DREU Final Paper
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"My Accessible+ Math: Creation of the Haptic Interface Prototype"

ABSTRACT

My Accessible+ Math is a project that aims to facilitate the learning method for visually impaired students who are enrolled in college-level math courses. To first approach this task, our team will create a My A+ Math software application that will interact with the haptic interface prototype being built this summer. This prototype will be a scrabble game-like inspired board with an actuated three-dimensional surface in the center. It will be able to display equations, shapes, and other mathematical representations. Braille keys will be set on the sides of the board for user to interact with while using the software application. Developing this project will benefit the teaching environment as well as the student when trying to comprehend a high-level course of mathematics.

INTRODUCTION

Average humans typically use what is known as our seven senses (sight, smell, taste, touch, hear, vestibular, and proprioception) on a daily basis. However, individuals with disabilities such as vision loss and blindness are incapable of applying some of them to their lives. Due to their lack of accessibility, pursing a computing major and/or career has been made difficult for visually impaired students to accomplish after high school. We hope to remove such existing barriers by inventing an interface prototype that is perceptible by touch and perhaps sounds in later versions. Human-Computer Interaction or HCI research has been an evolving subject and the haptic three dimensional output display of our project is a perfect example. My Accessible+ Math is made up of parts that are commonly available online and will be made as free open source software with a purpose of implementing open source hardware to allow more users to benefit from. This technology's design is fairly compact so that it is not overwhelming in a classroom setting and expandable in the event that multiple units are needed.

EXPERIMENTAL DETAILS AND PROCESSES

Staying within a budget of no more than five thousand dollars took our team a number of weeks to fulfill. Researching the price of every component also made us keep the complexity of the system in mind. Our haptic interface prototype was inspired by inFORM[1] created by MIT's Tangible Media Group. In Figure 1.1, a diagram of inFORM's hardware implementation is drawn out while Figure 1.2 shows an estimation of its value. Keeping in mind that the table and cooling devices for actuators of the system were not included in the estimate. The first question that came to mind was: *How will our project's implementation differ?* Well, after visiting all the possible webpages, we were able to develop a price estimation spreadsheet of our own as presented in Figure 2.1 with a technical diagram in Figure 2.2. Clearly, the number of pins were reduced from 900 to 440 with a dynamic surface area reduced to 10 inches by 11 inches. The potentiometer travel reduced from 100 millimeters to 20 millimeters. Plus, a Raspberry Pi, enables ad-hoc networking which would control the surface as opposed to a CPU. This reduces our cost to roughly a fifth of the original fill-size implementation, but is it feasible to complete by our set deadline?

After a few weeks, the team and I finally decided that the setup would have an array of 56 instead of 440 3D printed plastic pins built into the board. Each pin is nearly 3.5 millimeters apart and can extend 19 millimeters from the board's surface. Figure 3 shows the top, front and back view of the prototype respectively. It will help give a visual representation, but not all features were added onto the CAD model demonstrated. For example, the outer casing is not present in order to show what the inside of the prototype looks like. The pins, linkage, and servo were excluded from Figure 3 as well. Nonetheless, please refer to Figure 4 in the FEELEX project[2] (another source that inspired our creation of the project) to get a visual understanding. The team and I will post a picture of the real life prototype soon on our Facebook page. With the elimination of the potentiometers, each pin is set in motion by a Corona 939MG Digital Metal Gear Servo which is controlled by an Arduino MEGA 2560 board. Every motor shield contains 16 metal pins and one servo is assigned to one metal pin on the shield. Therefore, each 3D printed pin will project above the surface of the prototype's board because every servo is individually addressed with the running sketch we programmed in the Arduino Integrated Development Environment [3]. Due to the large amount of servos in the system, we will be stacking 4 Ladyada motor shields onto the Arduino MEGA 2560. All elements in the system will then fit together in a 3D printed plastic casing designed to easily open for repairs and/or add-ons. A possible addition to our project for future researcher to work on would be the electric slide potentiometers. My Accessible+ Math technical application's advantage of including them originally was for rapid actuation combined with super accurate sensing like pulling and pushing.

RESULTS

The creation of the haptic interface prototype just needs minimal tweaks to reach our team's completion goal at the moment. The intended results are for educators to be knowledgeable of detailed strategies to assist people (specifically students after high school going to college) with eyesight disabilities in learning math. The outcomes of the experimental tests performed by those students will be shared with other educators in an effort to scale-up this project at state level. Most importantly, it will increase the success of learners with low vision or blindness on pursuing computing majors and careers by eliminating barriers in studying math.

CONCLUSIONS

The entire DREU research experience has exposed me to the hardware side of my education path in growing to become a computer engineer. A great amount of hard work and research was put into the team and I's summer to accomplish the project for a proof of concept. Our intention to conduct a formal user study on individuals with visual impairments will be the next big step. I would love to be there through the process to see the reactions of each student and personally interact with them throughout the process. Their positive/ negative feedback is crucial for our team to obtain so we can further improve every defective aspect that might be mentioned. We hope that many students can one day experience this haptic interface, so that they prosper on learning Math.

ACKNOWLEDGEMENTS

Coming into this internship, I did not know what to expect until I was connected with my mentor, Dr. Daniela Marghitu. She always directed me to get a better understanding of anything I was not clear on. Her undergraduate student, Brandon, and graduate student, Derek, also taught me so much related to the project. My research experience would have been uninteresting without them and I am thankful to have collaborated with everyone in Auburn University.

REFERENCES

[1] Sean Follmer, Daniel Leithinger, Alex Olwal, Akimitsu Hogge, Hiroshi Ishii. inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation.http://tmgtrackr.media.mit.edu/publishedmedia/Papers/527-inFORM%20Dynamic%20Physical%20Affordances/Published/PDF. UIST 2013.

