Improving Design of Piezoelectric Braille Cell for Braille Display Devices

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***Abstract*—The braille system is one of the most recognizable language systems for those with visual disabilities. With the advance of technology, the use of braille system is not only limited to physical books with raised dots, but it is also has been implemented in mechanical devices. This allows digital information to also be displayed to be read by the visually impaired, using the devices called braille displays. However, one of the key components in braille displays are braille cells, which shows the desired braille characters. This technology is yet to be available in many countries especially in Malaysia, whereas the purchase of one set of the braille cells is often very expensive. More ever, the commercial braille cell has a cap breaking loose issue where it is easily being detached, disassembled and broken. Thus, this research aims to improve and resolve this issue by designing and fabricating a braille cell that consists of lock mechanisms. The result shows that by having this lock mechanics, it can resolve the cap breaking loose issues that happened in a commercial braille cell. On the other hand, this study also aims to evaluate the quality and feasibility of using 3D printing technology in fabricating braille cells to mimic the commercial ones. This can be done by analyzing the performance in term of dots stroke between the fabricated and commercial braille cell. The result shows that fabricated braille cell obtains a larger stroke length compare to the commercial braille cell at 0.75 mm against 0.7 mm respectively. This indicates that the fabricated braille cell dots would be more distinguishable for the blind people fingertips when they are reading the braille alphabets or characters. The greater increase in stroke length will result in clearer reading to the user and thus desirable.**

***Index Terms*—Braille Cell; Braille Displays; Piezoelectric Actuator; Braille Alphabets.**

I. INTRODUCTION

The braille system was one of the more notable systems of language employed to for ease of access to the disabled people. The braille system employs the use of raised dots writing system, which allows the blind people to be able to read and understand the message through their sense of touch instead. This system has a long history dating back as far as the 19th century, and only until recently it had been put to good use. However, the rise in technology had also given the braille system a plausible evolution in its method. In the past, books written with the braille system would have been thick, heavy and cumbersome. As of today, modern braille displays are no longer relies on static raised dots imprinted on books. Modern braille systems make use of specially designed actuators, such as pneumatic or piezoelectric actuators to rise up or lower down the sets of braille dots built-in onto a braille character [1]. Each of this braille cell represents one braille character and together with the whole set of braille cells then displays the information. This device also often comes with additional features such as a built-in microphone and audio speaker. It also consists a set of braille cells with the standard of 8-dots that representing the braille characters. Each of the dots has their own individual actuator which is controlled by the device's microcontroller and changes corresponding to the message being read. By having the braille display, the hundreds of braille books especially the thickness books can be easily embedded into this device and thus can be accessed and easily bring by the blind people.

One of the example braille displays that have been developed in Malaysia is named eBraille Quran. The eBraille Quran is a project aimed to aid the visually impaired and blind Muslims in the improving their readability on the Quran as well as improving their understanding and appreciating the Quran more effectively. The project was piloted in 2011 by UTM master student and is the first in the world for Quran employing braille display [2]. The concept of eBraille Quran utilizes the standard braille display with custom-made software controllers to read, recite and navigate the Quran conveniently. However, due to the scarcity of the components and imported braille cells from overseas, the production of the unit is ludicrously costly. The cost is about RM20,000 or 3552 euro per unit. Thus, not every one of blind people especially the Muslim blind people could afford to buy it due to high costs. As such, this research is developed to support this project in an effort to slice down the cost of the braille cells, which in turn will reduce the cost of the eBraille unit. This will make it far more affordable for the users and the manufacturers if it were to be marketed.

On the other hand, most of the available braille displays used piezoelectric braille cell that was sold by Metec company. The disadvantage of using this braille cell is that the braille cell cap that holding the raised dots' pins are can easily be detached, disassembled and broken. Also, the braille cell is lack of locking mechanisms where could cause the user to detach the caps unknowingly. If the braille display is dropped on the floor, the caps will detach by itself and is difficult to be fixed by the user especially the blind user. Figure 1 shows a Metec braille cell where the cap can be easily broken when it was dropped on the floor. It is also observed that braille dots were strewn about on the floor. Based on these issues, this research intends to improve the available braille cell by designing and fabricating a low-cost braille cell by using 3D printing technologies. