Haptic User Interface

Phase II

ECE 480 Design Team 6
For MSU Resource Center for Persons with Disabilities

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Sponsors: MSU RCPD, Marathon Oil, Chrysler, Artificial Language Laboratory
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Proposal
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Executive Summary

The Michigan State University (MSU) Resource Center for Persons with Disabilities is currently conducting research, in conjunction with Marathon Oil, Chrysler, and MSU’s Artificial Language Laboratory, for an alternative haptic-user-interface for visually impaired individuals. The devices on the market today are too expensive for the average consumer. In particular, current prices make it difficult for blind students to purchase devices that would help overcome challenges in mathematics and science courses. ECE 480 Design Team 6 will build upon the Fall 2012 Phase I design. The Haptic User Interface Phase II will enable blind students to “see” technical images and graphs from a computer screen and enhance their learning experience overall. A unique magnetic design enables device manufacture at a very competitive price.
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1. Introduction

1.1 Michigan State University - RCPD

The Resource Center for Persons with Disabilities (RCPD) office was originally created during the 1971-1972 academic semester, with the goal of providing equal access to the University for all students. The RCPD office provides services to MSU students, employees, and visitors to ensure that they have equal access to all MSU services and facilities.

The mission of the RCPD office is to lead Michigan State University in maximizing ability and opportunity for full participation by persons with disabilities.

The functions of the RCPD office are summed up by using the following acronym:

- Assess and document disability, academic, and workplace needs
- Build and facilitate individual plans for reasonable accommodations
- Link individuals with technology, education, and resources
- Extend independence through auxiliary aids, disability-related information, and self-advocacy

RCPD at Michigan State values full integration of all persons with disabilities throughout all University programs and services. Further information can be found on the RCPD website https://www.rcpd.msu.edu/.

1.2 Phase I Summary

An initial implementation of the Haptic User Interface (HUI) was developed during the Fall 2012 semester by a prior ECE 480 group. This will be referred to as the Phase I design. The Phase I design was a refreshable HUI, achieved by using solenoids. The magnetic force induced by the solenoid on the metal pins is responsible for displacing the pins through a casing to display the image. The
Phase I design was portable and featured rows of pins that would rise to represent portions of an image on a computer screen.

The HUI device was driven by computer software designed to open any image in a grayscale format and then allow the user to move the mouse cursor over the image to select portions of the image to be represented by the device pins. The technology utilized in this design consisted of custom software, a modern USB interface, AC/DC and DC/DC power converters, as well as microcontrollers and custom-made solenoid circuits.

The Phase I design achieved the stated goals of the project, but also presented many opportunities for improvement. The design met with mixed reviews from volunteer blind student reviewers. One of the major opportunities for design improvement involves the pins themselves, which, when driven by the solenoid, vibrate significantly. The users did not enjoy this and stated that it made the image difficult to discern. Additionally, the resolution on the display was fairly low, making it difficult to interpret an image. Furthermore, there was significant heat dissipation from the device. Finally the portability could be improved by using compact and lightweight ergonomics.

The Phase I did review positively overall as innovative and is an excellent starting point from which to build upon. Significantly, the Fall 2012 group was successful in keeping the cost of the project low; their total cost of design was only $110.

1.3 Phase II Requirements
The project is currently in Phase II and is intended to build off of the previous team’s work. The requirements requested for the current project are higher resolution and non-vibrating pins.
2. Research Project

2.1 Project Overview

The ECE 480 Design Team 6 for Spring Semester 2013 consists of a motivated group of individuals eager to learn about and help the visually impaired. None of the team members has had any prior experience working with blind individuals, so this design project serves not only as an opportunity to design a useful product, but as a great learning experience overall.

Successful implementation of the cost-competitive refreshable haptic display will enable Jordyn, an MSU sophomore computer science major, and potentially other blind students across the globe like her, to interact and alter drawings and other graphic materials. By allowing the blind to “see” graphs and images in real-time they will have yet another tool to enable them to further their studies. This device will be extremely useful for physics and mathematics materials. The device will be in conjunction with the specificity and needs of the Michigan State University RCPD. It will also take the direct feedback and demands of current blind students and faculty of MSU. Above all else, our goals of the device are for it to be the first commercially affordable device for the average person that is user friendly and productively useful.

2.2 What a Haptic User Interface Device Is

‘Haptic’ refers to the human tactile and muscle movement senses. Tactile feedback is the term applied to sensations felt by the skin. A haptic interface is a computer-controlled device that displays information to a user’s senses. Haptic devices allow the user to feel and perceive objects with which they interact. Haptic user interfaces are input-output devices, meaning they receive an input from the user (i.e. graphic image) and send an output to a device. For our HUI, the output is displayed via a pin-out of the input and the user is able to feel the image displayed on the computer. Through haptic devices, graphical images can be displayed on a computer screen and made accessible to blind persons who currently are deprived of access to standard Graphical User Interfaces (GUIs).
These devices enhance the learning experience of blind persons. Blind students who have accessibility to haptic devices are able to access graphical images for mathematics and science based classes.

