Low Cost Electronic Brailler

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Abstract: -The majority of blind or visually impaired students in the third world countries are still using the mechanical brailler for their education. With technology advancements and electronic communication, relying on paper-based brailler would not be efficient nor productive. The "LCE Brailler" is a low-cost electronic brailler whose main features are to vocalize, braille, save and convert Braille characters typed by a blind student to alphabetical ones, which are then displayed on a computer's monitor. In order to promote an interactive educational experience among students, teachers and parents, the proposed brailler has an affordable low price with advanced capabilities. The device's design is simplistic and its keyboard is familiar to the blind user. It is based on the raspberry pi technology. The LCE device was tested by visually impaired students and proved to provide accurate mechanical functionality, accuracy, braille-to-text and text-to-audio blind assistant with a user-friendly graphical user interface.

Key-words: -Braille, Blind, Python, Electronic, Braille-to-text converter, Raspberry Pi, Visually impaired People.

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1 Introduction

Statistics by the World Health Organization estimates 285 million people around the world to be visually impaired with 39 million blind and 246 million with low vision [1] . Braille is a tactile writing aid used by blind people and visually impaired people. Braille is not just a language. It is a code that allows all languages to be written and read. It uses raised dots to represent the letters of the printed alphabet in embossed paper. It also includes symbols that represent various notations to be used for punctuation, scientific characters, foreign languages, etc.

Considering the importance of such emerging technology for the education of young blind students, developing a low-cost device for translating the Braille code to the Latin or Arabic alphabet would allow schools to overcome this problem not only from an educational point of view but also from a financial point of view. By consulting a Lebanese institute for deaf, blind and learning disabilities, and as per their requirements, we have developed a low cost braille-to-text converter with a similar embossed braille keyboard familiar for the blind student.

The LCE, an electronic Brailler, can be used by visually disabled people to help them navigate computers much like a sighted person. Logarithm and coding are described by using PYTHON's Raspberry Pi technology as a language. The circuit board connects the Raspberry Pi to the Braille keypad designed to make it easier for the blind user to use.

The rest of the paper is organized as follows: in Section 2, we explain how Braille cells function to read and write. Its two Subsection provides an overview of the features and costs of the various types of braillers found on today's market as well as a description of the braillers in the research with their contrast. Section 3 presents the proposed "LCE BRAILLER" describing its uses and advantages, as well as its hardware design and software implementation. The experimental results and testing of the LCE are explained in Section 4. This paper is finally concluded in Section 5, accompanied by a YouTube video link that shows a blind student testing of the LCE.

2 Background on Braillers

Since the advent of the Braille in 1821, braille gradually came to be accepted throughout the world as the fundamental form of written communication for blind individuals, and today it remains basically as he invented it [2]. However, in third world countries, the introduction of the Smart Brailler in schools has unfortunately not been observed due to its high cost. Therefore, the mechanical brailler is still the first means of education for young blind students, before eventually learning how to use the standard QWERTY keyboard, consisting of 88 keys, in order to write alphabetical texts.

Braille is a method of tactile reading and writing for blind people in which the letters of the alphabet are represented by raised dots. It's read by moving your hand from left to right along each line. Louis Braille's work led him to base the code on just 6-points instead of 12 (as seen in Fig. 1). Braille keypad cells are pressed at the same time depending on the Braille combination of the particular letter or number the user needs to type.

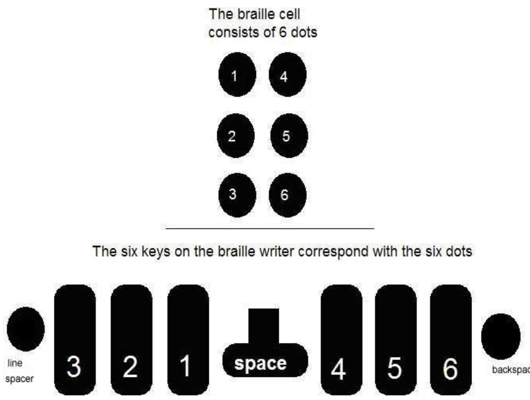

Fig. 1 The Brailler Cell and Keyboard

Fig. *2* shows the braille codes for the Latin alphabet. There is also a code used for math and science notations called Nemeth [3].

