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ORIGINAL PAPER

Design of an electronic prototype to teach braille

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Abstract
This work proposes an electronic device to teach Braille. The goal of our prototype is to be a pedagogical strategy to teach Braille to people suffering from visual disability. The teaching process applies to people with visual impairment, while visually deploying to those who support the teaching process. The prototype was tested among two groups of participants and the results are discussed.

Keywords Braille · Special Education · Technologies for Inclusive Education · Visual Disabilities

1 Introduction

According to the National Institute of Statistics and Geography (INEGI), visual disability in Mexico is the second leading cause of disability (after motor disability), thus affecting nearly 1.3 million inhabitants [1]. Furthermore, 26% of the visually impaired population either suffers from total vision loss or, has difficulties seeing with one or both eyes.

The state of Michoacán alone accounts for 70 thousand people visually impaired. Unfortunately, the lives of blind people are exceptionally limited, with activities such as studying, reading, and writing being rarely accessible to them. Hence, nowadays emphasis should be placed on inclusive education to integrate all students within the same teaching-learning environment, while identifying and responding to their individual needs, regardless of their disabilities.

Ensuring inclusive education implies making modifications within the traditional teaching methodology implemented in classrooms. Moreover, inclusive education requires three key aspects: society, participation and the media. Therefore, to achieve it we must motivate society to participate and provide all the necessary tools to the people who need them, so that they have equal opportunities [2].

The remaining of this work is organized as follows: section 2 presents an introduction to inclusive technologies for education, section 3 describes the research problem and the proposed solution. Next, section 4 describes our Braille teaching prototype, and section 5 discusses our research methodology. Finally, section 6 presents our results, whereas section 7 addresses our concluding remarks and suggestions for future work.

2 State of the art

Braille is not a language, but an alphabet, devised by Frenchman Louis Braille during the mid19th century is a system of tactile reading and writing designed for blind people and is also known as blinded graph. Braille helps represent letters, punctuation marks, and numbers, among others using raised dots that can be read with the fingers. In general, Braille is considered in six-point cells in relief, organized as a three-row matrix with two columns as seen in Fig. 1. Each matrix must fit the fingertip [3, 4]. Figure 2 depicts the entire Spanish alphabet in Braille.

Currently, visually impaired people can enjoy reading with the support of two technologies: the Braille symbols system and text-to-speech systems.

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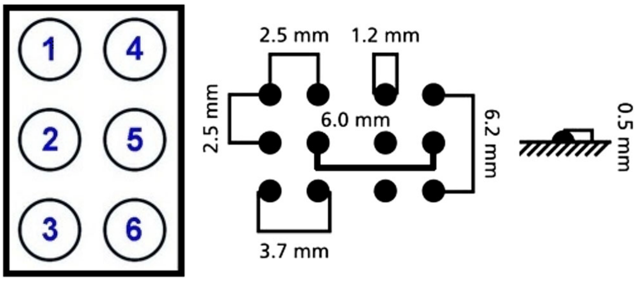

Fig. 1 Braille matrix structure

Currently, three major commercial technologies provide reading support to people with visual disability:

a) Braille printing: Multiple commercial devices seek to adapt Braille text and signage (see Fig. 3). The prints are used in text books, educational books, security documents, bank statements, restaurant menus, and many other functional texts. Braille printing devices rely on techniques such as serigraphy, embossed relief, or flexography. Some of the companies and organizations developing Braille printing projects in Mexico include ID3, Intelligent Forms, and La Salle University.
b) Screen readers: These are software programs or applications using a text-to-speech engine to translate on-screen information to speech. Examples of this technology include Non Visual Desktop Access (NVDA), Orca, and GW Micro Windows-Eyes.
c) Real-time Braille code creators: These devices can translate written text to Braille code immediately. To this end, real-time Braille code generators use cameras and memories, among other techniques. Examples of real-time Braille code generators include Classic Focus 40 Blue (see Fig. 4) and Tactile. The former uses a JAWS screen reader and transmits the information to upgradeable Braille cells, making the device act as a touch monitor. The latter is under development by the MIT and allows users to read printed text through cameras to then translate it to Braille cells.

