2011 IEEE Jordan Conference on Applied Electrical Engineering and Computing Technologies (AEECT)

Tactile Web Navigator Device for Blind and Visually Impaired People

Alaeldin A. Ahmed, Mustafa A. A. Yasin & Sharief F. Babiker, *Senior Member IEEE*
Department of Electrical and Electronic Engineering.
University of Khartoum
POB: 321, Khartoum, Sudan.

***Abstract*—Blind or visually impaired people have limited or no access to the internet. This paper presents a low cost tactile web navigator device aimed at enabling blind people to have feasible internet accessibility. This navigator design includes a microcontroller that communicates with the browser software proxy transcoder server running on a PC to acquire the text from a web page. The text is subsequently displayed using an array of solenoids giving the required tactile sense. The visually impaired user then uses his/her tactile sense to recognize the text in Braille language. This device also provides an English character mode. Many navigation functions like loading a webpage address, clicking on links and entering data (E-mails, passwords, etc) have been provided.**

The navigator was tested by volunteer blind users with excellent results. The cost of the implementation is an impressive ~12% of the commercial Braille displays.

Keywords- *Braille; Tactile; Web navigator.*

I. Introduction

The internet has become a mass communication media that links the whole world together; it does provide the knowledge, experience, news, social networks, E-commerce and jobs. Blind and visually impaired people need internet access means in their daily life in order to enroll into jobs and extend their knowledge sources. Most of the access means available to visually impaired people are expensive and not dedicated to the internet navigation, e.g. [1]. The major issue among these tools is their high cost [2], [3] and [4]. These means vary greatly in the level of user convenience they provide. They include screen readers [3], screen magnifiers (for those who are not totally blind) [5], Braille printer and Braille tactile displays. Each method has its advantages and limitations as will be illustrated. Screen magnifiers are not suitable for totally blind individuals. Blind people who are using hardcopy Braille printout or synthesized voice [6] output from the computer face limitations of interaction speed and accuracy. They do not have the flexibility of ‘reading’ the screen and making the necessary changes interactively or instantaneously. To receive and process the voice output, the person using the computer must be quite alert in listening. Also, the vocabulary of the synthesized voice is limited. Words with slightly different spelling but having similar phonetics may be pronounced in the same manner, leading to incorrect interpretation. Character by character sound output is very slow for interactive use of computers. A soft Braille display device, on the other hand, allows the users to ‘read’ the characters at their own pace and make on-line changes instantaneously [1].

Braille Display Terminal (BDT) that recognizes the text on the screen and displays it in the Braille display has been reported in [7]. This is a cell-based unit which displays 40 characters at a time. This BDT is implemented as an expansion card that fits into the PC expansion slot. Braille dots were implemented using thermo-plastic pins that expand on heating and contract on cooling.

Reference [8] presented a tactile web navigator that uses a transformation schema to render web pages on a tactile graphics display. This web browser supports voice output to read text paragraphs and to provide feedback on interactions to the users.

The commercially available navigators serving the sector of society who are blind or visually impaired are relatively expensive, costing many thousands of dollars on average [1]. These are normally unaffordable for a vast percentage of blind and visually people, while the affordability in developing countries is greatly reduced. The high cost is attributed to the level of sophistication and complexity of the solutions provided for such displays. It is recognized that a simpler tactile web navigation devices providing interactive linear access to the text content of web pages could be sufficient for most blind internet users; this is surely the case for blind users in developing countries.

The objective of this paper is to present a low cost tactile internet navigation device. The rest of the paper lists the requirements of the tactile web navigator system, followed by a description of the detailed solution designed during this research work. The paper also lists the limitations and possible suggestions for enhancements in future models. A conceptual view of the tactile web navigator system is shown in Fig. 1. The system design comprises software and hardware design as will be described in the rest of this paper.

II. System Requirements

Considering the limitations listed above for the different access mechanisms available for blind or visually impaired

978-1-4577-1084-1/11/$26.00

users, our interface system is intended to provide the following set of functions:

- A tactile interface that can display the web page text by tactile means.
- It is recognized that a large percentage of blind users are not familiar with the Braille representations. The system will therefore provide two modes of display, namely, the Braille and English characters; depending on the user selection.
- Cursor keys to allow the user to navigate through the displayed text by moving backward and forward in the text.
- Many function keys for different functions.
- A keypad for text input, this allows the user to enter the URL addresses, usernames & passwords.
- A communication link between the navigator and the PC. This link is used to convey user inputs to the PC and relays web page text contents back to the navigator.
- An audible feedback to notify the user when the device has started successfully and a tactile feedback to indicate that the page loading has completed.
- The system must be able to provide the following navigation functions:
  - Loading a page by entering its address
  - Loading a page by clicking on a link
  - Inputting data into forms and submitting the data thus entered
  - Reading the page content

The Braille navigator design is intended to provide a low cost solution that is easy to use and easy to modify and upgrade.

