NORTHERN ARIZONA UNIVERSITY

Memorandum

Design4Practice (D4P) Program

To: Professor David Trevas

From: Richard Hamilton

Date: July 5, 2020

Re: Self Learning

Introduction

For my self-learning, I chose to follow through on something I had been planning and purchase, build, and modify a 3D printer. 3D printing has become significantly more cost-effective for an average person to get started in and can be applied to many different applications. I chose 3D printing as prototyping is a large part of engineering design as well as a convenient way to test ideas for relatively cheap. This memo will go through printer selection, assembly, first prints, upgrading the printer, as well as slicing basics for the models.

Printer Selection

For the printer I chose, I started with browsing online resources for recommended budget printers. I was looking for a printer less than $300 that provided good build quality as well as a build space larger than 150 x 150 x 150 mm. The 2 brands saw mentioned most where *Creality3D* as well as *Prusa Research*. All of *Prusa's* printers are over $300 which quickly narrowed my selection to *Creality3D*. I settled on their Ender 3 Pro [1] which was on sale for $210. The Ender 3 Pro offers a 220 x 220 x 250 mm build space as well as a removable magnetic bed and comes in at a budget that leaves room for filament. The only downside is the lack of a self-leveling bed.

Printer Assembly and First Prints

The Ender 3 Pro comes with only the bottom plate and y-axis assembled. The instructions were good enough to assemble the rest in about an hour the full printer can be seen in Figure 1. The Ender 3 uses 3 belts and stepper motors to control the x and y-axis with a lead screw for the z-axis that turned out to be off center. The most tedious part of assembly is leveling the bed the first time. When I purchased the printer, I knew I wanted an automatic bed leveling feature, luckily this is easy to install. To add in this feature, A bed leveling probe must be installed as well as either a new circuit board or an addition to the current board. I chose to utilize a new board for the better stepper motor drivers as well as compatibility with bed leveling. The first print on my printer was a mount for the probe as seen with the probe in the white plastic in Figure 2. I also found a print to straighten the lead screw for the z-axis which significantly reduced noise during printing.

