HELPING TO INTEGRATE THE VISUALLY CHALLENGED INTO MAINSTREAM SOCIETY THROUGH A LOW-COST BRAILLE DEVICE

Desirée Jordan, Adrian Als, Paul Walcott, Ramon Sargeant
Department of Computer Science, Mathematics and Physics
University of the West Indies (Cave Hill Campus)
Barbados
Desiree.jordan@mycavehill.uwi.edu

Abstract

The visually challenged are often alienated from mainstream society because of their disabilities. This problem is even more pronounced in developing countries which often do not have the resources necessary to integrate this people group into their communities or even help them to become independent. It should therefore be the aim of governments in developing countries to provide this vulnerable people group with access to assistive technologies at a low cost. This paper describes an ongoing project that aims to provide low-cost assistive technologies to the visually challenged in Barbados. As a part of this project a study was conducted on a sample of visually challenged members of the Barbados Association for the Blind and Deaf to determine their ICT skills, knowledge of Braille and their use of assistive technologies. An analysis of the results prompted the design and creation of a low-cost Braille device prototype. The cost of this prototype was about one-half that of a commercially available device and can be used without a screen reader. This device should help create equal opportunities to the visually challenged in Barbados and other developing countries. It should also allow the visually challenged to become more independent.

Keywords: Visually challenged, visually impaired, low-cost Braille display, assistive technologies, Barbados

Introduction

According to the World Health Organization approximately 39.365 million people are blind worldwide and some 246.024 million suffer from low vision [1]. The visually challenged, those who are either blind or have low vision, have a reduced ability to perform many tasks which are considered trivial to the sighted. They are often alienated from mainstream society [2] because of their inability to interact in what many would consider a "normal way." This leads to social isolation and unequal opportunities.

In many developed countries assistive technologies such as Braille displays and screen readers are commonplace. These technologies although useful can be expensive; for example, the US based Manufacturer's suggested price for a 20-cell Braille Display (shipping and handling excluded) is nearly US$2,000 (with a one year maintenance contract) while an 80-cell device can cost US$14,000 (http://www.afb.org/section.aspx?Documentid=1282). In some instances this cost will be subsidized by governments or other funding agencies, for example the Assistive Technology Fund from the Ministry of Community Development and Sports in Singapore (http://app1.mcys.gov.sg/Assistance/AssistiveTechnologyFundATF.aspx). This fund subsidizes the cost of assistive technologies to help the disabled pursue mainstream education or jobs.

In developing countries, however, funding or subsidies for such technologies is limited thus compounding the problem of unequal opportunity. Not only is the cost of ownership restrictive as noted earlier, but also the ongoing maintenance cost which can skyrocket over a number of years. It should therefore be the policies of governments in these countries to provide low-cost assistive technologies to the visually challenged so that they may integrate with their communities and feel like valuable members of society, contributing to the economic growth of their countries [2].

This paper describes an ongoing project that aims to provide low-cost assistive technologies, specifically Braille devices, to members of the Barbados Association for the Blind and Deaf (BABD). As a part of this project a study was conducted using a sample of BABD members to determine their ICT skills, knowledge of Braille, and their use of assistive technologies. A major aim of this study was to determine whether there was a need for low-cost Braille Displays.

The research questions asked were:

1. What is the nature of the members' visual challenges?
2. What are members' knowledge and interest in Braille and other assistive technologies?
3. What are members' ICT skills?

The significance of this work is that its aim is to help integrate the visually challenged into mainstream society by reducing the cost of ownership of an assistive technology.

The remainder of this paper describes the research literature including initiatives which provided assistive technologies to the visually challenged. It also discusses the study and its results. It continues by outlining the requirements, design and development of a low-cost Braille device prototype. The testing of this prototype by one of the members of the BABD is then discussed and conclusions and future work presented.

Literature Review

Sight has long been considered the most important of the five (5) senses and loss of vision may cause various levels of psychological suffering, greater than that caused by other forms of sensory impairment. Three of the usual reactions are acceptance, denial and depression [3]. It was noted that persons with complete vision loss tend to have less anger, depression and hostility than those with partial loss.

