Digital Braille Watch

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Client: Holly and Colton Albrecht
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Abstract

The visually impaired rely on the Braille system to read and write. However, there isn't a current watch design that utilizes Braille. A watch of this type would allow the visually impaired to read the time accurately, discretely and efficiently. Current watch designs for the visually impaired include an analog tactile watch and an audio watch. However, the analog tactile watch is difficult to read and breakable, while the audio watch is disruptive and draws attention to the user. Since the current methods are inadequate, three preliminary digital Braille watch designs were proposed. The first design consists of four vibrating motors that display the time by vibrating in sequence. The next design uses solenoids to raise and lower dots, arranging them in a way that correctly displays the time. The final design uses eight rotating disks with two Braille dots apiece. These disks can be rotated to 90, 180 or 270 degrees to orientate in the correct position and display the correct time. After evaluating the pros and cons of each design, it was decided that the rotating disks design would be the best to pursue. Future work includes finalizing the specifications for circuitry and hardware, constructing the prototype, extensive testing, and modifying the prototype based on the testing results.

Background

Problem Statement

In order to independently determine the time, the visually impaired currently depend on audio or tactile analog watches. However, audio watches are disruptive, while the analog tactile watches are often fragile and difficult to read. Our goal is to develop a digital Braille watch that will efficiently display the time without the issues of the current technologies. This watch should display military time, be accurate and reliable, and utilize the standard Braille numerals.

Braille Basics

The Braille system is the most common writing and reading method used by the visually impaired. Each character is composed of a three row by two column grid of potential dot positions. Raised dots are placed in the six positions, using various combinations to denote different alphabetical and numerical characters. The reader identifies the characters by running his or her finger over the raised dots.

Certain size specifications exist to ensure that Braille is easy to read. Braille dots should be raised 0.019 inches off of a surface, with a base diameter of 0.057 inches. Distances between dots within a given character and between adjacent characters should be 0.092 inches and 0.245 inches center-to-center, respectively (Size and Spacing of Braille Characters).

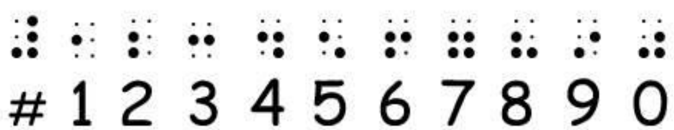

Figure 1 – Nemeth Braille numerals 0-9
Image courtesy of Dotless Braille:
http://www.dotlessbraille.org/AboutBraille.htm

An interesting note about Braille numerals is that they only use the bottom four positions of the three by two grid (Figure 1). Since our watch design only needs to display numerals, we can reduce the complexity of our design by displaying each number using a two by two grid.

Figure 2 – Audio watches verbally communicate the time
Image courtesy of Independent Living Aids, LLC:
http://www.independentliving.com/prodinfo.asp?number=756480

Current Methods

There are two main categories of watch products currently on the market for the visually impaired: audio watches and analog tactile watches. Audio watches, informally called talking watches, function by verbally relaying the time to the user whenever the user presses a button (Figure 2). This method is very effective in communicating the time; however, it can be very disruptive and potentially embarrassing for the user. The time is announced to anyone in the vicinity and can attract unwanted attention to the visually impaired individual. Analog tactile watches on the other hand are silent (Figure 3). They function much like traditional analog watches, except in this case in order to tell the time the user must touch the face of the watch and feel where the hands are located. There are also raised markings on the watch that indicate the positions of the numbers; however, there is no standard format for these markings and they vary from product to product. Our client has informed us that these watches can be difficult to read and come with a learning curve when they are first used. Also, the hands of these watches are exposed while the user is telling the time, and therefore they can be easily broken or damaged.

