 12 LEDs. The potentiometer knob signals to the user which axis the controller corresponds with. The LED ring lights increment to match the speed of the motor. The LED rings provide users with feedback, and are intended to invite users to approach and interact with the printer.

Extrusion. A third large arcade style push button on the side of the controller extrudes filament at a constant rate. When the button is released the filament retracts to keep prints clean. Both controllers have a button for extrusion.

Our interface requires at least two people to control the printer. The two controllers force users to interact with and explore the printer together. New and casual users can teach and learn from each other as they begin to explore the printers' capabilities. Users comfortable with the interface will be able to explain to others how the controls work, which movement corresponds to which axis, and how extrusion works.

Communication

Communication with the printer is handled by a single-board computer. In order to control the printer, we first needed to solve connecting our controller to the printer's firmware. We then had to stream g-code in real-time to the printer.

Hardware Interface. We use a BeagleBone Black to connect our interface to the 3D printer. The BeagleBone runs a Python script that sends g-code to the printers' firmware. The buttons on the controllers connect to the GPIO pins on the BeagleBone, and increment each axis.

Streaming G-Code. The printer receives commands of g-code as strings, transmits messages strings back to the BeagleBone and waits for a return message. Our script controls the stream of data into the printer.

FUTURE WORK

3D Etch-a-Sketch presents at least two directions for future work; further exploration of education for new and casual users, and investigations into more interactive fabrication techniques.

Education

First, using the 3D Etch-a-Sketch to support theories of learning, creativity and technology could lead to a richer educational experience for casual users. For example, instructions could guide users to work together to create specific shapes. The shapes could be mapped to a grid that corresponds with the appropriate g-code controls. Second, the device could be tested with a broader group of novice users. User tests could inform how beginners (or any user) react to opportunities to explore, play, and tinker with digital fabrication machines.

Other Directions in Digital Fabrication

Our work could also inform interactive fabrication [9,16], and other approaches to digital fabrication outside of traditional CAD/CAM [2, 15]. Next steps might include storing a users' design and repeating it over multiple layers, as well as a screen to visualize what users have created have already created.

There are also opportunities to explore interaction. While our current hardware is designed to look and feel like a game experience, other creative interfaces for 3D design, additive manufacturing, and digital fabrication could be built that invite play and exploration. For example, users could draw layers on paper or a screen, see them created in real-time, and see their layers repeated to grow a 3D part. It could be possible for the user to draw a start and end layer, and have the software and printer create a 3D shape based on the two layers.

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