III. SYSTEM DESIGN

The overall overview system design is depicted in Fig. 1. The navigator presented in this paper is predominantly event driven. On detecting a user event, the system performs some processing and takes the appropriate action. The navigator has many input keys, a processing unit that can communicate with the internet-enabled PC and a tactile display as an output as shown in Fig. 2.

The input unit is simply a key set that is arranged in a simple manner for the goal of simplicity of use. Each of the navigation functions mentioned in the system requirements section was assigned a separate function key. Read function is considered the default function after the completion of other functions and hence had not been assigned a function key. A cancel key has also been provided to skip the initiated function and therefore stay in the current web page. Moreover, a set of cursor keys are provided to enable the user to move through the web page reading the content. This system has provided two keys for moving forward and backward (right and left cursor keys) in the page text and two other keys for selecting among a list (links or forms).

The system supports text input via a keypad. English letters are distributed among the keys in an easy-to-memorize manner. A keypad schema similar to the standard keypad widely used in mobile phones has been adopted in this study. This choice is based on the fact that visually impaired users are widely familiar with this type of keypad. Each key comprises three letters, a number and a special character (like _, @, space …etc).

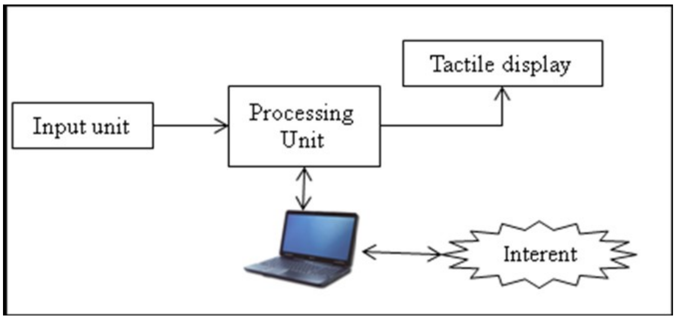

Figure 1. Block diagram of the navigator.

The processing unit is the brain of the embedded system where the PC communications and control are carried out. We used a programmable microcontroller chip as our processing unit since we need a number of I/O ports. The data which is transferred using the PC communication link may include predefined messages and the webpage text; all are transferred from the internet-enabled PC to the navigator and vice versa.

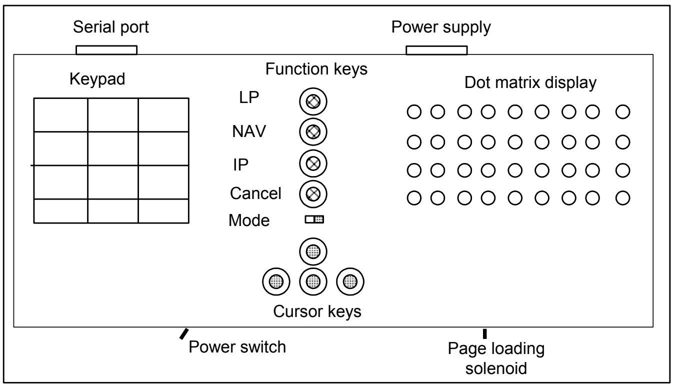

Figure 2. The layout of the navigator device.

The processing unit then controls the output unit which is a tactile display that could display the characters in British Braille code or the ordinary English language (the mode toggle switch selects among these options). The tactile display is composed of a matrix of solenoids that go up and down to shape characters and make them sensible and recognizable to the user's tactile sense (a solenoid is a coil with a plunger in the middle; it's shown in Fig. 3). In the design of the navigator, we paid special attention to the total cost as it is one of the design goals. For that purpose, we proposed a way to avoid the need of a large Braille display with 40 or 80 Braille cells. We replaced it by scrolling solenoid dot matrix that shifts one column left when the right cursor key is pressed and continues shifting left with a constant speed when the key is held. The scrolling speed could be adjusted to suit every user's sense-and-recognition speed. The user should receive some form of feedback when he/she issues a command.