2.3 Current Devices Available

Current machines used to produce graphic images for blind students are time consuming and expensive. The amount of time it takes to transfer images to paper or Braille reader so the student can feel it through a Braille style layout makes it difficult to produce the multiple images that would be needed for mathematics and science classes. The devices on the market, that implement graphs and drawings in Braille format are expensive ($5,000 - $10,000). Figure 2.3a shows the Alva 544 Satellite Braille Display, which costs $6,295. Figure 2.3b shows the PowerBraille Display, which runs from $4,495 - $10,550 depending on the resolution of the device.

The design of the MSU RCPD refreshable HUI uses different technology than the ones currently on the market. The Phase I device takes a virtual form of an image and allows for the user to feel it via a Braille style pin layout. A software program loads the graphic image, such as a graph from class, and displays it on the pins of the device. The pins are able to continuously move as the user moves the cursor along the image to allow the user to instantaneously feel the image.
depicted on the graph. Figure 2.3c shows the final product that was created by last semester’s ECE 480 design team.

![Last semester’s final product](image)

Figure 2.3c: Last semester’s final product

3. Customer Design Specifications and Objectives

The team’s immediate sponsor, Mr. Stephen Blosser from the RCPD, has requested that Team 6 enhance the functionality of the Refreshable Haptic Graphic Display to better meet the needs of visually impaired students that will use our product. The previous design successfully met the following criteria:

- Ability to upload images from a computer and convert them to grayscale
- Fast refresh rate
- Portable
- A solution that gave an accurate representation of an image

Mr. Blosser indicated that the students that used the device were impressed with previous design but had a couple concerns. Team 6 decided to meet with the student testers directly and did so during the second week of spring 2013. Following an informative discussion, the student testers provided Team 6 with a
list of complaints they had regarding the Phase I design. Their major complaints were:
- Vibrating pins were distracting and caused difficulty in determining images
- Low resolution

According to Al Puzzuoli, a blind RCPD faculty member who tested out the device, “…the pins trembled perceptibly as I touched them” and “(The pins) were spaced widely enough so that there was not a lot of definition to the images.” He concluded that “Both of these issues combined made for a somewhat murky experience.”

4. FAST Diagram

ECE480 Design Team 6 project objective is to enhance the functionality of the previous team’s design of a Refreshable Haptic User Interface for the visually impaired. This device will be in conjunction with the specificity and needs of Michigan State University’s Resource Center for Person with Disabilities. The previous team met their project goal by designing and building a refreshable display to allow blind users to feel a graphic image. After receiving feedback from the users, we discovered that the vibrating pins were distracting and resolution was too low. Our team goal is to resolve these issues while exceeding the user’s expectations and performing efficiently to avoid additional concerns.
5. Conceptual Design Descriptions

5.1 Introduction

Phase II will focus on resolving the two major issues that have been identified: stop the vibrating pins and increase the resolution. To do this we have come up with a three different designs that are outlined below.

5.2 Proposed Design 1 – Increased Solenoids and Pins

The first idea is to include more solenoids and pins in the device. This addresses the resolution issue. The reason for the current poor resolution is due to the fact that the pins are placed farther apart than what a Braille literate individual is used to feeling. The quickest solution to that problem would be to insert solenoids between two rows of existing solenoids to essentially double the resolution. Figure 5.2a shows the current rows of the device and how they are laid out and Figure 5.2b shows the Design I solution to increase the resolution.

![Figure 5.2a: Current rows of the design](image1)

![Figure 5.2b: Inserting solenoids between existing rows to increase resolution](image2)

5.3 Proposed Design 2 – Smaller Solenoids and Pins

The second design would reduce the size of the pins and solenoids. In Phase I there were 32 solenoids and pins. The proposed Phase II design would be to implement an eight-by-eight matrix of pins using 64 solenoids and pins. In order to fit 64 solenoids inside the device, the diameter of the solenoid would need to decrease from 8mm to either 6mm or 4mm. This would also address a problem identified by the student testers. The 8 mm pins made determining the graphic images on the display difficult because this is not a standard Braille dot size. By making the pins smaller, they would become similar to the size of Braille dots.
The device would produce a familiar sensation to the user and thus be more comfortable. Proposed Design 2 addresses the resolution issue and could even positively impact the vibration issue. The pins would not have to protrude as high as they currently do. This could decrease the vibration that occurs when the pins move but this would need to be tested.