According to Tunde-Ayinmode et al [4], certain social challenges of blindness (including employment, mobility and marriage) affect not only the blind themselves and their families, but society in general. Other effects of vision loss can include functional disability, social isolation, diminished productivity and a loss in quality of life [5].

In some cases, cultural and gender role issues have implications as well. Women who are denied equal access to health services, employment and education are less able to care for their families [6]. Women with disabilities are also at greater risk of abuse and social exclusion.

Low self-esteem and self-acceptance are also the result of vision loss [7]. However, access to rehabilitation services and societal support are important in the proper adjustment to life without sight [3-7].

The visually challenged comprise of persons who were impaired from birth and those who due to age, accident, or medical conditions have lost some or all of their vision over time. The one thing that they all have in common is the associated stigma attached to the impairment and the challenge to cope as they find alternative ways to navigate through life. Those who lose their vision through age (i.e. 55 – 75 yrs) increasingly become dependent on others, leading to depression and lack of participation in social activities [8]. This has the added effect of negatively impacting on their health and quality of life.

Boerner and Wang take the view that when the loss of vision occurs during midlife there are a variety of options that rehabilitation services can employ to help individuals to cope. In their findings, the use of technology was highlighted as one of the new coping strategies [9]. Among the technology tools listed were computer voice software and the use of the computer to write documents.

Traditionally, the visually challenged face many hurdles to gain independence. The work by Malakpa highlights that a key to this independence stems not only from special education and rehabilitation services, but also from employment opportunities [10]. The apprehension of employers in hiring such persons due to the perceived risks is only one hurdle to be overcome. There are also challenges with transportation, workplace safety and alienation by work colleagues. Malakpa posits that this vulnerable people group needs to be empowered to surmount these and many other impeding factors that prevent them from gaining and retaining jobs. Only then will the derived benefits (such as economic freedom and an improved standard of living) which ultimately lead to a heightened sense of self-worth, be achieved.

The need for access to information by all and sundry has not gone unnoticed by the library institutions. Babalola states that "Libraries have a moral obligation to make information available to all categories of users regardless of their gender, age, political affiliation or disability" [11]. To address this challenge they suggested a policy which included investment in assistive technology. This view is also being adopted at University of the West Indies (Cave Hill Campus) within the 2012/2013 academic year [12]. In the library at the Sakarya University the assistive technology employs speech synthesis [13]. This work involved converting books to digital format using a scanner and then employing text-to-speech software to read the book.

Aziz et al focused on the need for information access for visually impaired children by developing a prototype for assistive courseware [14]. This prototype identified several features which the courseware should exhibit such as audio, graphic and animation features. Additional features included appropriate formatting styles and text sizes. In their work, the use of the mouse was deemed impractical for visually impaired children, so the keyboard was the input instrument of choice.

The literature indicates that ICT and assistive technologies are very promising solutions to help the visually challenged in this modern era point [15-18].

Contextual Framework

This study was conducted in Barbados, the most Easterly of the Caribbean islands with a population of 288,000 (a 2010 estimate) and a land mass of 430 square kilometers (http://www.nationsencyclopedia.com/economies//Americas/Barbados.html).

According to the 2000 Barbados census there were 2,446 blind people in Barbados representing approximately 0.8% of the population.

The BABD is the most active organization for the blind and deaf in Barbados. It is a non-profit organization formed through an Act of parliament in 1957 and has a mandate to protect "the welfare of the blind, visually impaired and the hearing impaired in the society (http://www.mhm.bb/index.php?option=com_k2&view=item&id=34:the-barbados-association-for-the-blind-and-deaf&Itemid=57)."

Members of this association participate in activities such as: blind cricket, computer training and Braille reproduction. Also available is a small assistive technologies resource centre which allows members to utilize computers with screen readers.

The Study

In order to determine the ICT skills, knowledge of Braille and use of assistive technologies of members of the BABD a study was conducted in August 2011 which is detailed in the following sections.

Participants

Eighteen visually challenged individuals agreed to participate in the study. Eight of them were male while ten were female. The average age of the participants was 44.75 years (with a standard deviation of 8.6) and they were all Barbadian.

