Digital Braille Watch

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Client: Holly and Colton Albrecht
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Abstract

The Braille language has provided the visually impaired with a way to read and write for many years, yet no device exists that allows the visually impaired to read the time in Braille. In order to tell time, the visually impaired currently rely on either talking or tactile watches. However, talking watches are disruptive, while tactile watches are difficult to read and fragile. Our goal is to design a watch that allows the visually impaired to read the time in standard Braille. In order to accomplish this, four preliminary digital Braille watch design options were proposed. The first idea involves using solenoids to raise the correct dot orientation to the surface. However, this design was determined to be power inefficient and difficult to scale. The second option utilizes eight rotating disks to display the four Braille numbers required to tell the time, which was a design pursued by the Spring 2010 Braille Watch design team. This prototype met the client's requirements in terms of functionality but was far too large to be useful as a watch. The third concept, made up of eight sliding plates that shift back and forth to display the correct dot sequences, allows for an ergonomic product. Our final design uses four discs that rotate under a set of four pins. These rotating discs will contain ridges, which push the pins when beneath them and cause them to move above or to remain flat with the watch surface. Based on the location of ridges, different combinations of dots will be displayed on the watch surface and can be read by the user. Due to the lower power consumption of four moving parts and the scalability of this design, it was chosen as the design option to pursue. Our team's future work will include finalizing and fine tuning the design, assembling a prototype, testing, and performing final modifications to our prototype based on the testing results and our client's input.

Background

Problem Statement

Currently, people with a visual impairment must rely on one of two methods in order to tell the time independently. However, talking watches disrupt the surrounding environment and draw attention to its user, while tactile watches are fragile and challenging to read. Our goal is to design a digital Braille watch capable of displaying the time using the standard Braille numbering system. This watch should display military time, be accurate and reliable, silent, and easy to read.

Braille Basics

The Braille language is the universally accepted form of written communication for the visually impaired. It utilizes a system of dots arrayed in a three row by two column grid. Raised dots are then located in any of the six positions, displaying different letters, numbers, and symbols based on their configuration.

In order for this method of communication to be accurate, precise, universal specifications have been developed. Each dot must have a base diameter of 0.057 inches while being 0.019 inches in height. Within each individual grid, the dots must be at least 0.092 inches apart, measured center-to-center, and each individual character should be a minimum of 0.245 inches away from the neighboring character. [1]

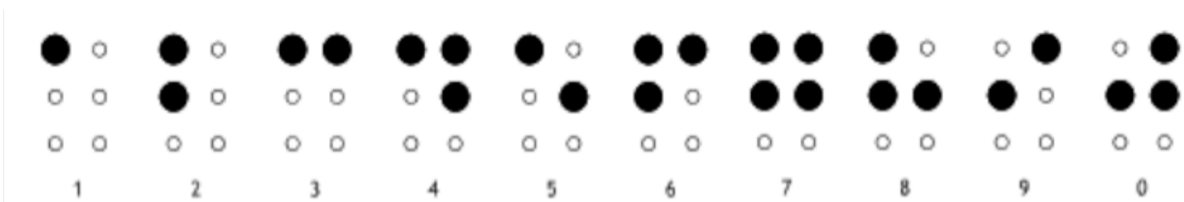

Figure 1 – Braille numerals 0-9
Image courtesy of PharmaBraille:
http://www.pharmabraille.co.uk/braille-alphabet.html

The numbers 0-9 are represented using only the top four dots of the three by two grid simplifying matters for our design process (Figure 1). Instead of having to manage an oblong, rectangular three by two grid, the design of the watch is much simpler and requires only a two by two grid to display any number.

Current Methods

There are two main categories of watch products currently on the market for the visually impaired: talking watches and analog tactile watches. Talking watches function by

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

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 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. Since the hands of these watches are exposed while the user is reading the time, 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 Auguste Reyond:
http://watchluxus.com/braille-watches-by-auguste-reyond

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

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/

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. [2]

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, thus moving parts and electronic components must be contained properly. The time has to be accurately displayed whenever the watch is connected to a power source. Holly does not require that our prototype be 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 will be turning to outside sources to try to offset the financial burden on our client. Based on advice from our advisor, John Puccinelli, we will be writing a budget proposal to the Biomedical Engineering Department at University of Wisconsin-Madison to request funding. It is our hope that the BME department will grant us sufficient funding so that we will not have to use any of our client's money.