Figure 3 – Visually impaired touch the hands of the tactile analog watch to tell the time
Image courtesy of Independent Living Aids, LLC:
http://www.independentliving.com/prodinfo.asp?number=684512

Figure 4 – Haptica Braille Watch design by David Chavez
Image courtesy of Tuvie Design of the Future:
http://www.tuvie.com/haptica-braille-watch-concept/

In addition to these currently available watch products, there is a watch that has recently been designed called the Haptica Braille Watch (Figure 4). This design features a set of 16 rotating disks that circulate Braille dots in and out of the display to assemble the desired Braille numerals. Each disk contains a single Braille dot that is moved in concert with the other disks to display the time in Braille. This concept was created by David Chavez in 2008. Chavez is not an engineer and, to our knowledge, has not yet created a prototype for his design.

Design Criteria and Considerations

Design Specifications

Our clients for this project are Holly and Colton Albrecht. Colton is Holly's visually impaired son; together, they came up with the idea for the digital Braille watch. As such, the project will be created in accordance to their wishes and specifications. Their main requirements are that the design is able to correctly display the current time in standard Braille, utilize military time, and operate without any noise. The watch must not be dangerous to the user, so moving parts and electronic components must be contained properly. It has to be accurate within the minute whenever it is connected to a power source. Holly doesn't require that our prototype is any particular size; rather she is looking for a proof of concept. However, the watch should be designed so that it would be possible to scale down to watch-size in the future. For more information on the product design specifications, see Appendix A.

Funding

Since caring for a visually impaired child can be financially taxing, it is difficult for our client to provide funding for this project. As a result, we turned to outside sources to try to offset the financial burden on our client. Based on advice from our advisor, Dennis Bahr, we wrote a budget proposal (Appendix B) to the Madison Institute of Electrical and Electronics Engineers (IEEE). We asked the IEEE, which Dennis is a member of, for $500 towards the completion of our prototype. It is our hope that the IEEE will grant us sufficient funding so that we will not be forced to use any of our client's money.

Vibrating Dots

The task of designing a Braille watch has been presented to two previous BME design groups; this design is a continuation of what our predecessors have accomplished. It features four vibrating motors that vibrate in sequence to communicate the time (Figure 5). When the user presses a button on the watch, the four motors vibrate to signify one Braille numeral, and, after a short pause, they vibrate again to denote the second numeral. This process is repeated until all four numerals have been relayed to the user. A major obstacle that the previous groups faced was the challenge of separating the vibrations of the four motors in order to provide accurate readings. The last group accomplished this by placing the motors on the outside of the watch and inserting a piece of viscoelastic foam between the motors and the display. Strands of copper wire were wrapped around each motor and led up around the foam to the display. The user would feel the tips of these wires to tell the time.

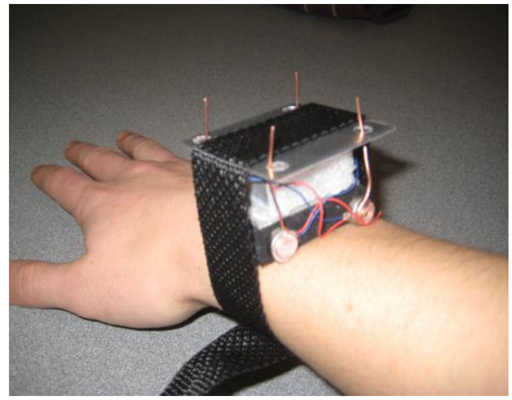

Figure 5 – Vibrating dots prototype created by past BME design team
Image courtesy of BME 200 Fall 2008 Digital Braille Watch Team:
http://homepages.cae.wisc.edu/~bme300/braille_watch_f08/secure/

The fall of 2008 team that worked on this project was able to construct a working prototype of this design; however, it has some major draw backs. Our client Colton informed us that many visually impaired people have increased sensitivity to touch in their hands. This is due to the fact that many of them use their fingers to detect subtle tactile differences, including those encountered while reading Braille. As a result, the vibrations of this prototype have an over-stimulating effect. Also, because of the size of the watch, the user must use their entire hand to read the device. This ends up creating an experience that is very different from actual Braille reading, which only requires one finger tip. In addition to posing this challenge, the design is also relatively power hungry. Watches are devices that are expected to run for long periods of time while using limited amounts of power. The act of generating vibrations is very power-intensive compared to the other mechanisms of a normal watch. This means that this watch would not last very long compared to other watches, and its power source would have to be replaced or recharged more frequently. After meeting with our clients, they informed us that they did not approve of this design and they want us to take a different course of action with this project.