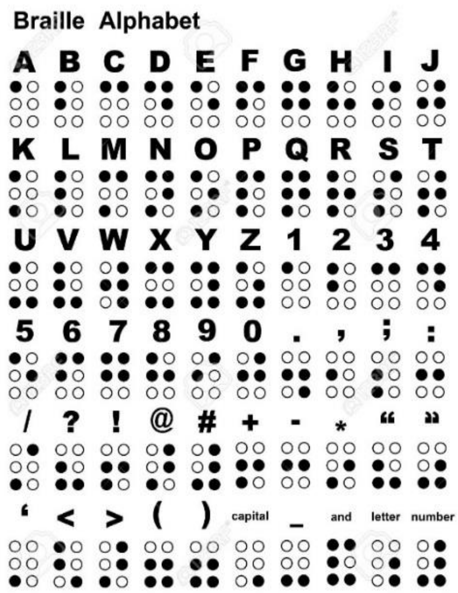

Fig. 2 Representation of English characters, symbols and numbers using Braille system

2.1 Existing Braillers in the Market

In today's market, there is two different types of braillers, the mechanical and the electrical brailler.

2.1.1 Mechanical Braillers

The "Classic Perkins Brailler" was inbuilt the Nineteen Fifties. It's like the initial Braille authored by David Ibrahim. It's a mechanical brailler with an oversized variety of elements, leading to a weight of 4.7 kg and a worth of over 700 dollars [4]. In 2008, Perkins announced their newly built brailler, "The Next Generation Perkins Brailler". It is twenty fifth lighter and quieter (keystroke noise is reduced) than the Classic Perkins Brailler. It weighs concerning 3.6 kg and prices around 710 dollars [5].

"Jot-a-Dot" is a small "Quantum Technologies" pocket-sized brailling apparatus [6]. With an ergonomic keyboard style, it is a 6-dot, mechanical brailler and reads the braille as it is being written. It weighs around 350 g and costs $425 [7]. "Tatrapoint" is another "Quantum Technologies" Mechanical Brailler. Slightly longer than the Perkins Next Generation Brailler, this brailler is around half the height, though. It weighs approximately 2, 75 kg and costs 1.540 dollars [8].

2.1.2 Electrical Braillers

Electronic braillers are those where electronic signals are translated into the user's input. Typically, electronic devices are quicker and simpler to use than mechanical ones. Some for writing in braille, and some for reading and writing. "Perkins Electric Brailler" is distinguished by its simpler typing, which allows users to increase efficiency. It costs around 995 dollars [9].

With more benefits, “The Smart Brailler”, shown in Fig. 3, is perhaps the best one. It accelerates learning, facilitates multi-sensory learning through visual and audio feedback, and integrates with mainstream Technology. In addition, it edits, saves and transfers brailed documents to digital text files via USB. It also involves non-braille users and encourages better communication between students and sighted teachers or parents using Roman letters on the display screen [10]. Perkins has priced the Smart Brailler at $2195, although its price could be between $2000 and $2500.

Fig. 3 Perkins Smart Brailler.

The “Mountbatten electrical brailler” from Quantum Technology has an easy-to-use right and erase feature and also has an audio response that informs the user what commands are entered. It has the ability to attach a PC keyboard to allow viewed peers to write in braille. Mountbatten Pro has a voice synthesizer that allows file management and text editing [11]. The cost of the Mountbatten is about 3,895 dollars.

Another type is "Cosmo Braille Writer" or "eBrailler Cosmo" produced by Electronic Brailler LLC. It can be used as a braille embosser or as a Braille input and output system for a computer while using the Duxbury Braille Translation program. The Cosmo Braille Writer does not have electrical components or cables with in the keyboard itself. Cosmo Braille Writer's price is 2,330 dollars [12].

A comparison between the majority of the braillers mentioned above on the basis of their prices and the different functionalities of the braillers is shown in Table 1.

Table 1. Comparison Table between braillers in market.

Brailler	**Price ($)**	**Weight (kg)**	**Edit, saves convert to text**	**Audio Feedback**
Mechanical(Perkins)	750	4.7	No	No
Next Generation	710	3.6	No	No
Electric(Perkins)	995	5.08	No	No
Smart Brailler	2195	3.9	Yes	Yes
Jot-A-dot	425	0.35	No	No
Tatrapoint	1540	2.75	No	No
Mountbatten electrical brailler	3895	4.7	Yes	Yes
Cosmo Braille Writer	2330	-	Yes	Yes

2.2 Braillers In Research

As shown in the comparison table (Table 1), Braille embossers are known for their bulk and high price levels. As a consequence, the third-world countries are also unable to take advantage of this emerging technology. Because of these drawbacks, several researches have been carried out to introduce low-cost braillers. In Table 2, we will present some papers and projects that worked on fulfilling this objective.

