AN INTELLIGENT HUMAN-MACHINE INTERFACE FOR READING DIGITAL TEXTS FOR THE BLIND

Diego de Siqueira Braga, Fernando Buarque de Lima Neto and Sérgio Campello Oliveira

University of Pernambuco (UPE), Polytechnic School of Pernambuco (POLI)
Street Benfica, 455, Madalena – 50750-410 – Recife, Pernambuco – Brazil
Phone: (81) 3184-7555 ext: 7542
Fax: (81) 3184-7536
{dsb,fbln,scampello}@ecomp.poli.br

Abstract –This article reports the acquired experience of developing a new module for 'KnowTouch', an Intelligent Braille display product that involves hardware and software for aiding the blind. This new module recognizes some characteristics of the user and adapts the device accordingly. Here we describe in detail the main function of this new module: the next page function. In short, this functionality works as an auto-scroll that perceives the average time spent by the user on each page. Just after a minutes use, the module is able to infer the time necessary for the user to read the next page and automatically scroll it for him/her.

Keywords – HMI, Assistive technology, Cybernetic, Embedded system.

1 Introduction

According to World Health Organization (WHO), there are over 160 million visually impaired people around the world, where 45 million of these are completely blind [1]. In Brazil alone the number of visually impaired is around 16.5 million, of which more than 3 million have severe visual impairment [1]. Because of their disabilities, many of these persons have limited their basic rights as citizens. For example, education is hampered by the difficulty of providing them with full access to all written material available. This problem is further accentuated in the panorama of the digital age, because special techniques are required and trained professionals to promote a proper education, which not all disabled people have access.

The impact of the above factual observations increases the difficulty of integration of visually impaired people in good placement in the labor market. Marginalization and social exclusion are not infrequent outcome. According to VANDERHEIDEN [2], 30% of the disabled who are economically active are unemployed. This, in spite of their desires for inclusion in the labor market.

The purpose of this work is to build an intelligent prototype - composed of hardware and software - to allow easier reading of digital text for visually impaired people. In short, the software captures the contents of a digital textual document and converts its digit characters into Braille. After this conversion, the information is sent to the hardware of the system that reproduces them into an intelligent interface for tactile Braille signs. Hence, making it possible for digital texts to be read by the blind; and now with the simple but useful auto-scroll function.

2 Background

This session brings together the key concepts necessary to understand the proposed work. To this end, the text presents the current Braille system, discusses conceptual issues of Human-Machine Interface as well as related work.

2.1 Braille

The Braille system is a method that is widely used by blind people to read and write, and was the first digital form of writing[3].Figure 1 shows an illustration of a process of reading using Braille.The Braille system was invented in France by a young blind man named Louis Braille, recognizing the year 1825 as the landmark of this important achievement for the education of visually handicapped and their integration into society [4]. Through this system, the visually impaired have the resources to form concepts about spelling and graphical layouts like sentences, paragraphs, punctuation, etc.

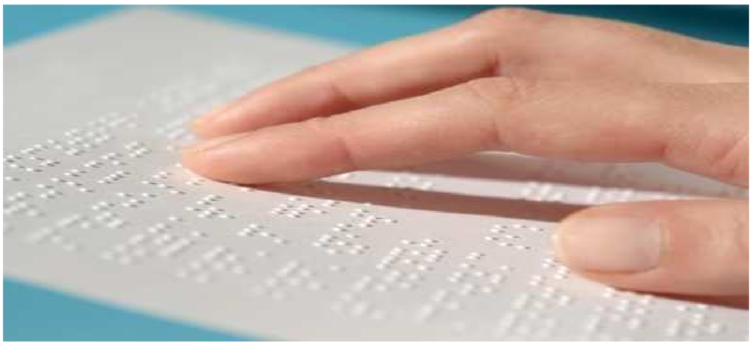


Figure 1 – Illustration of a process of reading using Braille. [Extracted from Public Domain]

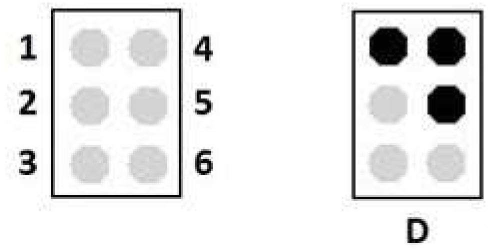


Figure 2 – Braille character generated by the combination of points 1, 4 and 5 - which represents the letter "D".

