The Developing Low – Cost Closed – Loop Actuator

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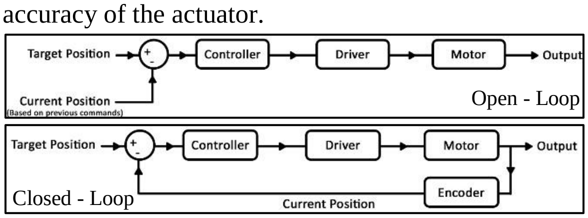
Actuators are mechanical devices that provide movement or positioning that are operated electrically, manually, or by fluid[1]. The use of closed-loop control to improve performance with 3D printers is a current area of research. Adding the needed sensors and hardware to a low-cost 3D printer has been too expensive to manufacture. Currently, open-loop actuators are less expensive but are more inaccurate due to the lack of positional feedback. The capability to recognize and rectify skipped steps[2] while the machine is running builds reliability within the product and cuts down on production time due to printing errors. The actuator will use off the shelf electronics for linear feedback, a stepper motor, and a low-cost ball screw. This research, if successful, aims to develop a low - cost closed-looped actuator that improves the reliability and performance of various machines at a lower price point.

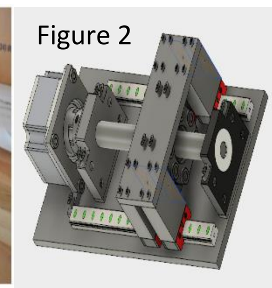
I. INTRODUCTION

Throughout the 20th century, our views of closed-loop automation applications in technology have changed drastically. The majority of CNC (computer numerical control) machines use linear actuators. These include 3D printer's screen printers[3], milling machines, robots, etc. The gold standard for linear actuators is closed loop control. Closed loop control involves using feedback to improve the positional accuracy of the actuator.



When using a closed-loop actuator, the information comes from the controller, to the process, passes through the sensor and loops back to the controller to give feedback. Due to its low-cost, consumers rely on open-loop control gantries by trusting the device to go where instructed without really having the ability to check to make sure the motion happened.

Commercially available linear actuators can achieve accuracies on the order on 1 micron. Unfortunately, these actuators cost $5,000- $15,000. Adding the needed sensors and hardware to 3D printers has been too expensive to manufacture. This makes these actuators inaccessible to hobbyists and those participating in developing unfunded research labs.



About the cost efficiency, take these two figures for example. Figure 1 located on the top, is a manufactured printer actuator which sales for $745 for a single inch stroke. Figure 2 located on the bottom, is a 3D printed actuator which cost roughly about $331 to build independently. This actuator will use off the shelf electronics for linear feedback, a stepper motor, and a low-cost ball screw. Figure 2 is much cheaper than a manufactured one and does the exact same job as Figure 1. There are many benefits to printing and/or building your own actuator1. Not only cost efficiency but customization and quality as well. My project involves the mechanical design, electrical design, manufacturing and testing of a closed – loop actuator.

II. METHODS

Any successful project must have a plan or blueprint to flow smoothly. So, I started with sketches. I drew out my plan on plain paper with part names and dimensions. Then I converted my sketch into an AutoCAD software called Fusion 360 where I design my first model of the actuator. Fusion 360 is a free AutoCAD software that allows you to design, test, and fabricate your work in one single cloud. I used two different tools with Fusion 360. One called CAD

(Computer Aided Design) & CAM (Computer Aided Manufacturing)

After I design my sketch in Fusion 360, I created a 3D proto-type model of the actuator. I 3D printed every part and built a prototype to help and guide me through the manufacturing process of the actual actuator. Once I tested my prototype and everything was successful. I began ordering my parts.

*Linear Rail $27.99	Linear Position Strip $0.00
*Bearing Blocks $14.99	Motor driver $32.84
*Ball Screw $52.95	Power Supply $10.84
Assortment of Screws $40.00	Linear Position Integrated Circuit $13.07
*Bf/Bk End Support $14.30	Shaft Coupling $7.14
*Motor $14.07	Micro-Controller $0.00
*24 x 24 Sheet of Aluminum $50	Production Cost $20.00
	Total Cost - $331.07

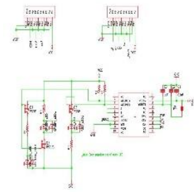
The starred components are the main parts I used when manufacturing the actuator. Most parts were chosen because of their low cost, high efficiency, durability, and commercial availability. To also minimize cost, some parts I manufactured myself out of a 24x24 sheet of Aluminum.

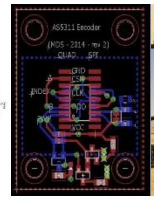
I used stainless steel bearing blocks & rails because they're durable in harsh conditions and cost less. I used aluminum as the body material due to low weight, ease of manufacturability, and low cost. I also minimized cost because I manufactured some parts such as the base, the motor mount, and the stage out of a 24x24 sheet aluminum. I chose a Nema 23 stepper motor for this application due to its' size and torque ability. (200 lbs. of continuous thrust) I used a ball screw due primarily to its' commercial availability, high efficiently, and load life characteristics.

My design provides fast and effective actuation, and its exceptional structure is scalable for multiple applications. It took about 2 weeks for the ordered parts to come in. While I waited for my parts to come in. I took the necessary trainings for the equipment I would use to manufactured the low-cost actuator.

I used a CNC (Computer Numerical Control) Machine, which uses a spindle and a motor to cut through different materials. I used a Waterjet Machine, which uses high pressure water and sand to cut through different materials. I used a 3D printer for the prototype model. I used an Other-mill Machine which is a smaller version of the CNC Machine to manufacture a PCB (Printed Circuit Board) for the Electrical Design of my project.

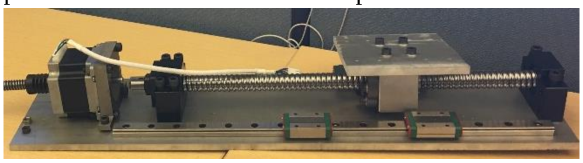
Due to lack of time, the Electrical Design was only introduced rather than implemented into the actuator. To reduce time and cost I used an open source[4] schematic and board design. I tried to manufacture the PCB (Printed Circuit Board) but wasn't successful due to errors within the Other-mill machine.





III. DATA / RESULTS

So far, I have laid the foundation down for further research. I have manufactured the low – cost actuator. The only task left is to set up the electrical design to produce a low - cost closed – loop actuator.



IV. CONCLUSION

I successfully manufactured a low - cost actuator. I will continue my research independently to develop a low – cost closed – loop actuator. My overall goal is to develop a low – cost closed - loop actuator that improves the reliability and performance of various machines at a lower price point.

My overall research impact is to improve various machines such as 3D printers and build more reliable products and cut down on production time due to errors. In the future, I plan to manufacture a closed – loop 3D printer.

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ACKNOWLEDGEMENTS

This work was funded by the National Science Foundation Award ECCS-0939514, the Center for Energy Efficient Electronics Science and the Department of Electrical Engineering and Computer Sciences at UC Berkeley.