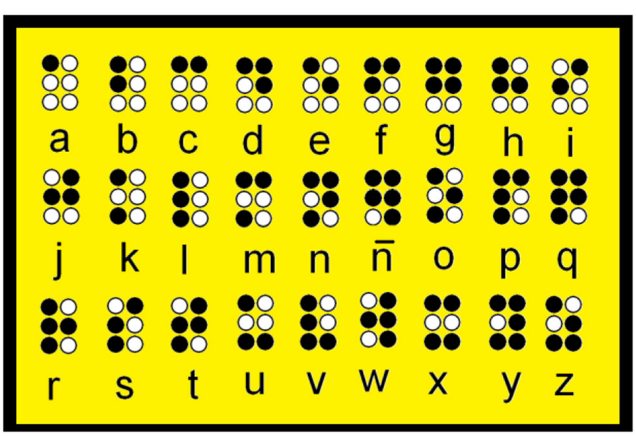

Fig. 2 Braille Spanish code

3 Problem and proposed solution

3.1 Research problem

According to INEGI, 45% of the total population in Mexico requires optometric care, and 58.4% suffers from vision deficiency or low vision [1]. Such data indicate that Mexico must design and implement as soon as possible a well-structured and nation-wide process to promote the teaching-learning process among visually impaired people beyond primary education levels [2].

3.2 Solution

This work proposes an auxiliary device for teaching Braille to both blind people and people without vision loss. The device's teaching process can be described as follows:

a) The system teaches Braille symbols through repetitions in defined sequences.
b) User selects individual symbols to practice Braille code.
c) The system evaluates the learning by means of the relation of the tactile Braille symbol and its letter.

4 Prototype

Our Braille teaching prototype is a system composed of two parts, as depicted in Fig. 5: a visual part and a tactile part. The visual part visual allows to the people who do not present / display visual incapacity and a tactile part. The visual part that allows non-visually impaired people, to use the system to learn whereas the tactile part is responsible for building the Braille matrix. Similarly, our prototype has the following characteristics:

- Generates Braille alphabet programmable sequences, giving visual output to a LED matrix that shows the corresponding letter and an array of LED's that show the Braille symbol.
- The system in tactile form by means of a 3 × 2 arrangement of servo motors simulates the reliefs of the Braille matrix.

Fig. 3 Text prints in Braille

- Allows users to select individual letters,, thus breaking the alphabet down in a visible and / or tactile way, according to the needs of the user.

- Randomly generates a tactile Braille symbol and compares it with the letter selected by the user through the keyboard, indicating whether they are corresponding or not.

As depicted in Fig. 6, our prototype introduces users to the Braille alphabet through a pre-Braille system, which is the use of large objects that can resemble the braille code matrix to provide greater perception and training.

5 Methodology

The four most common methods for teaching the Braille system include Alborada, Bliseo, Pérgamo, and Thyme [5]. The Alborada method relies on cards for learning to read and presents the alphabet letters in a fairly logical order. Bliseo starts by deepening the special knowledge of the generator sign and introducing the letters of the alphabet. The Pérgamo methodology presents letters in such a way as to avoid confusion; moreover, it facilitates perception in Braille. Finally, Thyme is an introductory method with attractive materials used with embossed representations. Thyme uses a double-spacing format to facilitate reading and moving from one line to another. Our methodology takes as a reference the aforementioned methods and the functions of the prototype (i.e. the electronic device). Figure 7 introduces a flowchart to depict the methodology stages.

Fig. 4 Classic Focus 40 Blue device that converts text into Braille in real time

5.1 Introductory stage

This stage introduces users to the Braille alphabet. It aims at both, people who are not familiar with the system, and those who need to practice the basics. At this stage, users select a letter of their preference to learn its Braille symbol equivalent, the system displays the Braille symbol visually or tactile, according to the selection of the corresponding user. For visually impaired users, the system displays in form tactile with servomechanisms to allow users to feel the matrix. The Braille matrix is represented visually for the instructor or for people with no vision loss can verify the symbol. Note that the two deployment alternatives are available for users with no vision loss are applied to people who have not lost their sight. Figure 8 depicts an example of the unfolding of this stage.

5.2 Training stage

This stage is designed for users who have knowledge of the Braille system. In it, our prototype works with ordered sequences of Braille symbols that increase in complexity as the sequence advances. The first letters correspond to a single-point Braille matrix; then two points are used. As users go forward, complex combinations are displayed. The sequence used is that recommended by the dawning method: a, o, u, e, l, p, i, b, m, s, n, v, d, ñ, g, t, f, r, c, and, j, q, h, z, x, k. This sequence is displayed in groups of five letters to reduce learning complexity.