Data Collection Procedures

Data was collected for this study at the BABD and the National Disabilities Unit headquarters. A convenient sample of members was selected based on their availability when two of the researchers visited the sites in August 2011 to collect data. All participants were ensured of the anonymity and confidentially of the research. Since the participants of the study were visually challenged the researchers first read the questionnaire items then recorded the results after receiving the answer. These questionnaires took about 20 minutes to complete for each participant.

The Instrument

The questionnaire inquired the demographic information of the participants, specifically age, gender and nationality. The participant's occupation, the number of hours a week they work, their visual challenge and the length of time they had the challenge was also determined.

Questions queried the knowledge and use of Braille devices including the length of time used, the grade known, the frequency of use and the experience level of the participants. Participants not knowing Braille were asked whether they were interested in learning and within what time frame. They were also asked about their use and issues with other assistive technologies.

The participants' use and ownership of computers and their computer competencies were also queried. Finally, participants were asked about the software they wanted Braille enabled.

Data Analysis

In this study descriptive statistics were utilized.

Limitations

The limitation of the study was the size and bias of the sample. Although the sample selected represented less than 1% of the overall population of visually challenged people in Barbados, it represented approximately 60% of the membership of BABD. This sample may therefore be deemed as adequate. Bias resulted from the fact that most of the participants were members of the Barbados Association of the Blind and Deaf. This however is acceptable since the BABD is the most active association for the visually challenged in Barbados.

Survey Results and Discussion

Eighty-three percent (approximately) of the participants were employed, however their occupations varied widely as illustrated in Figure 1. Just over ninety-three percent (based on 15 participants) of these participants worked for 40 hours a week or more.

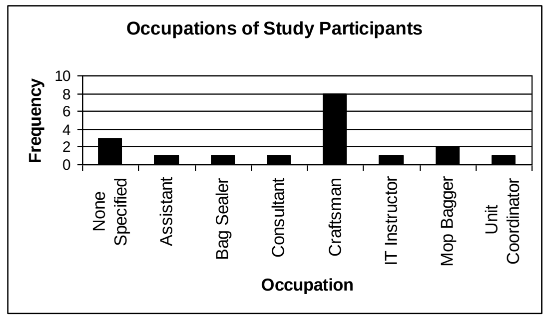

Figure 1. The occupations of the participants of the study

What is the nature of the members' visual challenges?

Forty-four percent (approximately) of the participants were completely blind and about fifty-six percent partially blind. The average time visually challenged was 30.78 years (with a standard deviation of 16.4).

What are members' knowledge and interest in Braille and other assistive technologies?

About 53 percent of the participants (nine participants) were able to read Braille and on average have been reading Braille for 28.86 years (with a standard deviation of 9.0). The frequency of use of Braille by these participants is illustrated in Figure 2.

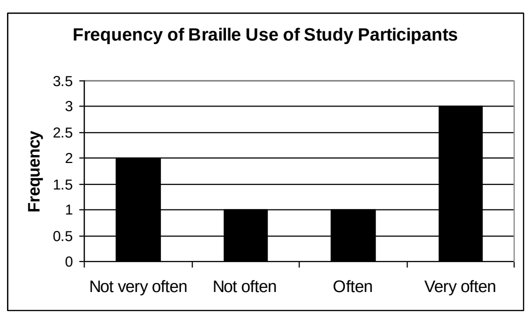

Figure 2. Frequency of Braille use of study participants

Five of the participants who knew Braille knew both Grade 1 and Grade 2; while one participant only knew Grade 1 and another only Grade 2. In addition, another three members indicated that they were willing to learn Braille.

One participant owned a Braille device and used it frequently, while eight out of ten participants would use a Braille device if they had access to it.

All of the participants queried (eleven) stated that they used the JAWS screen reader. Although they expressed satisfaction with its use they thought that the voice should be changed because the pronunciation of Caribbean words was poor. A few of the participants (three) also used the built-in narrator as a backup if the screen reader failed. Only one participant utilized Windows Eyes but did not find it as intuitive as JAWS.

What are members' ICT skills?

About eighty-eight percent of the participants stated that they had used a computer before. In fact many of the participants could engage in several computer related activities including turning on a computer, 92 percent; logging into a computer, 92 percent; browsing the Internet, 54 percent; using email, 39 percent; reading a document, 92 percent; and writing a document, 100 percent.