2.2 HCI

The Human-Machine Interface (HMI), or Human-Computer Interface / Interaction (HCI) is a multidisciplinary area that involves studies in computer science, human factors, linguistics, psychology, among others. HCI aims to understand how the interaction between man and machine happens and how would it possible to improve it. There are several user groups around the world pursuing the HCI goals with new trends constantly emerging [10]. HMI can be used, for example, to help patients suffering for various degrees of visual impairments.

Importantly, there is a distinction between interaction and interface. The interaction includes several aspects in which the user will need to interact to perform its task, included in this context is, for example, the layout of the office, the practice of labor and the environment [11]. While the interface is concerned with systems in which the user will have direct contact through the physical, perceptual and cognitive [12]. This paper deals with better interfacing for achieving more interaction.

An HMI device should provide resources to (i) entry - allowing the user to manipulate the system and (ii) output - allowing the system to indicate the appropriate response to user actions. Among the main features of an HMI device are: Usability, Accessibility and Ergonomics [13].

Accessibility - with regard to the disabled - has received much attention from scholars of HCI. According to the GNOME Accessibility Project providing accessibility means removing barriers that prevent people with disabilities from participating in substantial life activities, including the use of services, products, and information [14]. There are several types of HCIs [15], differing from each other according to the contact form, system or environment in which it is used, but the most important parameter is the user. Although Ergonomics was sought as well this paper deals primarily with Accessibility (the Know-touch device) and Usability (its new auto-scroll function)

2.3 Previous attempts to easy e-reading for blind people

Assistive technology or adaptive technology (AT) is an umbrella term that includes assistive, adaptive, and rehabilitative devices for people with disabilities. AT include products, resources and services to facilitate the development of activities of daily living for disabled people, aiming their autonomy, independence, quality of life and inclusion [16]. Examples of resources for TAs are wheelchairs, canes, orthotics and prosthetics, magnifying glasses and hearing aids.

In the context of the HMI has a diversity of devices that can be used by the visually impaired, such as printers (embossers) lines Braille readers [17][18][19] and screen magnifiers [20][21]. The Know-touch device and its new auto-scroll function are certainly reinforcement for the AT arsenal.

3 Knowtouch - An Overview

The KnowTouch (KT)[22]is, in a simple definition, a reader e-book that "reads"for the blind files in the "kt" format. It is characterized by integration of hardware and software to comprise a solution that provides reading access to for the visually impaired in a dynamic, practical and accessible manner.

The format "KT" is the text encoding format for Braille characters. It enables a greater autonomy of the proposed prototype, this because the file "kt" is stored directly on the device without the need to be connected to the internet or even to a computer containing the software translator. That is the translation is performed entirely on the device itself - which increases considerably the use of its processing resources but grans its users with great mobility.

The developed software is capable of converting a text document format for digital Braille Brazilian. It translates the text into a format that includes the physical device, the "kt". The translation system, although the output format in standard Braille Brazilian, is able to translate digital texts regardless of user language. Texts in English, French or Spanish can be translated by our software, for example. The translator software, developed in this piece of work implements the translation of digital texts for Braille grade-1 [23]and grade-2 [24]. In our literature review we could not find other software capable of translating documents for these two types of Braille simultaneously. The mentioned conversion accepts the following file extensions .TXT, .HTM e .HTML. All KnowTouch navigation can be done through the keyboard, following the guidance sound recorded on a menu (auto-scroll reduces the next-page button hit). Figure 3 shows the GUI Software Translator KnowTouch.