A tactile feedback was also provided by a single separate solenoid to indicate that a web page has been loaded; the solenoid is activated when the page is being loaded and de-activated when the page has been loaded. An audible feedback was also provided to indicate that the device is ready when it is switched on by the user.

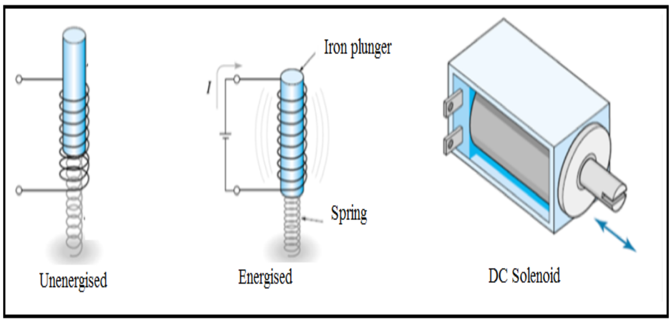

Figure 3. Solenoid structure and operation.

A. *Tactile Display Control (Solenoid Dot Matrix)*

The dot matrix requires individual control of dots to display characters. Individual control lines may be used but it is not economic; we consume as many control pins as the number of dots (think about increasing the matrix size). In order to avoid using individual control lines for each dot, an efficient multiplexing technique was used.

The multiplexing scheme used in this work achieves turning on one row of dots for a short period of time and then turning on the next. Doing this fast enough will completely eliminate any flicker and the solenoid will appear activated, [10]. We connect the solenoids in row and column manner (as shown in Fig. 5). We apply a positive voltage to the first row and hence each dot in that row will be waiting for a ground line to activate. We then apply a ground to the required dots in that row to a short period of time and shift the positive supply to the next row. Doing that very rapidly, the user will never sense these discontinuities in voltage. The duty cycle per dot is considerably reduced in this case. Fig. 5 shows the dot matrix with two activated dots (shown with the centers filled). The dots are activated when a positive voltage is applied in one end and a ground at the other. The rows with 0/Z label are either with ground connected to them or tri-stated; this is also applicable to the columns. Next the second row gets the positive voltage and a ground is applied where the dots must be activated and so on. The benefit is: for an $m \times n$ dot matrix we only require $m+n$ control lines. By the deployment of an external decade counter chip we can reduce the number of control lines further to $n+2$.

A flyback diode (shown in Fig. 4) is used to eliminate flyback action caused by the sudden voltage spikes induced across an inductive load when the supply voltage is suddenly reduced or removed. When the voltage is removed from an inductive load we have a large reverse voltage build up as the magnetic field collapses, resulting in an induced back electric motive force (emf) in the windings of the inductor.

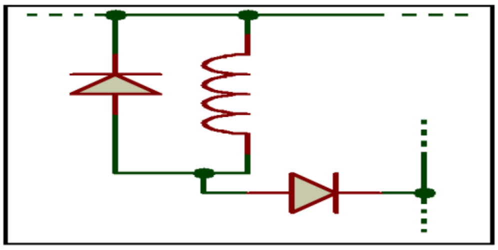

Figure 4. Single matrix cell

Furthermore, another diode is connected in series to each solenoid (shown in Fig. 4) to allow the current to pass through the solenoid coil in only one direction. This is highly required to restrict other current paths to ground in the matrix (but the required path).

B. *Software Design*

The behavior of the system is determined by the software. The system's behavior was described by state diagrams that show the predefined messages and how they are exchanged between the two parties, *viz.* the navigator and the PC interface. A state diagram scenario was developed for each of the navigation functions mentioned in the design requirements section and for the two parties, the navigator microcontroller and the PC.

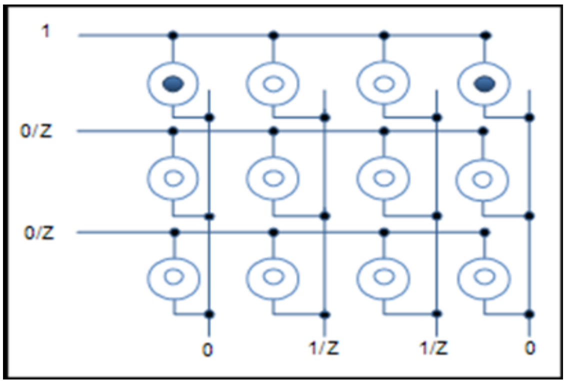

Figure 5. Solenoid matrix display

IV. System Implementation

The implementation comprised a keypad for text input, a set of function keys, a set of cursor keys, a processing unit and a 4×9 solenoid dot matrix display, a top view of the device layout is shown in Fig. 2. The circuit for this implementation is shown in Fig. 9.