Discussion of the results

Almost half of the members of the BABD were completely blind which indicated the need for assistive technologies such as a Braille device. Just over half of them were also already able to read Braille and were interested in using a Braille device if they had access to it. The frequency of use of Braille by some of the participants indicated a high reliance on it. These results clearly show a need for a low-cost Braille device.

Most of the participants indicated that they had used a computer before. In fact, many were able to turn on a computer, login and read and write documents (utilizing a screen reader). Provided that the Braille device prototype required only basic ICT skills such as these then it would be easy for these participants to use the Braille prototype.

A Braille device could potentially help participants secure jobs other than craftsmen. This could potentially improve their standard of living and independence. This would also boast well for national development and individual pride.

Based on the results of the study and the subsequent discussion it can be inferred that a Braille device would substantially improve the quality of life of many members of the Association. This device could potentially open the doors for new, better paid employment and increase social interaction. These are all desirable outcomes.

The Requirements, Design and Development of the Low-Cost Braille Device

The Requirements of the Prototype

After a careful analysis of the results of the study it was decided that the prototype Braille device should have the following requirements.

- It should be low-cost, at least substantially lower than currently available commercial devices. As a result, it was decided that a 20 cell Braille device (rather than a 40 cell) would be developed;
- The device should be at least Grade 1 Braille compliant; and,
- The device should be easy to setup and operate.

An additional requirement for interoperability purposes was that the Braille device should employ USB communication given the pervasive support for this architecture on most modern devices.

The Design

The basic design of the Braille device prototype was a 20 cell Braille display with two buttons (for page up and page down functionality) with a serial connector to a computer. The computer would store the text to be displayed in a text file and would be responsible for transmitting the ASCII characters to the processor of the Braille display. The processor would be responsible for refreshing the display and displaying the Braille characters on the 20 cells. The page up and page down button would interrupt the display's processor and display the new line of information. Further details of the operation of the hardware and software are described in the following sections.

Device Hardware

The refreshable Braille display (RBD) prototype is driven by the PIC18F4680 microcontroller generated control signals. This microcontroller is a 40-pin plastic dual in-line package with 64 Kbytes of flash program memory, 3328 bytes of data memory and 1024 bytes of data EEPROM memory.

There are 5 bidirectional 8-bit I/O ports – A to E – where all pins except power and ground are multiplexed with different functions. The pins are set to function as digital I/O. The clock, strobe and data signals to the Braille-cell modules are transmitted via these pins. Port B is configured as an input port since it contains the only external interrupts for this microcontroller.

There are three external interrupts, two of which are used in the Braille Display. Push-button switches are attached to these pins and the interrupts generated, which result in the user's request being immediately recognized and processed.

Serial communication to the Braille-cell modules is done via the Enhanced Universal Synchronous Asynchronous Receiver Transmitter (EUSART) in a process known as 'bit banging'. To achieve successful communication the baud rate of the EUSART is set to match that of the software running on the computer. The EUSART's 'transmit' and 'receive' pins are multiplexed on pins 6 and 7 of Port C, respectively. Pin 6 transmits a command character to the computer, while pin 7 receives the data that is then sent to the Braille Display cells.

Data received from the computer are stored in special file select registers (FSRs). This allows indirect addressing, thus the series of memory addresses can be treated as an array. This greatly simplifies the data storage and retrieval process. Communication between the RBD and the computer is facilitated by the MCP2200 USB to UART converter. The RBD and the USB connection are shown in Figure 3.

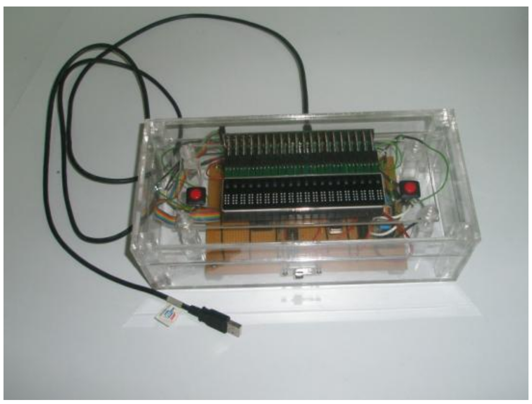

Figure 3: Refreshable Braille Display

Windows Application Software

The software used to create the interface between the user and the Braille device was developed in C++ using the WIN32 API library. This software generates a Grade 1 Braille encoded version of the text document that is to be displayed. The file has a maximum of twenty (20) Braille characters per line. To improve user friendliness, the software ensures that words are not split across multiple lines during the tokenization and encoding process.