The user performs five to ten repetitions of each group of letters according to their needs. The prototype visually represents the letter and the Braille matrix, in

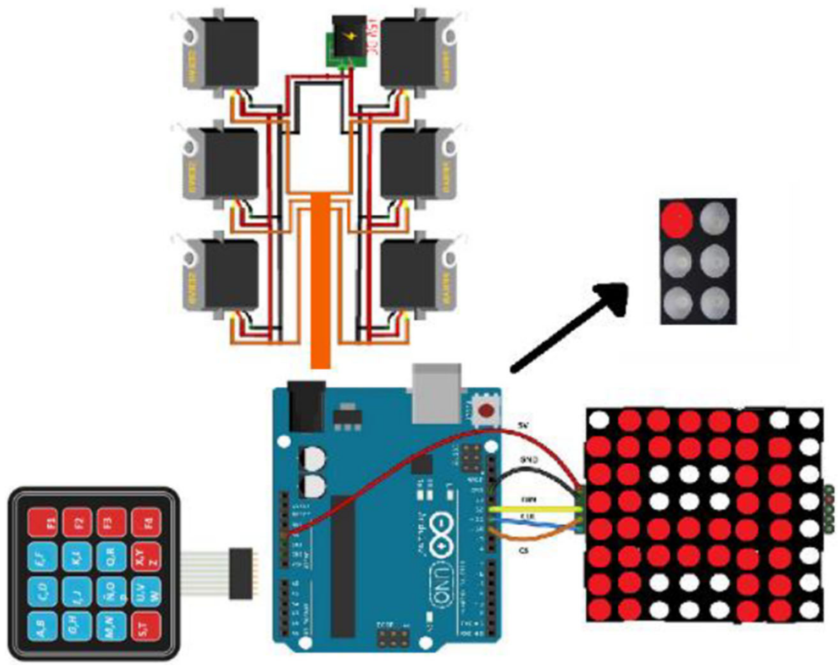

Fig. 5 General diagram of the electronic Braille system

addition to tactile form through the movement of servo-mechanisms generates the Braille symbol. This allows both people who have not lost sight and people who no longer have sight to learn the sequences. Notice that this stage is not assessed, since it is only practice. Similarly, this stage allows instructors to learn the Braille system didactically, to then be able to support visually impaired users with few risks.

5.3 Assessment stage

This stage follows at the end of the training phase, usually after seven days (or less, depending on each user's learning pace), the user is evaluated by randomly generating a Braille symbol tactile that must be related to the corresponding letter by selecting it from the keyboard. If users choose a wrong letter, the system allows two more attempts before displaying another random Braille symbol to be matched. Conversely, when users select a right answer, they automatically increase their score, and the system then displays another symbol to be matched. After a ten-symbol round, the system displays the final score, and the test ends. Users can choose to take the test whenever they consider it necessary while they are training.

Fig. 6 Physical structure of the electronic prototype

6 Results

We tested our prototype among two research groups. One group comprised 15 non-visually impaired users, and the other group was formed by five people with complete visual impairment. In both groups, none of the participants was familiar with the Braille system. Overall, we obtained good results (see Table 1): on average, users learned 85% of the Braille alphabet, whereas recognition speed increased in the last test, if compared to the first test, by more than 150%.

7 Conclusions and future work

Our prototype works correctly, and its functions allow users to understand Braille symbols. The prototype's strategies of visual and tactile teaching help users who are not familiar with the Braille system to learn it from scratch almost immediately. Likewise, visually impaired users improve tactile sensitivity to detect Braille symbols with greater speed. The prototype it