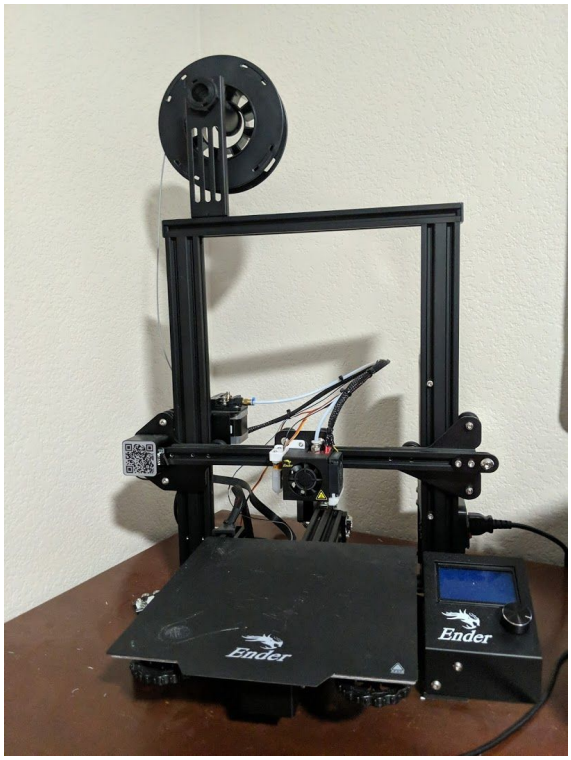

Figure 1: Ender 3 Pro fully assembled

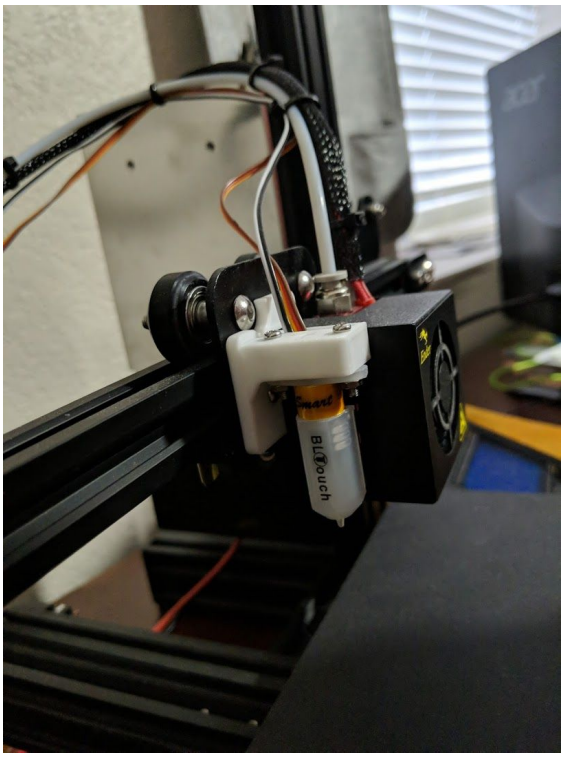

Figure 2: BLTouch Leveling Probe and Mount

Printing Results

After flashing the new circuit board with an open-source firmware called Marlin using a guide found online [2], the printer was ready for the first real print. All prints mentioned in this memo were found on *Thingiverse.com [3]* and were sliced using *Ultimaker Cura [4]*. The first print was a calibration cube (Figure 3) designed to check the printer tolerances and stepper motor tolerances. This cube is designed to be 20 x 20 x 20 mm. Using calipers, the result from the Ender 3 was 20.1 x 19.9 x 20 mm which is within tolerances. For the second print, I used a “Benchy” (Figure 4), a tug boat model that is designed to test printers with overhangs, holes, and radiused edges printed without supports. This print came out quite well considering the overall cost of the printer was about $300 after modifications.

Figure 3: Calibration Cube

Figure 4: “Benchy”

Slicing

Slicing 3D prints using a program such as *Ultimaker Cura* is how gcode is created. This gcode is then loaded onto the printer and tells the print head a tool path and when to extrude plastic. Many other forms of CNC manufacturing use gcode for directions and manufacturing processes as well. When slicing, there are many variables that can be changed and modified. The most important variables are layer height, number of walls, and infill percentage. The layer height determines how high the print head moves between layers and influences print time as well as final quality. A lower number such as 0.1 mm layer height results in a nicer finish but about two times the print time of a 0.2 mm layer height. The walls on a print are the perimeter of the object. When adding more walls, the print time is increased as well as filament consumption however the strength of the print also increases. Generally, this number is kept between 2 and 4 depending on how much the print can bend and deflect. Finally, the infill is how much material is inside the print. Many people think that 3D prints are solid however that is not the case as the print time and amount of filament needed to do that would be extreme. Most prints are hollow inside with a certain percentage of interior filament for strength. This number can be drastically different depending on the structural needs of the print as well as the final strength required. For my prints, this number was between 15-25%.

Final Thoughts and Applications

Applications for 3D printing can range from creating low volume custom parts to prototyping. Already, I have printed a prototype drone for the Iam3D club that I am part of to test once the meetings resume. I have

also created and printed some parts for around the house such as holders for fan remotes and brackets. Applications such as these 3D printing excels in, high volume production and high strength applications, however, is where it falls short. Print times are much longer than injection molded parts and while high strength filaments can be used, nothing can come close to metal parts. Learning how basic gcode works as well as designing for manufacturing, such as how overhangs and sharp corners can affect tool paths and can cause parts to be nearly impossible to make without supports, can carry over into many applications when it comes to design.

Overall, regarding the assembly, print quality, available resources, and experience, I can recommend the Ender 3 Pro to anyone looking to start 3D printing. For a total cost of about $300 and “some” time, you can have a feature-complete printer with auto bed leveling, thermal runaway detection, quiet stepper motors, and a heated removable bed that is still compact. The only noise I hear from the printer is the part cooling and power supply fans. The printer settings can be adjusted to print PLA, ABS (an enclosure is highly recommended), wood filament, carbon fiber, PETG, as well as many other types of filament. Resources are available online in forms of written guides and videos as this is a popular budget printer. More pictures of the printer and prints can be found below in Appendix A.