[2] Hiroo Iwata, Hiroaki Yano, Fumitaka Nakaizumi, Ryo Kawamura. Project FEELEX: Adding Haptic Surface to Graphics. http://intron.kz.tsukuba.ac.jp/publish/PDF/SIGGRAPH01.pdf. 2001.

[3] The Arduino Software. https://www.arduino.cc/en/Main/Software. 2016 Arduino.

FIGURES:

Figure 1.1: A diagram of the hardware aspect for the inFORM project

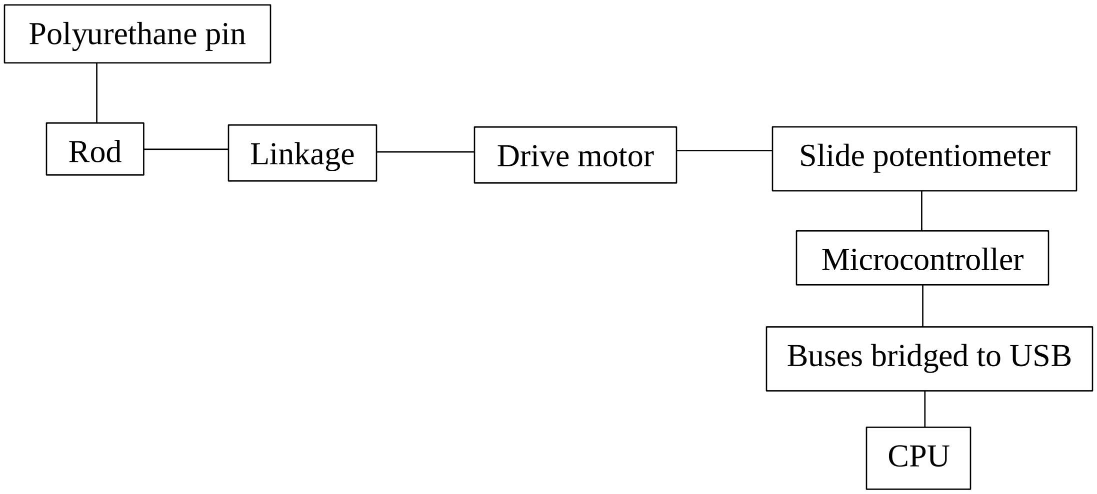

Figure 1.2: Cost estimation of most important elements needed to build the inFORM system

Item	Stock #	Use	Source	Quantity Needed	Price
Microcontroller	Arduino Mega 2560 Rev 3	Microcontroller	store-usa.arduino.cc	150	$45.95
Linear Potentiometers	RSA0N11M9A07	Actuator	mouser.com	900	$99.75
Sullivan Gold-N-Rods	LXFU90	Linkage	towerhobbies.com	900	$5.99
Ladyada Motor Shield (includes drivers)	1438	stepper/driver	adafruit.com	150	$17.91
RS485 Buses	RS485	controller --> CPU		50	$2.99
Subtotals					
potentiometers	$89,775				
microcontrollers	$9,579				
linkage	$5,391				
buses	$149.50				
total:	$104,895				

Figure 2.1: Cost estimation of most important elements needed to build My A+ Math system

Item	Stock #	Use	Source	Quantity Needed	Price
Microcontroller	Arduino Mega 2560 Rev 3	Microcontroller	store-usa.arduino.cc	75	$45.95
Linear Potentiometers	RSA0N11M9A0F	Actuator	mouser.com	440	$27.93
Sullivan Gold-N-Rods	LXFU90	Linkage	towerhobbies.com	440	$5.99
Ladyada Motor Shield (includes drivers)	1438	stepper/driver	adafruit.com	75	$17.91
RS485 Buses	RS485	controller --> CPU		15	$2.99
Subtotals					
potentiometers	$12,289				
microcontrollers	$4,790				
linkage	$2,636				
buses	$44.85				
total:	$19,759				

Figure 2.2: A diagram of the prototype aspect for our My A+ Math project

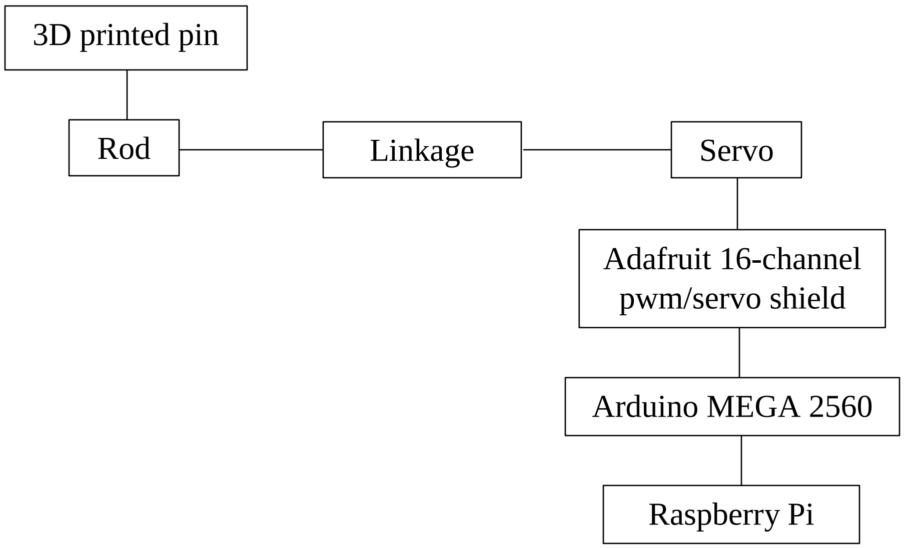

Figure 3: Most of the 3D model of the prototype created on Tinkercad and printed with Makerbots and The Cube. (top, front, back views)