Other functions of the software include establishing the serial port connection between the computer and the Braille device as well as monitoring of the control signals from the device. These signals enable the bidirectional scrolling through text either one line at a time or skipping multiple lines at a time. This latter option is akin to using the page-down and page-up functions on a standard keyboard. One unique feature of the software is that a wrap-around boundary condition is implemented thereby allowing a single button-press to navigate to the beginning of the file if at the end, as well as the converse.

Assembly Language Device Firmware

The firmware that drives the Braille cells was created in the assembly language of the PIC18F4680 microcontroller. Once the device is powered this firmware is responsible for configuring the PIC microcontroller, initializing the EUSART, resetting the Braille cells and waiting for communication data from the Windows application. Another function of the firmware is to send control signals to the application to select the single- or multi-line bi-directional scrolling option. Priority interrupts are used to detect and communicate the scrolling mode of the device.

The User Testing of the Device

A completely blind unit coordinator/instructor from the BABD with forty (40) years of experience reading Grade 1 Braille was used to test the device. The instructor, who had no previous experience using Braille displays, was given a short (2 minute) hands-on tutorial on the features of the device. The functions of the switch and each of the buttons on the device were explained. The windows application was started and a text document for user testing was selected. The test subject was asked to voice the message on the RBD while navigated the electronic document. This voicing was compared to the text on a video screen to measure the accuracy of both the user and the Braille device.

Results of the correlation between the candidates voicing and the text displayed on the screen revealed that there were two discrepancies. In one instance, a flaw with the tokenization procedure resulted in several words being concatenated. The candidate flagged this as a typo in the text. In the second instance, there were three occasions when the incorrect character was displayed. The characters 't', 'e' and 'd' were displayed as 's', 'a' and 'e', respectively. These anomalies were later found to be the result of two faulty Braille cells.

The test subject commented that the form factor was more convenient than the other Braille options currently available. The weight of the device and placement of the switch and the buttons were acceptable. The size of the device was a drawback and the candidate expressed a desire for a more compact solution. However, when compared to the size and weight of Braille textbooks, the device was welcomed as a better alternative.

The two navigation push-buttons required too much sustained pressure to invoke the software interrupts, thereby detracting from the user experience. On several occasions the user's reading was delayed until a press-button event was detected and the Braille display updated. Additional software improvements will be necessary to handle the cases where multiple button presses are detected for one press-event (i.e. bouncing). Finally, the user noted that the refresh rate of the Braille cells was not optimal as there were instances when it took one or two seconds for the Braille dots to stabilize after the display was updated.

A limitation of Grade 1 Braille is the lack of some special characters (e.g. apostrophe). Thus there is no way to represent contractions. This was observed when the word "we'll" was voiced as "well" by the candidate.

Despite these short comings the candidate remarked that he believed that the prototype "was an excellent first effort" and considered the issues highlighted as being minor. Moreover, most of the issues could be resolved by using more sensitive switches and improving the device drivers.

Discussion and conclusion

A Braille device prototype conforming to the Grade 1 standard has been successfully developed. This device which was developed using a grassroots approach costs approximately one-half the cost of commercial devices and did not require a screen reader.

The study conducted has shown that members of the BABD are interested in adopting this type of device for general use and in fact the member that tested it found that its performance "was an excellent first effort" with minor issues.

Government or private sector support for this initiative could lead to the adoption of this device not only by the BABD but also by educational institutions (primary, secondary and tertiary). In fact, the manufacturing of the device in large volumes would benefit from economies of scale thus driving down the cost of the device (since the most expensive component, the cells cost less when bought in bulk).

The private sector could sponsor the visually challenged and give them a free device and an appropriate job. This would not only provide value for the company and the visually challenged person, but also the country as a whole since it would contribute to national economic development.

Finally, upgrading the device to the Grade 2 standard would allow a richer experience for the visually challenged since it would provide contractions and other special characters to be integrated into the text.

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