Table 2 Comparison table between braillers in research.

BRAILLER	**Year**	**Main Components Used**	**Main Functionalities**
Low cost Electronic Braille Typewriter [13]	2001	-PIC16F877 Microcontroller - 3Stepper Motor Controllers	Write paper-based Braille text.
A modified Perkins Brailler [14]	2002	-Electronic circuit board mounted on the underside of the Brailler. -Computer with Windows OS	Brailler for text entry into windows applications.
Text to Braille Converter [15]	2016	-Camera -Raspberry Pi	Conversion of a captured text to braille on paper.
E-Brailler [16]	2016	-Arduino -Refreshable braille cell using piezoelectric concept	Entered text from braille keyboard to braille cells using piezoelectric concept (Not on Paper)
Low cost real time braille keypad [17]	2018	- PIC16F877A microcontroller -puTTY Software	Conversion of braille to text with audio feedback

3 The Low Cost Electronic Brailler

The goal of this project is to develop a low cost braille-to-text converter. For this aim, we designed, implemented and tested, the LCE Brailler. The latter has a design similar to that of the Braille keypad recognized worldwide, with the goal of allowing the visually impaired to use computers much like a sighted person.

3.1 LCE functionality

The Braille keypad uses the Braille cells as 6 keys that can be pressed simultaneously on the basis of the actual Braille combination to type a specific letter, word or number. This device can detect which of the six braille keys is pressed and can automatically convert braille characters to alphabetical ones that are displayed on the connected screen and can be printed using a printer.

This kind of brailler is beneficial to blind or visually impaired people, particularly students, who will be able to work with familiar characters and not be forced to learn the “QWERTY” standard keyboard that we normally use. It involves these students in the learning process, offers a platform for writing and reading skills, and allows them to interact with sighted classmates, teachers and parents who are not familiar with the Braille Code.

The key benefit of our facility is its low cost relative to all the braillers listed above, which makes it accessible for people with low economic incomes. Another significant benefit is that its keyboard is designed in a similar way to the mechanical braillers used by blind people, making the transition to the LCE Braille keyboard very simple. In addition, audio assistance is provided so that the visually impaired person can hear and recognize the equivalent alphabetical character of his / her Braille character and direct him / her through his / her work.

3.2 Block Diagram of the system

The block diagram (Fig. 4) shows the principal parts of the LCE brailler system, it is represented as following:

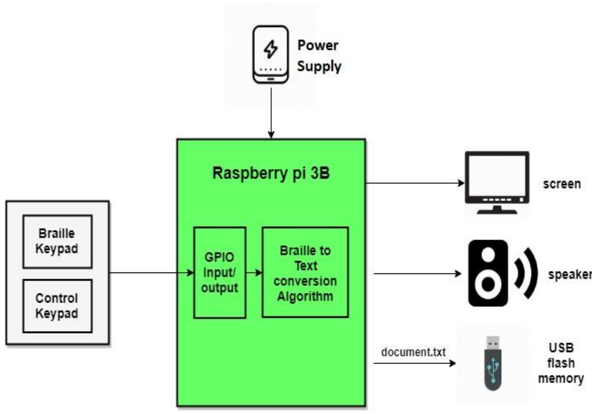

Fig. 4 System block diagram

- The keyboard is connected to the raspberry pi through the GPIO inputs.
- The Raspberry Pi 3 is powered by a +5.1V micro USB power bank.
- An SD card is inserted to the raspberry pi, it provides the initial storage for the Operating System and files.
- The raspberry pi receives the key pressed and will be programmed in an appropriate way to transfer the braille code to alphabetical letters.
- The result will be stored in the USB flash memory inserted.
- The screen has no use for blind person but it can be added for non-disabled user to see what data has typed.
- The speaker is used to provide speech to the corresponding text entered.

3.3 Description of each block

To explain the system deeply, it can be divided into 3 modules: Inputs, Raspberry Pi 3B and Outputs.