Actuating Dots

As suggested by our client, we began our design search by looking at HumanWare's BrailleNote system (Figure 6). This device has an 18 character refreshable display and is used as a link for the visually impaired to the digital world. To form the display each Braille dot is a pin that actuates up or down through a flat surface (Figure 7). This gives a familiar Braille configuration similar to feeling bumps on a sheet of paper.

Figure 6 – HumanWare's Braille Note is used by the visually impaired to read computer screens
Image courtesy of HumanWare
http://www.anu.edu.au/disabilities/atproject/BrailleNote/index.php

After doing patent research for possible mechanisms to drive the pins up and down, it was found that many solutions have been proposed. Some of these included attaching the pins to a spring mechanism or an electromagnetic solenoid. These mechanisms are highly complicated and mechanically intense. For our display we would need 16 individual actuating mechanisms to display the four numerals, making for a complicated product. This complexity would make it exceedingly difficult to both create a prototype and to eventually be able to scale it down to actual wristwatch size. Also, since the pins would be driven up and down many times, this mechanism would also use quite a bit of power; causing it to need a power source larger then those commonly found in wristwatches.

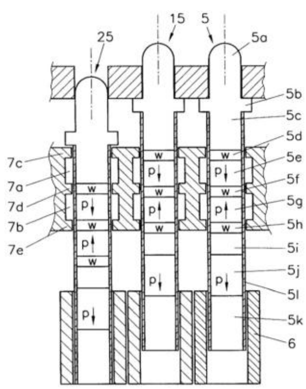

Figure 7 – Actuating dots mechanism
Image courtesy of Litschel, Dietmar, and Schwertner

Rotating Disks

This design uses eight rotating disks to form the required Braille numerals. Each disk would have two raised dots, which could be configured to form the top or bottom half of the character cell (Figure 8). When read by the user, this design would create the sensation of classic Braille.

This design was inspired by the Haptica Braille Watch concept proposed by David Chavez. Although the designs share the concept of having disks rotate in and out of the display area, this design has a much easier mechanism. By placing two dots on each disk instead of one, the amount of disks needed to form the display is reduced from 16 to 8. This reduction of moving parts has several critical benefits. There would be considerably less power consumption for each reconfiguration. In addition, it would be easier to scale down a prototype to wristwatch size.

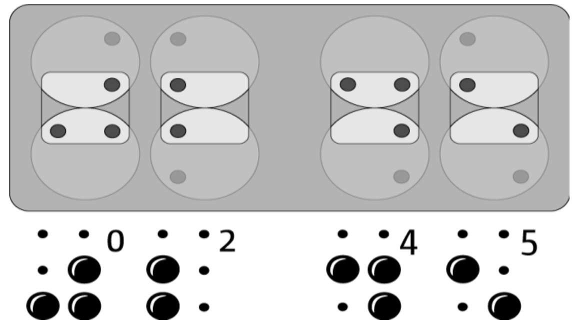

Figure 8 – By a rotation of 90º, 180º or 270º, the disks can display the correct time

Design Evaluation

The vibrating dots, actuating dots, and rotating disks designs were evaluated on a scale of one to ten and weighted for a variety of design criteria (Table 1). The most important criteria were given more weight in the matrix, which include ergonomics, aesthetics, accuracy, and design simplicity. These aspects were determined to be the most important design characteristics since they are critical in terms of the ease of use and effective functionality of the final product.

Table 1 – The design matrix displays the design evaluation on a scale of one to ten (one = poor, ten = excellent) and is weighted on a variety of design criteria for all three design concepts.