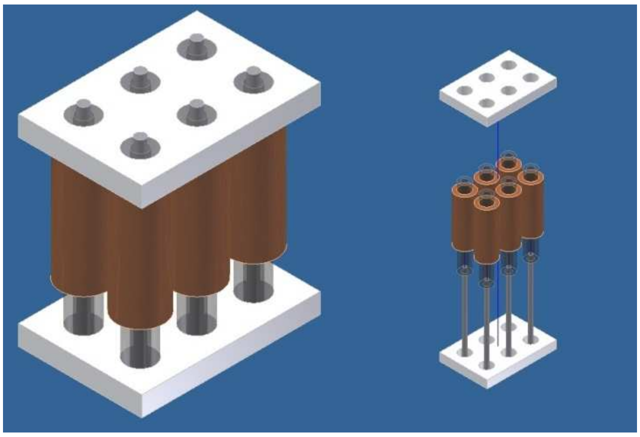
The separation between the physical device and the translator software allows "kt" files to be distributed directly to end users, libraries, etc., so that the disabled user can have access to the titles without having computers and license for the translator software.

The KnowTouch still presents an unique learning system that can help the visually impaired who does not possess the knowledge of reading Braille. Through interaction with the user, making use of audio features and tactile stimulation KT can become also an excellent resource for learning Braille.

Figure 3 – GUI Software Translator KnowTouch**.** [Extracted from BRAGA[22]]

The device KnowTouch is formed by a group of cells arranged in a matrix (2 rows, 16 columns).Each cell represents a Braille cell and consists of an array of pins (3 rows, 2 columns).The KT has a flat surface in the absence of data communication and "printing" the selected text in Braille, according to information received. It consists of a panel with holes filled with mobile pins. These mobile pins are powered by solenoid coils that electromagnetically move the pins of the panel up through a set of hole forming standard Braille.

All data sent by the software are received by a microcontroller embedded in the device that encodes for the firing pin.This encoding is sent to a power circuit comprising a current source that drives the pin elevating system to force the pin to stay above the flat surface of KnowTouch in order to form the words Braille. Figure 4 (a) shows the manufacturing process of a Braille cell and (b) Schematic drawing of the KnowTouch's Braille cell.The prototype of KnowTouch can be seen in Figure 5.



(a) **(b)**

Figure 2 - (a) Overview of the manufacturing process of a Braille cell.
(b) Schematic drawing of the KnowTouch´s Braille cell. [Extracted from BRAGA[22]]