-Inputs: The input of the system is composed of 2 parts: The keyboard and the power bank. The keyboard forms the input of the system, it is composed from 12 keys consisted of push buttons or switch based on their functionality and divided into 2 categories that are Braille keys and control keys. The Braille keys consist of 9 buttons which is used to generate Braille code pattern for any alphabet, number and special symbol: from set of 6 keys, up to 68 different combinations can be generated, there is also a SPACE key to put space between characters. The ENTER button function as to agree with current command or to go for a new line in the text document, the BACKSPACE button acts as a delete button for wrong input braille alphabet.

The control keys consist of 2 buttons and 1 switch. The first is the New File button which performs creating new document, the second is a shutdown button used to power off the raspberry pi safely. The language switch key is used to select language (Arabic or English). The keyboard keys are designed as shown in Fig. 5.

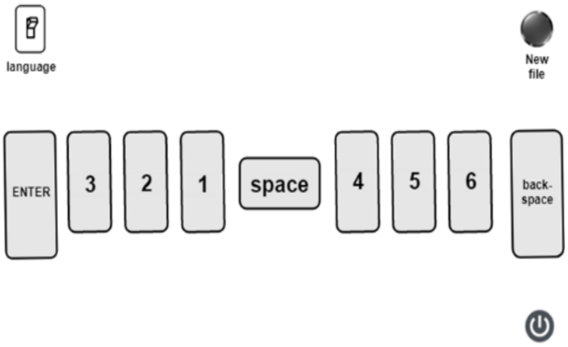

Fig. 5 LCE Keyboard

-Raspberry pi 3B: The Raspberry Pi forms the controller of the system which interprets the inputs, apply the conversion algorithm and give the output. The Raspberry Pi is a low-cost, credit-card - sized device that uses a regular keyboard and mouse to plug into a device monitor or TV [18]. The Raspberry Pi 3 is powered by a +5.1V micro USB supply. Raspberry Pi is best used for need of a complete computer, for instance to operate a robot and performing multiple tasks. In this project, there was a need to run multiple programs, so it was the choice of a raspberry pi 3B. The inputs are connected to the raspberry pi through the GPIO Pins.

- Outputs*:* The outputs of the system are divided into 3 parts: Flash memory, Screen and Speaker. USB flash memory is a data storage system with an integrated USB interface. It is typically removable and rewritable. In the proposed brailler, it’s necessary to insert a USB flash drive before turning on the machine.

The screen can be a TV screen, monitor screen or touch screen connected to the raspberry pi by HDMI input and used for non-blind person to see what data has been typed from the Braille keypad. Since the machine is low cost, there will not be a build-in screen, but each user can connect his own screen. The speaker connects to the aux jack or HDMI on the Raspberry Pi, and used to generate speech corresponding to any text.

3.4 The LCE Brailler final prototype

Finally, the LCE Brailler is enclosed in a well-designed, light-weight and low-cost enclosure (Fig. *6*). The distribution of buttons makes it simple to be used by the blind persons.

Fig. 6 The LCE Brailler final prototype

3.5 Software Realization

In order to convert braille to a readable text, we used PYTHON as it is an interpreted, object-oriented, high-level programming language with dynamic semantics. To implement the code, we used some built-in modules such as The Tkinter module, RPIO module, num2words module, and the subprocess module, also we created a module where all dictionaries will be written. A module is a file containing a set of functions; in our case dictionaries. A dictionary is a collection that is unordered, changeable, and indexed. In Python, dictionaries are written with curly brackets, and they have keys and values. For the Arabic language, we need to enable Unicode input in order to allow python using the Arabic keyboard.

3.6 Program steps

First, and before running the program, a USB flash memory must be inserted, after that an audio output demands to enter a filename in order to create a new file or open an old file. When the user presses ENTER, the file is created and saved automatically in the flash memory.

After entering to the file, the user start typing with braille code, the program check the keys pressed:

- If the new file button is pressed the program save the old file and demands to enter a new filename again.

- If key 3,4,5,6 pressed that is mean we have entered to the numbers mode. It continues to type in this mode until the user presses the letter indicator (5, 6) which allow him to return to the letter mode.

- If key 5 pressed, it is mean we have entered to the punctuations mode, it continues to type in this mode until the user presses the letter indicator.