The implementation also comprised:

- A keypad for text input.
- Atmel® ATMEGA32 was the microcontroller used.

- UART serial protocol was the PC communication link (the PC's serial port).
- The p-type power MOSFET IRF9640 was used to provide high-side switching for each row. ULN2003 transistor array chip was also used to drive the columns of the matrix to ground.
- An external power supply was used to provide 5V and 12V. The 5V was used for the digital integrated circuits and the 12V was used to supply the solenoids.
- A cooling fan, a buzzer feedback (sound) and a solenoid feedback (tactile).
- 4017 decade counter to select rows by sequence (one after another) and to reduce the control pins required from the microcontroller.

The design is based on the concept of transcoding proxy server used with mobile applications. The server is a Visual Basic application on the PC that embeds a web browser to read the contents of a page and extract the text content from the web page HTML code. The extracted text would subsequently be passed on to the microcontroller on the navigator. The server recognizes hypertext and links and subsequently passes them to the navigator on user's request. The server also recognizes prompts for data input, passwords etc.

The overall data flow in this system is shown in Fig. 6. The operation of the navigator is illustrated in Fig. 7 where we show the Visual Basic application we developed & Fig. 8 where we show a high level view of the transformation applied to the raw data until the final Braille format is generated.

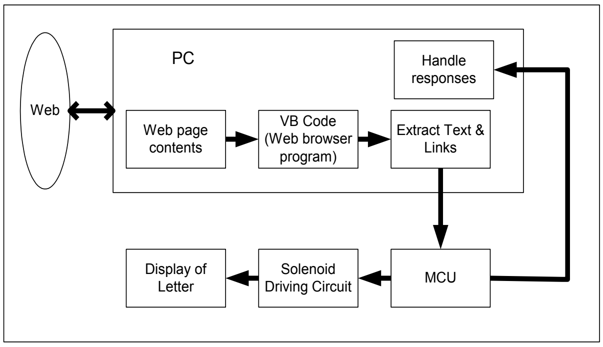

Figure 6. MCU interaction with VB transcoding proxy server on the PC

The software implementation process was started by coding the state diagrams described previously in the system design. Two software programs were developed, the PC interface using Visual Basic language and the MCU code using embedded C language. Microsoft Visual Studio 2008 IDE was used for Visual Basic programming and CodeVisionAVR IDE for embedded C programming.

Figure 7. Example of web browser interface

Figure 8. Web browser output and tactile display output

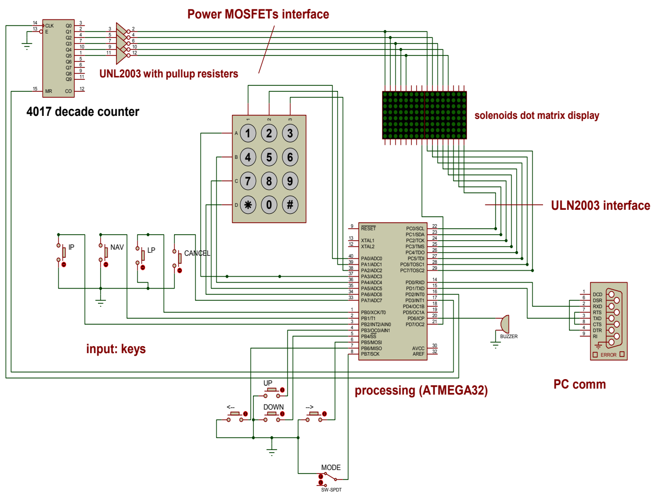

Figure 9. Navigator circuit diagram

V. PATTERN GENERATOR

As mentioned above, the device has been designed and implemented to support the Braille notations together with the plain English language text. Our design has provided the 'pattern generator' that allows the users to design a convenient and readable tactile representation of the letters. Using a 4×5 matrix to represent the English characters, e.g. the letter notation for the letter 'C' could be {0x07, 0x08, 0x08, 0x07}.