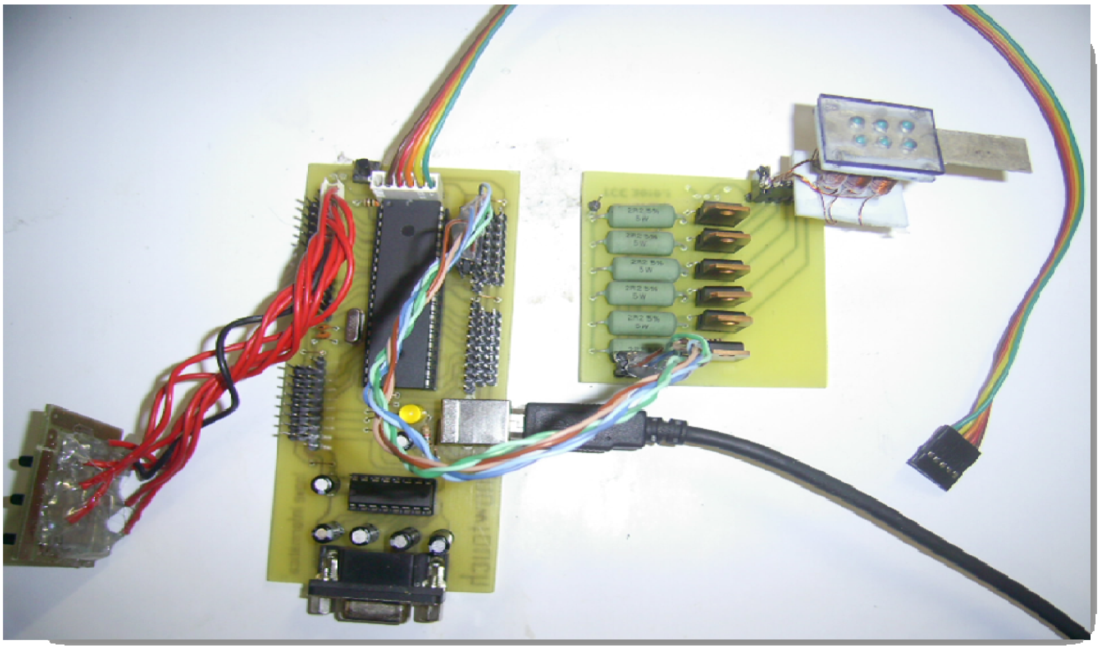


Figure 5 – KnowTouch´s prototype mounted on a printed circuit board. [Extracted from BRAGA[22]].

4 Adaptive next button control for Knowtouch

To turn the using experience of the KnowTouch more enjoyable, a new System Customization Module is under development. The idea behind this module is to provide the user a more pleasant reading experience. The first change implemented is the creation of an "Adaptative Next-Function" (auto-scroll function), this is a function that allows the system to know characteristics and preferences of its user and, with this knowledge it can adapt itself to the pace of each one readings.

In short, the functionality proposed here works as an auto scroll that, once switched on by the reader, perceives the average time spent by the user on each page, and just after a few minutes, is able to set (with a reasonable precision) the time when the user finishes reading each page. This happens due to the inclusion of a cybernetic arc into the system, where the feedback signal is obtained from the use of the device: the time to read each text displayed. Without the need to insert explicit data, the usability becomes more intuitive and supportive.

In its first version of the KnowTouch device, the changing of the displayed text was user requested by pressing the next button key, with the inclusion of this new feature this action will no longer be necessary. Because just after the first few minutes of use, the system realizes the average time spent reading each text displayed on the device and begins to move the pages automatically.

The operation of the new functionality is described by the state diagram illustrated in Figure 6.As can be noted, the state 'Reading' only changes because of three situations: (1) reading time is reached, (2) the user presses the Next Button or (3) the user presses the Previous Button. The first situation (new) will trigger the change of the displayed text. This situation illustrates the full functioning of the device, where it makes the transition from text automatically without any input from the user.

The other two situations, where the Next Button or the Previous Button can be pressed before the passage of time come to an end, will trigger the immediate change of the text (whose way will obviously depend on the key pressed) and also return to the system a feedback signal containing the correction necessary to correct the reading speed.

It is noticeable that the correction signals are different for each type of feedback. This has been purposely designed to model the behavior of learning curves according to the needs of each situation. It is better that the system misses stipulating a time slightly larger than the real, thus making the user initially need to press the "next". So when tightening next consecutive times the reading time decreases softly, but when you press previous the system considerably increases the reading time to reduce the risk of having this button to be pressed again.