- If key 4 pressed, then we have entered to the symbols mode, it continues to type in this mode until the user presses the letter indicator.

In the same moment, the language selector is checked:

- If Arabic is chosen, the conversion of braille cell is done to Arabic letter.

- If English is chosen, the conversion is done to English letter. The program waits and check if key 6 is pressed, then we have entered to the capital letters mode, it continues to type in this mode until the user presses the letter indicator.

If the exit key is pressed, the file is saved finally and the machine is shutdown.

The algorithm presents an infinite loop with interrupts to break this loop.

3.7 DATA Dictionary Implementation

In order to convert the Braille cell Characters entered through the GPIO inputs of the Raspberry Pi, we compare it to a set of "PYTHON Dictionaries" written in our code. The set of dictionary, which are standard, helps us compare the braille characters entered to English, Arabic, numbers, punctuations or symbols in order to convert it accurately.

A part of the Braille English Alphabets is shown in Table 3.

Table 3. Part of the Braille English Alphabets

CHARACTER	BRAILLE	BRAILLE DOTS
a	⠁	1
b	⠃	12
c	⠉	14
d	⠙	145
e	⠑	15
f	⠋	124
g	⠛	1245
h	⠓	125

3.8 Data Flow Diagram

Fig. 7 shows the data flow diagram of the LCE Brailler:

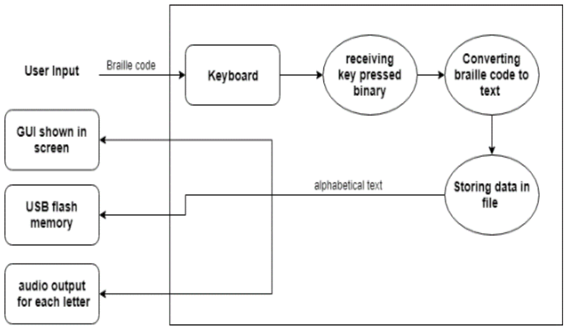

Fig. 7 Data Flow Diagram

As explained above, one of our objectives is for the device to be simplistic in use:

- The keyboard is used to enter the braille code;
- The code is translated into alphabetical language through the PYTHON based program;
- All the data entered will be stored in files and into USB's.
- Data's will be shown through a screen for the sighted helper (teacher/parent).
- Every letter entered will be read to the user for a more helpful and accurate use which will be explained in the following paragraph.

3.9 Text-to-Speech Realization

In order to realize an audio output for the text. The system will read the text and send it to the speaker so that the blind persons can easily communicate. For this aim we implement in the code a function to call the command "espeak" from the terminal, which is responsible of generating a speech for every text entry we give.

3.10 Project Interfaces

The system includes a simple interface which can be used by the sighted user when he connects a screen. The Graphical User Interface is developed using Tkinter module imported to the code.

The *"Welcome Page"* (Fig. 8) appears a few seconds to introduce the application with audio assistance.

The *"Main Page*" (Fig. 9) includes a field to enter the filename that the user chooses, it can be an old filename, and in this case, the program opens the old file. If not the program creates and save a new file when he pressed in ENTER button.

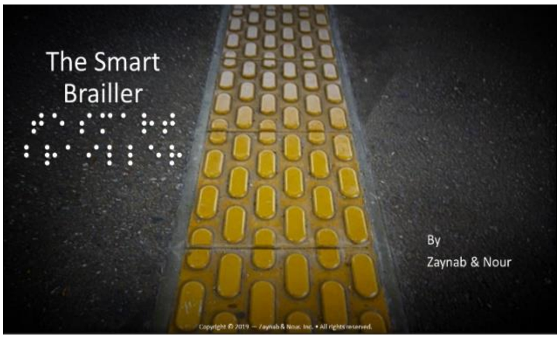

Fig. 8 Welcome page

Fig. 9 Main Page

The *"Document Page"* (Fig. 10) is composed from the text editor, and a button to save the file and exit the program.