Appendix A

Figure A1: SKR E3 mini Circuit board upgrade

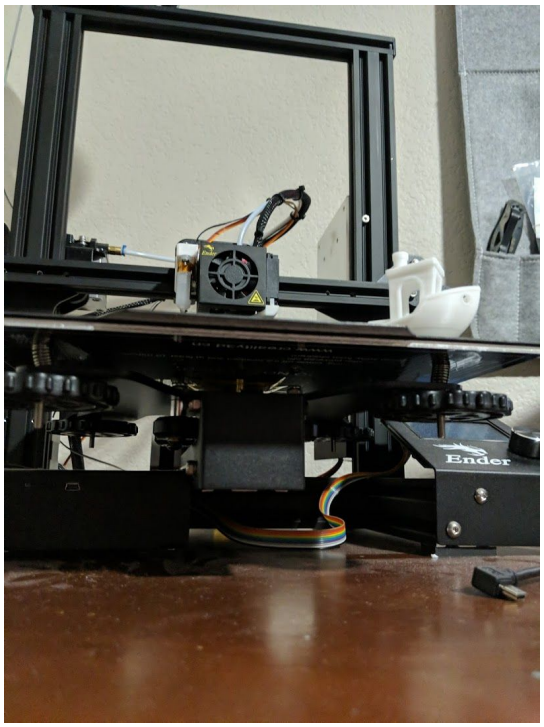

Figure A2: Underside of printer showing bed leveling knobs.

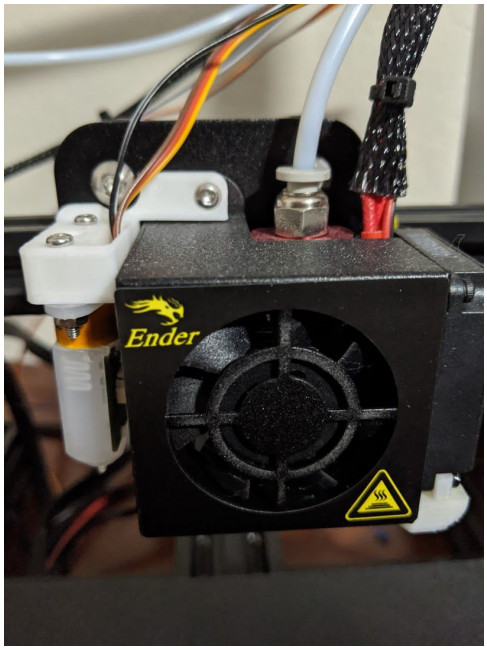

Figure A3: Hotend with part cooling fan and bed leveling sensor

Figure A4: 2 pieces self-watering planter printed at 0.2mm layer height, 3 walls, no infill

approx 12 hours of total print time

References/Links

[1]"Creality3D Ender-3 pro High Precision 3D Printer", *Creality 3D*, 2020. [Online]. Available: https://www.creality3d.shop/collections/ender-series-3d-printer/products/creality3d-ender-3-pro-high-precision-3d-printer. [Accessed: 04- Jul- 2020].

[2]"Marlin 2.0.x guide for Ender 3 using SKR mini E3 v1.2 : ender3", *Reddit.com*, 2020. [Online]. Available: https://www.reddit.com/r/ender3/comments/e894j7/marlin_20x_guide_for_ender_3_using_skr_mini_e3_v12/. [Accessed: 28- Jun- 2020].

[3]"Thingiverse - Digital Designs for Physical Objects", *Thingiverse.com*, 2020. [Online]. Available: https://www.thingiverse.com/. [Accessed: 03- Jul- 2020].

[4]"Ultimaker Cura: Powerful, easy-to-use 3D printing software", *ultimaker.com*, 2020. [Online]. Available: https://ultimaker.com/software/ultimaker-cura. [Accessed: 03- Jul- 2020].

Helpful videos:

https://www.youtube.com/watch?v=ocAeZRPVusw&

https://www.youtube.com/watch?v=2B4qdKdqJj4

https://www.youtube.com/watch?v=xoWOH2v0wA8