5.4 Proposed Design 3 – Magnetic Latching

Proposed Design 3 explicitly addresses the vibration issue. This design would consist of an array of magnetic bars that could create an eight-by-eight matrix (64 pins). The higher pin matrix addresses the resolution issue. The use of magnetic bars will allow the pins to latch when in use, instead of constantly moving up and down. This addresses the vibration issue. The bars would have small holes drilled in them in order to allow the pin to glide up and down as needed. In order to raise the pin when needed (i.e. to feel the graphic image output from the computer) a pulse needs to be sent to both bars. Therefore two consecutive pulses are sent to the device from a power source. These pulses charge the bar; setting the polarity so the magnet is attracted to the bar. This allows for the pin to protrude the surface and the user to feel the graphic image. The latch effectiveness of Proposed Design 3 has been independently tested by Team 6 and our RCPD collaborator/sponsor Mr. Blosser and been shown to be satisfactory.

6. Proposed Design Solutions

6.1 Conceptual Design Initial Selection

Proposed Design 3 was selected for initial investigation. The latch design, implemented by the magnetic bars, would allow higher resolution and eliminate the vibration that currently exists with Phase I HUI, therefore meeting the Phase II design requirements and addressing the two major issues identified by users.
6.2 Testing – Prototype I

Mr. Blosser assisted in the design and creation of the magnetic latch prototype. He demonstrated the latching device’s ability to raise the pin when pulses were sent and drop the pin when the polarity was reversed. Prototype I was very basic and only demonstrated the use of one pin built from a stack of magnets. Team 6 then performed additional tests of the single magnet stack pin prototype. To test the prototype we used the power supply provided in lab and connected two banana-to-banana connectors to the ports of the power supply. We clipped one of the alligator clips of the prototype to one of the banana ends. Then to complete the circuit we briefly touched the other alligator clip to the banana connector. This momentary pulse consistently raised the pin. Alignment issues between the magnet stack pin were identified and resolved using a single magnet design. Figure 6.2a and Figure 6.2b exhibit the prototype.

Mr. Blosser stated that he ordered magnets that have a smaller diameter online and would like to implement those in the next prototype with eight-by-eight array of pins. The smaller magnets would be the shape of the pin and enable an eight-by-eight array design. Decreasing the diameter of the magnets will decrease the distance between the pins. This reduction will establish a device that is competitive with the resolution of existing products. Also it would be consistent with how Braille is written. Braille characters are close together, so the reader is able to read in a fluid motion.

Figure 6.2a: Magnet Schematic

Figure 6.2b: Prototype I
6.3 Testing – Prototype II

Prototype II is an improvement upon Prototype I. After testing Prototype I, it was discovered that the magnets alone did not exert enough force to withstand the force of the user’s finger. In order to increase the force, a solenoid would need to be added. With the addition of a solenoid, the design proved to be effective. To build the solenoid, a hypodermic needle was used as the base and copper wire was wounded onto it. A cylinder magnet was placed within the tubing. Figure 6.3a is a schematic of the solenoid. The polarity reversing concept to raise and lower pins was demonstrated for Prototype II. Prototype II is depicted in Figure 6.3b. Figure 6.3c illustrates the reversing of the polarity to either raise or drop the pin.
6.4 Solenoid Driver Circuitry Simulations

In order to drive the solenoid, a circuitry design needs to be implemented. Figure 6.4a is a model and simulation of the circuit that was used to power each solenoid for the Phase I project. The output of the circuit is a solenoid, which acts as an inductor. The vibrations that were created each time the pin raised and dropped are seen in the output signal.
Team 6’s first circuitry design included a push-pull circuit. The push-pull circuit was implemented in order to have short pulse width, which will create better control and will eliminate the vibration issue. I will also decrease the heat dispersion, since the pulse width of each pulse has decreased. Figure 6.4b is a simulation of this design, along with the circuit schematic. However, the problem with this design is the current and voltage signals do not match. The second issue is that with a higher inductance, the voltage and current signals decay with time.

To correct these issues, a revised design was created. This design includes the addition of a voltage comparator and a differentiator. When the input signal rises, the output voltage is a short positive pulse corresponding to the current in the solenoid. Therefore, the magnet in the solenoid will be forced to rise up based on the polarity. When the signal is on its falling edge and the current changes direction, the solenoid switches polarity and allows the pin to drop down. The voltage comparator and differentiator also solved the problem of

Figure 6.4b: First circuitry design

To correct these issues, a revised design was created. This design includes the addition of a voltage comparator and a differentiator. When the input signal rises, the output voltage is a short positive pulse corresponding to the current in the solenoid. Therefore, the magnet in the solenoid will be forced to rise up based on the polarity. When the signal is on its falling edge and the current changes direction, the solenoid switches polarity and allows the pin to drop down. The voltage comparator and differentiator also solved the problem of
decaying voltage and current signals. Figure 6.4c illustrates the success of the addition of the voltage comparator and differentiator to the push-pull circuit.