Actuating Dots

As suggested by our client, we began our design search by looking at HumanWare's BrailleNote system (Figure 5). 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 6). This gives a familiar Braille configuration similar to feeling bumps on a sheet of paper. [3]

Figure 5 – 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 it 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. Additionally, since the pins would be driven up and down many times, this mechanism would use ample amount of energy; and would require a power/energy source larger than those commonly found in wristwatches. Due to these reasons, we did not include this design on the design matrix.

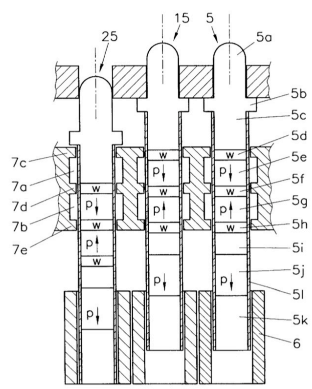

Figure 6 – Actuating dots mechanism
Image courtesy of Litschel, Dietmar, and Schwertner

Rotating Disks

This design is based off of the prototype last spring's Braille Watch design group created. Their design uses eight rotating disks to form the required Braille numerals. Each disk has four raised dots, which can be configured to form the top or bottom half of the character cell (Figure 7). When read by the user, this design creates the sensation of classic Braille. [4]

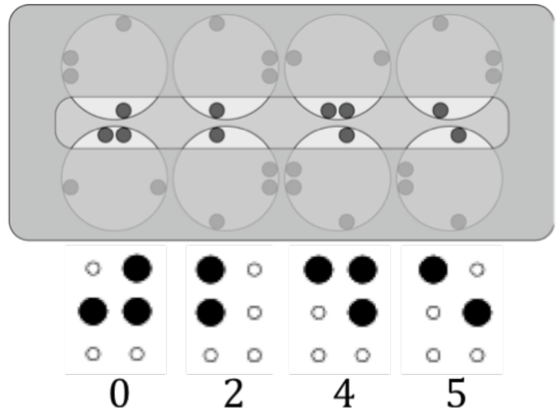

Figure 7 – By a rotation of 90º, 180º or 270º, the disks can display the correct time
Image Courtesy of Spring 2010 Braille Watch Team

This design met the client's requirements and is the first existing Braille time-keeping device. However, many downfalls exist with this design. As can be seen in Figure 8, the prototype is much too large to fit on the wrist of a user, thus, the size must be reduced significantly. Also, this device uses eight moving parts, leading to high power consumption. Although the eight rotating disks is an improvement over the sixteen solenoids of the previous design, ideally the number of moving parts could be cut further. With this specific design, there is not much opportunity to significantly reduce size and power use within the time limitations of the semester. Finally, due to the mechanical nature of this design, the Braille numbers were often difficult to read. The Braille display relied heavily on the accuracy of the servo motors used to rotate the disks.

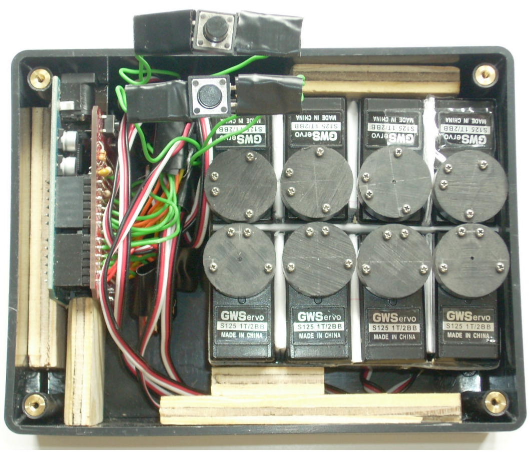

Figure 8- Internal view of rotating disk prototype
Image Courtesy of Spring 2010 Braille Watch Team

Sliding Plates

The Sliding Plates design is rather unique from previous design concepts. It consists of eight plates that lay paired up along the watch, with each pair creating a single Braille digit. Every plate can slide up or down within the face of the watch, revealing one, two or no dots as necessary (Figure 9).

An advantage to this design is its potential to be small. The plates would be thin, which corresponds with making a light and ergonomically friendly watch. Additionally this model is less likely to have alignment errors that could cause user confusion. Each Braille dot would be spaced at a standard distance relative to the others. Nonetheless, there are drawbacks. This design contains complications with regards to the mechanism driving it. While possible, sliding the plates back and forth to specified positions becomes intricate, making it challenging to create. Also the Sliding Plates design still has eight moving parts, a problem shared with last semesters design. The numerous moving parts puts this design's power requirements well above that of either of the existing methods.

