Braille Display Solutions for the Visually Impaired

Introduction

The United States today houses 12 million visually impaired citizens in its borders, a population whose challenges go largely unaddressed in today's digital age. With the recent explosion in the popularity of e-reader devices, a number of engineering teams have taken it upon themselves to bring virtual reading to the visually impaired. There are special considerations one must take into account when developing adaptive displays using the preferred braille, however; market solutions thus far have struggled to balance cost effectiveness with ease of use across several design approaches. This paper reviews current solutions and a general approach to braille display.

Current Commercial Solutions

Market solutions for braille readers follow a form factor of having braille cells, each housing between six and eight individual pins from which to display characters, laid in a horizontal row of some 20 or 40 cells. Each of these cell assemblies contains its own PCB coupled to a backplane board, employing piezoelectric bimorph reeds to drive the tactile pins [1]. Pin action is triggered by a PWM output from a microcontroller or FPGA situated on the device, or in some models a USB device via I2C [2]. These then control 36V cylindrical coils to ultimately activate the pins on the display and output characters to the reader [1]. By activating a series of these cells the devices output braille text to the user, who can read the device naturally by running their fingers along the row of cells.

While designs of this nature have the benefit of ease of access for braille readers, the precise manufacturing and materials cost has so far made such devices prohibitively expensive for most. This is made apparent by looking at the solutions currently on the market. Choosing four available private solutions of this design, specifically the VarioPro 64, Orbit Reader 20, Orbit Reader 40, and Smart Beetle Display, one can note a retail price of $10,000, $700, $1400, and $995 respectively[3,4,5,6]. While pricing of this magnitude is likely a large barrier for the intended users ability to obtain these products, some recent attempts have been made at refining this approach.

High-Level Design Approaches

Much of the cost in designing braille display solutions comes from manufacturing large-scale arrays of mechanically independent piezoelectric pins. While this design is uniform across commercially available products, a single cell display has been proposed as a possible fix to the cost problem [7]. This design uses piezoelectric reeds and cylindrical coils to create tactile feedback similar to other devices on the market, but instead utilizes just one braille cell to output text to the reader. Instead of running one's hands along an array of cells to read words, the reader simply holds their finger in place over one of these cells as it outputs braille characters at a constant rate. This takes advantage of the piezoelectric approach's high refresh rate [2] to output words at a reasonable pace to the user while reducing cost.

Another major approach aimed at reducing cost is the "braille cursor" which refreshes the display using a magnetic actuator. This design trades out the piezoelectric pin layout of the previously mentioned designs for a simple set of steel pins seated in plastic that are pulled out of the chassis of the device as an electromagnet passes over on a linear slider [8]. By refreshing cell pins with this scan-over approach, the cost is reduced twofold: first by changing the pin material from relatively costly bimorph reeds to a simple steel or iron needle, and second by allowing significant scaling in the number of braille cells with little significant cost increase [8]. This approach maintains ease of access for the visually impaired while lowering cost as well, as the multi-cell layout more closely mirrors braille reading in non-digital settings [9].

Drawbacks and Tradeoffs

An effective braille display must balance cost and accessibility in its design for the user. Looking at the approaches discussed in this paper, one can notice two significant philosophies with regard to the layout of the braille display: the use of a single-celled display to output characters to a stationary user, or the use of a multi-celled display to output characters to a user which in turn runs their fingers over the display. While the former approach is far more simple to implement and requires 1/20th to 1/40th the amount of braille cells, static displays have a dramatic effect on users' abilities to read accurately. In an experiment assessing reading accuracy in these two approaches, researchers recorded error rates of 0.25 ± 0.11 and 0.27 ± 0.11 for users provided static, unicellular devices, and corresponding rates of just 0 and 0.06 ± 0.04 for those given devices which emphasized users running their fingers along cell pins [9]. This is hypothesized to be the result of increased proprioception or a different tactile feel for more movement-based approaches, however further finger tracking systems have been developed to help researchers narrow down the exact cause [10]. The tradeoff here is sharp; greatly reducing the number of cells required in manufacturing in turn greatly reduces cost, but at a measurable loss in ease of use for end users.

One also notices this cost-accessibility tradeoff when looking at the two row-based approaches discussed thus far. The electromagnet mechanism mentioned provides a cheaper alternative to the common state-of-the-art approach, but at the expense of having a slider loom above where users would place their hands. This slider, while allowing for a much cheaper pin design, also greatly reduces the screen's refresh rate by requiring the electromagnet to physically scan over all cells twice before a full update is completed [8]. By contrast, conventional displays can send updates to the entire display simply with one electrical signal, but with dramatic increases in mechanical complexity and thus cost.

References

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