![Figure 6.4c: Revised driver circuitry](image)

## 6.5 Planned Testing and Implementation

Testing the eight-by-eight array prototype that will raise multiple pins when specified to insure that the magnetic field of each pin will not interfere with others is the first priority. If this problem arises, our plan is to shield the pins to eliminate this issue.

The second stage testing involves the creation of software that is necessary for a working device. New code will need to be written in order to send the pulses to the new magnetic bar design. Some of the current code will be altered to support this device, while other portions will remain the same and be used. Rigorous testing of the integrated code will be a priority. That will insure that the user interface continues to function properly.
The third stage testing will occur after the rigorous second stage testing is successful. The design will be tested with several different graphic images to insure proper functionality. Current blind students will participate in testing and assess the device. Corrections may be made to reflect reviews from testers.

Once the third stage of testing is completed without any unexpected behavior, and with all system parameters meeting design specifications, the eight-by-eight design prototype will be implemented and any scale-up issues identified. The final prototype will undergo refinements and final packaging to prepare it for presentation at design day.

7. Risk Analysis

Team 6 is giving careful consideration to identification and mitigation of risks involved when the Phase II HUI is in use. For the magnetic latching design solution there are a few risks associated. The first one is the amount of heat dissipated by our product. With sixty-four solenoids, there will be a significant amount of current running through the device. While the plan is for only a pulse with a short pulse width to be sent to each solenoid, a heating issue could still arise. In order to resolve this problem, the addition of heat sinks could be added to each individual solenoid. A small fan could also be added to reduce the amount of heat that is produced within our device.

The second issue is noise. When the pin latches up it taps the top of the casing. While it may only be slightly noticeable with a one pin prototype, once the full scale model is implemented there will be sixty-four pins. With sixty-four pins the noise level will increase. There are two solutions to this concern; one is installing rubber stoppers onto each pin. The rubber stoppers would prevent the two metals from ever touch and would therefore decrease the amount of noise when the pins rise. The other would be to select a material for the case that would help absorb some of the noise.
A third potential risk would occur if the pins became projectiles. The solenoids each have a significant amount of force that is induced onto the pins. If the pins were not contained well within the casing, a serious issue could occur. The previous solutions that reduce the noise will also contribute to maintain a safe device. A lock mechanism for the case is also under investigation to ensure use by the intended person and not by the intended person's children.

8. Project Management Plan

8.1 Team Member Roles

Every member of the ECE 480 Design Team 6 will have both a technical role that is subject to change, as well as an administrative role determined by Dr. Grotjohn. Though these technical and administrative roles exist, it is up to the team as a whole to work together toward a common goal to guaranty success. Some minor technical roles have yet to be decided at this time. These minor technical roles will be assigned as there need arises. ECE 480 Design Team 6 will work collectively to ensure each member's individual tasks are met.

8.1.1 LeRonn Wilson

Overall Product Implementation / Project Manager

Mr. Wilson's responsible includes the overall product implementation and final testing of the device. His responsibility as team manager is to coordinating meetings, facilitate communications with the facilitator, sponsor and team, and maintaining the GANTT chart.

8.1.2 Bin Tian

Circuit Design and Simulation / Document Preparation

Mr. Tian is responsible for the design and simulation of the solenoid driver circuit that will be needed to supply power to each of the solenoids. Mr. Tian is accountable for the preparation and coordination of all written
documents as well as all final editing of every document. It is also his responsibility to organize and maintain the team documentation portfolio.

8.1.3 Eric Bell  
**Hardware Design and Implementation / Website Management**  
Mr. Bell’s responsibilities include the design of the hardware components used within the device. This also includes the implementation of these components into our design solution. Mr. Bell is responsible for the upkeep of the website so all interested parties may look at documents related to the design project.

8.1.4 Kristen Kirchhoff  
**Hardware Testing / Presentation Preparation**  
Ms. Kirchhoff is responsible for testing the hardware for each stage of the project. The devices included in the testing are: the circuitry for the solenoid driver, the power supply, and the magnetic latching mechanism. Ms. Kirchhoff is responsible for managing the preparation and execution of any material to be presented. The presented material will be coordinated via power point slides and prepared for using effective and engaging presentation techniques.

8.1.5 James Hunter  
**Software Modification / Lab Coordinator**  
Mr. Hunter’s responsibilities will be to modify the custom software that was previously created. The new software will need to be able to control an eight-by-eight matrix of solenoids and pins. Mr. Hunter is responsible for ensuring the cleanliness and orderliness of the laboratory. He is also responsible for checking out any items from the ECE shop and putting in orders for parts.
9. Budget

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| Total Cost                          | $260  |
10. References