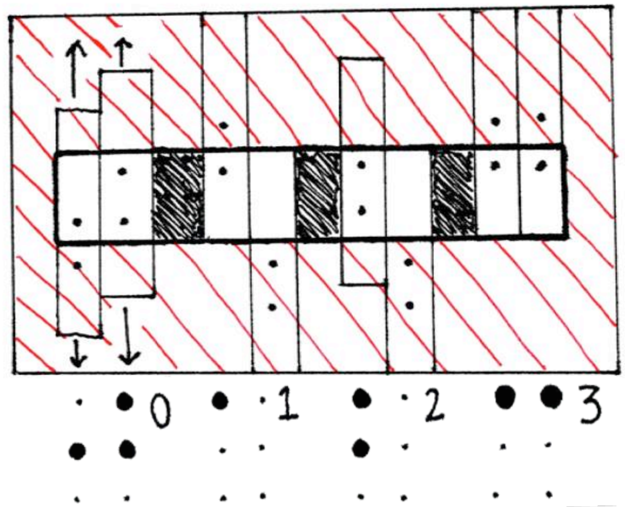

Figure 9 – Plates slide up and down to display the correct time

Disk and Pins

The Disk and Pins design, much like its name suggests, consists of disk and pin sets. Four disks are located beneath the watch surface, one for each Braille numeral. Above each disk four pins are positioned so that they rest on the disks surface. The portion of the disk against which the pins rest has both raised and recessed sections (Figure 10). If a pin is on the raised surface, it will be pushed slightly above the watch plane, and if not, the top of the pin will remain flush with the surface of the watch (Figure 11). When the disk rotates to different positions, different combinations of pins are raised. In this way all necessary numbers can be displayed.

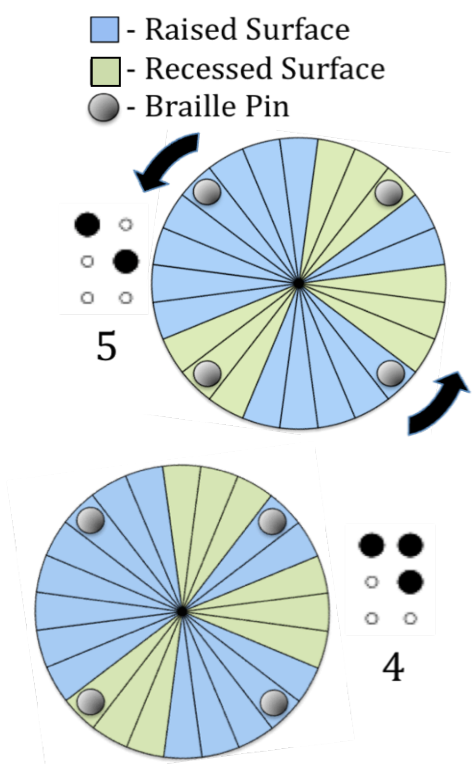

Figure 10– The raised and recessed surfaces on the disk cause different numbers to be displayed

A clear benefit to this design is that only four moving parts are needed. This cuts down on the energy necessary to run the watch. Smaller servos than those which last semester's group used can be utilized, since the disk would not have to turn more than 165 degrees to achieve numbers zero through nine. Not only does this design permit smaller components, but it also removes ambiguity of the Braille number display. The pegs stay in place, causing the Braille dots to remain aligned. And though this design provides little room for alignment error in the disk placement, its benefits far outweigh its minimal downfalls.

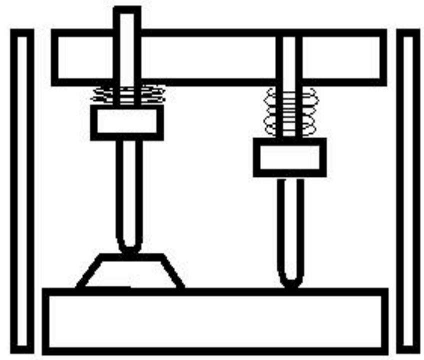

Figure 11: The raised surface on the disk pushes the Braille pin to the surface of the watch

Design Evaluation

The rotating disks, sliding plates, and disk and pins designs were evaluated on a weighted one to ten scale for a variety of design criteria (Table 1). The most important criteria were given more weight in the matrix and 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.