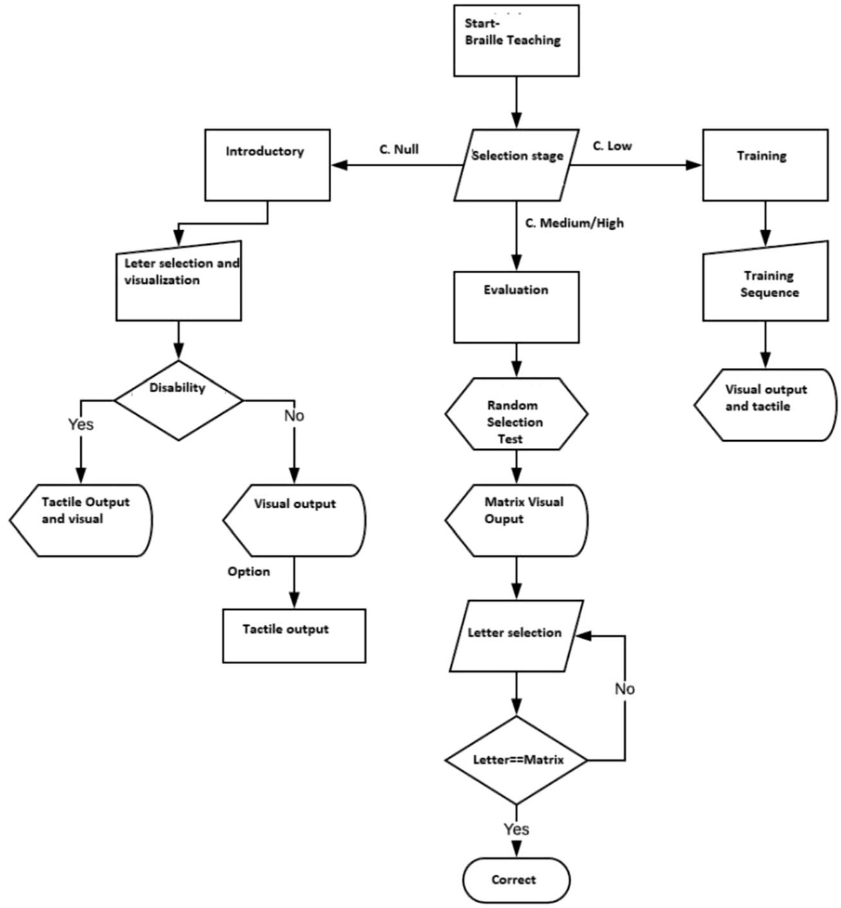

Fig. 7 Algorithm of the teaching methodology

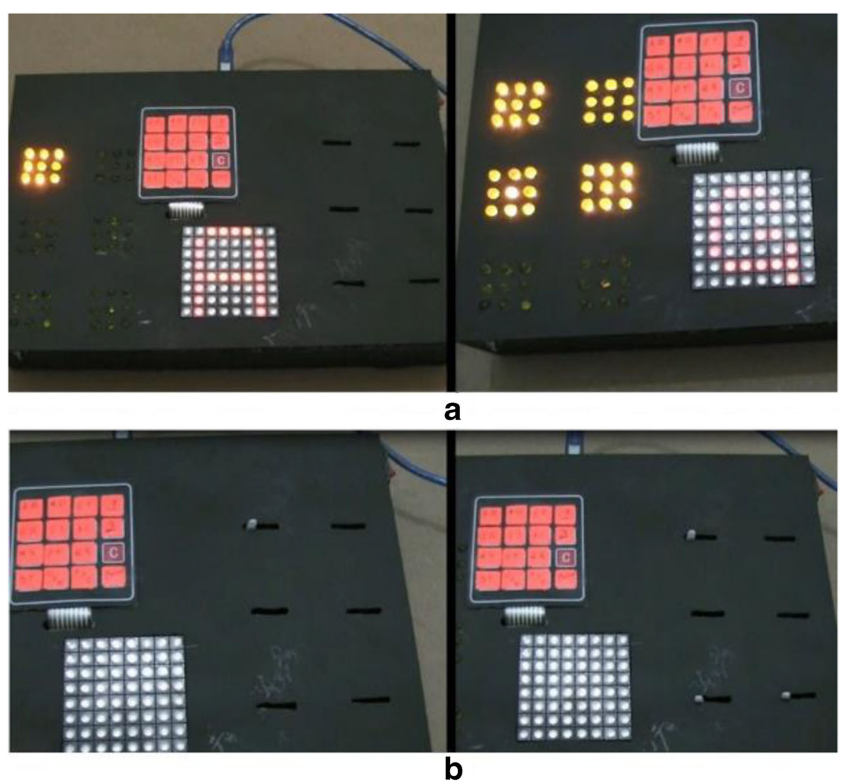

Fig. 8 Testing with the electronic device. a).- Visual Ouput, b).- Tactile Output

Table 1 Test results

Test	Group 1		Group 2	
	Success Average	Speed Avarage	Success Average	Speed Avarage
Inicial	4	15 s	6	18 s
4th day	16	13 s	19	11 s
Final	21	10 s	24	8 s

should be used only as an introductory tool, thus being supplemented by means of 3D printed pieces with a matrix of the exact size of the Braille alphabet, to train user fingertips.

Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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