Weight	Design Aspects	Vibrating Dots	Actuating Dots	Rotating Disks
0.05	Prototype Cost	8	6	7
0.15	Aesthetics	4	7	9
0.25	Ergonomics	3	8	9
0.05	Safety	10	9	9
0.10	Durability	9	6	8
0.15	Accuracy	7	10	10
0.15	Design Simplicity	9	4	7
0.10	Scalability	8	6	7
1	**Total**	**6.35**	**7.10**	**8.45**

Ergonomics was weighted most heavily in the design matrix since the two current methods and the previous teams' designs were deficient in this area. Also, we feel that ergonomics is the most important criteria in functionality and success of a watch design. The tactile analog watch is difficult for the user to read, while the audio watch doesn't allow the user to discretely check the time. The vibrating motors design provided an over-stimulation, making it almost impossible to read. The actuating disks and rotating disks designs both provide an easy way for the user to discretely and accurately check the time. Aesthetics also was weighted heavily because the watch shouldn't draw attention to the visually impaired person using it. Since it's a watch, the design must provide an accurate display of the time. The design must also be simple in order to reduce cost, increase durability, and enhance performance. After evaluating the designs, it was determined that the rotating disks design scored the highest and, therefore, was selected as the design to pursue.

Future Work

Materials and manufacturing specifications need to be established for both the hardware and software components of the prototype. It has been decided that radio-controlled (RC) servos will be used to rotate the disks (Figure 9). RC servos can be smaller than two cubic centimeters and are power efficient due to their pulse-width modulation control. The small size of the servos allows them to be easily orientated in a way that corresponds with the design (Figure 10). Pulse-width modulation means that a servo requires a short pulse of varying frequencies in order to rotate a desired angle. For

Figure 9 – Servos will be used to rotate the disks containing the Braille dots
Image courtesy of Tower Hobbies:
http://www.rctankcombat.com/archive/2007-03/jpg00016.jpg

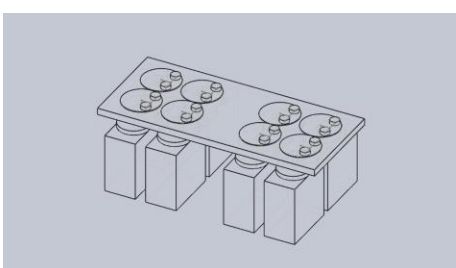

Figure 10 – The rotating disks design will include eight servos, which each control a different disk in the display

example, many servos require 3V over a pulse of 1.5 milliseconds in order to rotate ninety degrees. The power efficiency and small size of servos is what makes them ideal for this project. However, for prototyping purposes, one of the greatest attributes of servos is that they can be controlled by a microprocessor (What's a Servo).

The prototype will be programmed using an Arduino Duemilanove USB Board (Figure 11). Arduino is an open-source computing platform based on an input/output board. It functions using an ATMega168 microcontroller that implements the wiring programming language. Wiring is an open source form of java specifically used for electronics with input/output boards. By downloading the Arduino-0017 and Wiring-0022 programs, code can then be uploaded to the Arduino Board via an USB cord. The code for the prototype will control the servos so that they rotate each minute and orientate in a way that displays the correct military time. An additional feature may be added that allows the user to turn a dial and, thus, change the displayed time. The Arduino Duemilanove contains thirteen output pins, providing an easy method for the programmer to separately control eight servos and any additional knobs or buttons (Arduino Duemilanove).

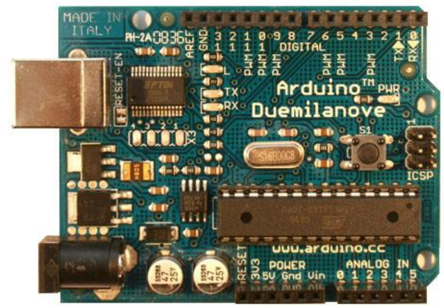

Figure 11 – The Arduino Duemilanove will be used to program the watch
Image courtesy of Arduino:
http://www.arduino.cc/en/Main/ArduinoBoardDuemilanove

There are many hardware specifics that are still being researched. The material for the disks and Braille dots still needs to be determined. Also the electrical components, such as the servos and microcontroller, will need to be encased. It will be difficult to predict what size case will be needed until further progress is made on the programming and other hardware specifics. Ideally, the final prototype will look as much like a watch as possible, however, this will be challenging due to time constraints and a limited budget. After the prototype is constructed, testing will be done with the client to test the effectiveness and limitations of the device. A survey will also be done to determine the value of our design to the visually impaired population. The design will then be modified to fit the results.