Weight	Design Aspects	Rotating Disks	Sliding Plates	Disk and Pins
0.05	Prototype Cost	6	7	9
0.15	Aesthetics	7	8	9
0.25	Ergonomics	7	8	9
0.05	Safety	9	9	10
0.10	Durability	8	8	8
0.15	Accuracy	10	10	10
0.15	Design Simplicity	9	9	7
0.10	Scalability	5	10	9
1	**Total**	**7.70**	**8.65**	**8.80**

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 the functionality and success of a watch design. The rotating disk design is too large and lacks potential to be scaled down to a typical watch size. The sliding plates would be a better design ergonomically; however, the disks and pins offer an efficient way to produce a pocketsize watch. Aesthetics also was weighted heavily because the watch should not draw any attention to its user. One of the most important features is the watch's ability to reliably and accurately display the time. The design must also be simple in order to minimize cost, increase durability, and enhance performance. After evaluating the designs' pros and cons, it was determined that the disk and pins 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. The need for a 165 degree rotation will allow smaller servos to be used than those used on the project last semester. RC servos can be smaller than two cubic centimeters and are power efficient due to their pulse-width modulation control (Figure 12). The small size of the servos allows them to be easily orientated in a way that corresponds with the design. Pulse-width modulation means that a servo requires a short pulse of varying frequencies in order to rotate a desired angle. For example, many servos require 3V over a pulse of 1.5 milliseconds in order to rotate ninety degrees. The power efficiency, small size, and number of servos are what make them ideal for this project. However, for prototyping

Figure 12 – Servos can provide a desired angle rotation and can be as small as a quarter
Image courtesy of Robot-HK:
http://www.robot-hk.com/products_m18.asp?lang=en

purposes, one of the greatest attributes of servos is that they can be controlled by a microprocessor. [5]

The prototype will be programmed using an Arduino Mini USB Board (Figure 13). 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 a USB cord. The code for the prototype will control the servos so that they rotate each minute and orient in a way that displays the correct military time. A button may be added so that the user can toggle between modes and read the date as well. The Arduino Mini contains six output pins, providing an easy method for the programmer to separately control four servos and up to two additional buttons. [6]

Figure 13 – The Arduino Mini will be used to program the prototype
Image courtesy of Robotshop:
http://www.robotshop.ca/arduino-mini-microcontroller.html

As for the Braille pins, it has been decided that slender acrylonitrile butadiene styrene (ABS) plastic rods shall be used. Also the electrical components, such as the servos and microcontroller, will need to be encased. The projected size of the prototype is about the size of a cell phone. Ideally, the final prototype will look as much like a watch as possible, however, this may be challenging due to limited funds and time. After the construction of the prototype, testing will be done with the client to check the effectiveness and limitations of the device. The design may be modified based on defects that may be revealed during testing to further enhance the design.

References

[1] "Size and Spacing of Braille Characters." *Braille Authority of North America*. n.d. 15 Sep. 2010. <http://www.Brailleauthority.org/sizespacingofBraille/>.

[2] "Haptica Braille Watch Concept." *Tuvie Design of the Future*. 2009. 24 Sep. 2010. <http://www.tuvie.com/haptica-Braille-watch-concept/>.

[3] Litschel, Dietmar, and Schwertner. Device for Representing Relief Items. Caretec GmbH, assignee. US Patent 6109922. 2000.

[4] "Braille Watch." *UW-Madison Biomedical Engineering Design Courses – Project Pages*. 2010. 22 Sep. 2010.

[5] "What's a Servo?" *Seattle Robotics Society* .n.d. 30 Sep. 2010. <http://www.seattle robotics.org/guide/servos.html>.

[6] "Arduino Mini." *Arduino*. n.d. 10 Oct. 2010. <http://www.arduino.cc/en/Main/Arduino BoardMini>.

Appendix A: Product Design Specifications

Product Design Specifications—Digital Braille Watch

September 24, 2010

Team: Nick Anderson, Taylor Milne, Kyle Jamar, Chandresh Singh
Client: Holly and Colton Albrecht
Advisor: John Puccinelli

Problem Statement:

In order to determine the time, the visually impaired currently depend on audio or tactile analog watches. However, audible 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*: Audible and tactile analog watches are commercially available for the visually impaired