The full English characters and numbers are subsequently represented as shown in Fig. 10. The pattern generator could also be used to extend the use of this navigator to include other languages.

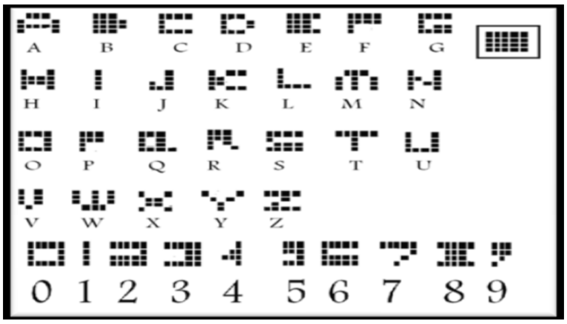

Figure 10. English alpha-numerics.

VI. Results and Discussions

The navigator was subsequently tested by volunteer blind users. The users were able to read Braille characters and to interact with the navigator. Some limitations regarding the speed, size and comfort were identified and recommendations were made to enhance the next models.

VII. Conclusions and Future Work

A functional low cost linear tactile web navigation system has been successfully developed for blind internet users. Hardware and software design and implementation of the navigator were described.

This system could be improved with the following proposed modifications:

- Eliminating the intermediate PC: the navigator may be upgraded to be connected directly to a network access link eliminating the need for the intermediate PC.
- Supporting the PC keyboard: as the standard keyboard was always seen as the preferable input device for the blind users.
- The power dissipated in this system is typically ~30W. The power consumption could be reduced by replacing the relatively high current inductive load solenoids by the more efficient low power piezoelectric linear motors. This will also further reduce the overall size and will improve the performance of the device.
- Supporting USB2.0 interface: The PC serial interface is already been phased out and it is barely supported by laptop computers in recent models. Using USB2.0 would guarantee ease of interface with modern computers.
- Augmenting searching and bookmarking functionalities.

Acknowledgment

The authors would like to acknowledge the financial support provided by the Federal Professional Union for Sudanese Engineers. The authors are also grateful to the technical staff of the Electronics Laboratory (UofK), members of the Cubesat project and the staff of Elneel Research Center for valuable assistance. Special thanks are due to Dr. El-Sadig of the Faculty of Arts, UofK, for volunteering to test this system and for providing valuable comments.

References

[1] N. Sriskanthan, K. R. Subramanian, Braille display terminal for personal computers, Technological Institute, Nanyang, Singapore

[2] Focus Braille Displays for the Visually Impaired by Freedom Scientific. Article at: freedomscientific.com/products/fs/focus-product-page.asp, accessed 18/Aug/2011.

[3] JAWS Screen Reading Software by Freedom Scientific. Article at: freedomscientific.com/products/fs/jaws-product-page.asp , accessed on 18/Aug/2011.

[4] A. King, G. Evans, P. Blenkhorn, “Blind people and the World Wide Web”, UMIST, Manchester, UK.

[5] E. Pearson & T. Koppi, “Essential Elements in the Design and Development of Inclusive Online Courses”. Proc. of World Conference on Educational Multimedia, Hypermedia and Telecomms 2002.

[6] L. Josifovski, D. Mihajlov & D. Gorgevik, "Speech Synthesizer based on Time Domain Syllable Concatenation", SPECOM’97 Cluj-Napoca, October 27-30 1997.

[7] N. Sriskanthan, K. R. Subramanian, “Braille display terminal for personal computers”, IEEE Trans. On Consumer Electronics, Issue Date: May 1990, Vol. 36, pp. 121-128

[8] M. Rotard, S. Knödler & T. Ertl, "A tactile web browser for the visually disabled", Proc. of the sixteenth ACM conference on Hypertext and hypermedia, ACM New York, 2005

[9] Article at: webbie.org.uk/webbie.htm, accessed 18/Aug/2011.

[10] How to drive an LED display matrix. Article at: best-microcontroller-projects.com/led-dot-matrix-display.html, accessed 18/Aug/2011.

[11] H. Petrie, V. Johnson, P. McNally, S. Morley, A. O'Neill and D. Majoe, “Inexpensive Tactile Interaction for Bind Computer Users: Two Application Domains”, IEE Colloquium on Developments in Tactile Displays (Digest No. 1997/012)