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Appendix A: Product Design Specifications

Project Design Specifications—Digital Braille Watch

February 17, 2010

Team: Nick Anderson, Nick Thate, Andrew Hanske, Billy Zuleger
Client: Holly and Colton Albrecht
Advisor: Dennis Bahr

Problem Statement:

To determine the time, the visually impaired currently depend on audio or tactile analog watches. However, audio watches are disruptive, while the analog tactile watches are often difficult to read and fragile. Our goal is to develop a digital Braille watch that will efficiently display the time without the issues of the current technologies. This watch should display military time, be accurate and reliable, and utilize the standard Braille numerals.

Client Requirements:

- Digital military time display
- Silent and without vibrations
- Time in standard Braille

Design Requirements:

1) Design Requirements
   a) *Performance requirements:* See Client Requirements above
   b) Safety: All electronics must be contained and the watch must not contain hazardous materials
   c) *Accuracy and Reliability*: The watch must accurately display military time within the minute
   d) *Life in Service*: The watch must be able function continuously while connected to a power source
   e) *Shelf Life*: Not specified for prototype
   f) *Operating Environment*: The device must be able to operate reliably in a dry environment
   g) *Ergonomics*: The watch should not contain rough edges or loose components and the display surface should be easy to read
   h) *Size*: The prototype does not need to be watch-sized but should be scalable
   i) *Weight*: See Size Requirement
   j) *Materials*: The device must comprise of non-toxic components
   k) *Aesthetics, Appearance, and Finish*: The watch should be aesthetically pleasing
2) Product Characteristics
   a) *Quantity*: One working prototype
   b) *Target Product Cost*: $100 or less when mass-produced

3) Miscellaneous
   a) *Standards and Specifications*: Must display time according to the standard Braille language
   b) *Customer*: The customer would like a device that physically displays the time using Braille digits
   c) *Patient Related Concerns*: None
   d) *Competition*: Audio and tactile analog watches are commercially available for the visually-impaired

Appendix B: Budget Proposal

February 25, 2010

Dear Madison Institute of Electrical and Electronics Engineers,

I'm writing to you on behalf of my engineering team to request funding for our Biomedical Engineering (BME) design project. The goal of our project is to design a digital Braille watch that the visually impaired can use to accurately and reliably read the time.

Our clients, who consist of a mother and her son who is visually impaired, introduced this idea to the UW Madison BME department over two years ago. Current watches that exist for the visually impaired include an analog tactile watch and an audio watch. However, our clients expressed that the analog watch can be difficult to read and that the audio watch can be disruptive. Upon further research, we discovered that many of the visually impaired have experienced similar problems.

Our idea is to design a watch that consists of eight disks. The disks will be oriented in two rows of four, and each will have two Braille dots on its surface. Each disk will be attached to and rotated by a servo, each of which will receive a signal from the same microprocessor. The microprocessor will be used to send the appropriate signal to each servo. This will correctly position the disks and, thus, display the correct time. We are currently working on a SolidWorks drawing that clearly demonstrates this design, and we would be willing to send this to you as soon as it is completed.

As parenting a visually impaired child can be financially straining, it is difficult for our client to provide funding for this project. I'm in turn hoping that you would be willing to support our team in assisting this great cause. We estimate that it will cost us approximately $500 to construct a working prototype. Any dollar amount would be greatly appreciated, but sufficient funding would ensure that we could be successful on this urgent project.

On behalf of my team, I would like to thank you for your time. We hope you are interested in supporting this wonderful cause and look forward to hearing from you soon.

Sincerely,

Nick Anderson