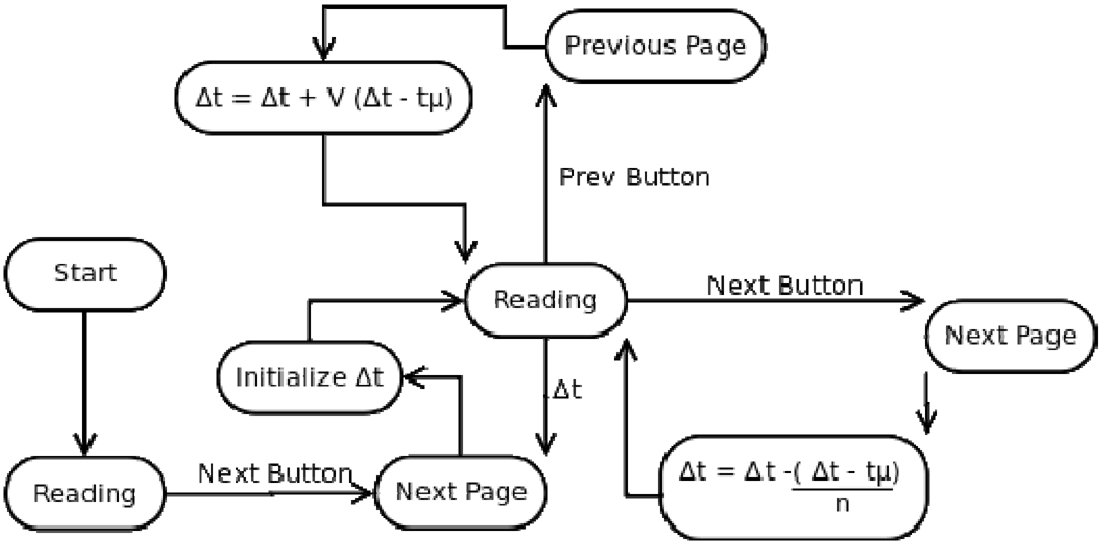


Figure 6 – Adaptative Next-Function State chart, where: **Δt** is the reading time;**tμ** is the last reading time registrated; **n** is the number of times that the Next Button was pressed and **V** is the variance of the registrated times.

5 Experiments and Results

Table 1 presents a comparison between the use of KnowTouch before and after inclusion of the Next Button Adaptive Control using three texts of different sizes (100, 1.000 and 10.000 Braille characters).

Table 1 – Comparison between the Traditional and Adaptive mode of reading of the KnowTouch.

Size of texts (number of Braille characters)	Number of times a button was pressed using a Traditional Mode	Number of times a button was pressed using a Adaptative Mode
100	4	4
1.000	32	6
10.000	313	91

The column "Number of times the button was pressed using the Traditional Mode" in Table 1 represents the use of the traditional way of reading the Braille reader (i.e. manual advance of pages) and presents the amount of 'Nexts' needed to complete reading , i.e. the minimum amount of times the "Next" button must be pressed so that the entire text is presented to the Braille reader. This value is obtained by dividing the number of Braille characters in the text by the maximum amount of Braille characters that can be displayed on the device's physical KnowTouch (ie 32 Braille characters, arranged in two rows with 16 characters each).

The column "Number of times the button was pressed using the Adaptive Mode" in Table 1 shows the number of times a button (Next or Previous) needed to be pressed to complete reading of the text using the Next Button Adaptive Control. It is possible realize a considerable reduction in the amount of times that a button must be pressed, indicating an adaptation to the user profile based on your time of device use. This reduction also brings an improvement to the usability of the device, it represents less wear on the user reading longer texts.

6 Conclusions

6.1 Results overview

The autonomy provided by the Braille translation software, the simplicity and ease of obtaining components, the technologies used in the manufacture of mobile device and the Adaptative Next-Function make KnowTouch a tool to support the visually impaired is deemed to be highly relevant.

6.2 Discussion

A pitfall of this work was the time imposed impossibility to perform thorough usability tests with the visually impaired, mainly because the prototype has not yet reached sufficient level of human usability. Further work is needed to make it more anatomical and easier to handle. There may be a delay to adjust the reading of Braille characters in the developed device, because the sensitivity of touch in a sheet of embossed paper is different from the pins that are raised in the KT, however quite possible transposition in implementations of prototype alpha.

The experimental nature of the project, with no complete mastery of the technologies employed in the pin elevation system were technical difficulties imposed in addition to not appropriate tools for testing prevented us to reach a final product so far.

6.3 Future work

At the point we can foreseen some improvements.

6.3.1 Test other Intelligent Computing techniques

Other types of Intelligent Computing techniques could be tested with the intention of making the KnowTouch device even more adaptable.

In Braille learning module, for example, could use the techniques of Knowledge-Based Systems [26] and / or Intelligent Tutoring Systems [27]to improve learning for visually impaired.

6.3.2 Test other driving mechanisms

Other types of drives, pins Braille, could be developed in order to be able to facilitate the reading of the characters by the visually impaired as well as reduce the size of the device and consequently improve their portability.

Other possibilities of high relief could be used, for example, the use of piezoelectric deformations [28] or the use of Electroactive Polymers [29].

6.3.3 Other testing

Conduct usability testing of the interface developed with professionals working in the education of blind and massively validation with the visually impaired.

6.3.4 Implementation of the final product

Finally, it is suggested to build an experimental prototype resulting in actual product development.

The construction of a physical device with the application of the concepts of Universal Design [30] would increase product acceptance by the visually impaired.

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