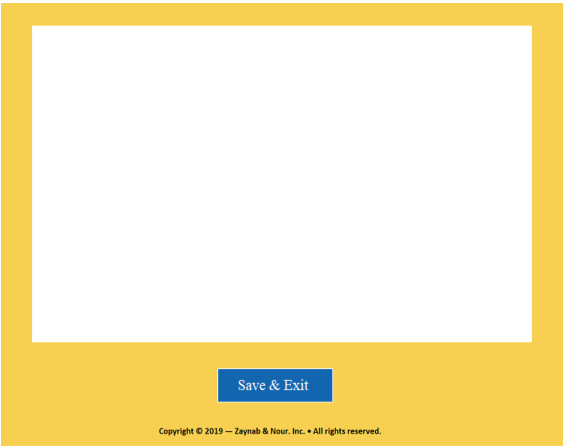

Fig. 10 Document Page

3.11 LCE Features

All the work and researches done with all the hardware and software implementations have led to the creation of the Low Cost Electronic Brailler. The features of the LCE Brailler are the following:

- Reading the entered Braille code and converting it into English and Arabic alphanumeric characters.
- Auditory feedback: Each steps is read by the system for the blind student in addition of the spelling of each letter typed from the braille keyboard.
- Graphical Interface allowing the sighted user to see and control what is being written.
- Data entered to be stored in a USB flash memory which will then allow the document to be retrieved and printed.

3.12 LCE Advantages

As a result, the LCE Brailler is mainly a low cost brailler costing 182$ for its manufacturing. Its advantages are the following:

- Low Cost Brailler: Affordable device by schools and parents with low budget income.
- Learning speed-up: by converting to text, it bridges the interaction gap between the blind student, his teachers, parents or classmates.
- Easy document save: automatic save of the documents into USB flash memory.
- Easy Use: the LCE Brailler uses the standard braille keyboard known by the blind student, thus its use will as simplistic as possible.
- Auditory help: System reads the steps to follow as well as spells the letters being written to make sure no writing mistake is made.
- Sighted users involved: for teachers or parents participation by reading and retrieving through flash memory the documents written.

Although the files and documents are being saved, the user has no choice but to retrieve them from the inserted USB memory.

Following are the pros of our solution compared to the other low cost braillers listed in Table 2 found in Section 2.2:

• Two of the researchers are from more than 15 years ago and not currently in the market; one can convert the braille to text with the electronic circuit mounted under the mechanical brailler, the other is only a low cost braille typewriter;

• The "Low cost real time braille keypad for communication" uses the PIC16F877A Microcontroller for the conversion code and need to connect to a computer; the PuTTY software displays the text and converts it to speech format. Our project uses the Raspberry Pi which can be used as a computer and reduces complexity.

• The "Text to Braille Converter" from 2016, is a device that converts the captured text to braille, whereas the "E-braille" produces refreshable Braille cell modules from an entered set of combination of the keyboard, but both don't perform the opposite which is our main objective.

4 Experimental Results

To test the efficiency of the writing process using the Braille keyboard compared to the conventional keyboard, this system is tested using three different types of users including school principal, teachers and blind students in Al Hadi Blind School in Lebanon. All English characters and Arabic characters were given as test inputs. Additionally, the participants have been asked to type different sentences in both Arabic and English languages. The accuracy, simplicity of the LCE brailler were very satisfactory for both the students and teachers.

Moreover, the blind student will not find difficulties in accessing new or existing files to edit them as the LCE interfaces are accompanied by an audio assistance leading the blind student in his work. It is a convenient and flexible solution to the interaction with blind students. Moreover, it gives them the power to feel on par with their sighted classmates. Finally, the graphical accompanied software is user-friendly and it was highly admired by the teachers.

5 Conclusion

In this paper, we presented a comparison among existing braillers and showed their main functionalities as well as their components, inconveniencies and scope of experiments. Additionally, we presented our proposed LCE brailler product with its features and highlighted its advantages in comparison with the presented products and papers. The proposed solution was experimented and tested by students and teachers at *"Al Hadi Blind School"* in Lebanon. The results of the designed kit clearly describe the operational accuracy and effectiveness in making Braille learning an easy and comfortable option. The obtained results proved the validity of the design and of the implementation and gained high satisfaction from its users. In addition, the control buttons were able to achieve their respective purposes without errors. Moreover, the simplification of the hardware design reduced the high cost of the device.

Acknowledgment

Testing of the Low Cost Wireless Electronic Braille would not be possible without the help and cooperation of the visually impaired people of Al Hadi Blind School in Lebanon. A video of the device being tested by a visually impaired student is available on our YouTube channel in the following web link.

https://www.youtube.com/watch?v=Ete8KiQnW3s

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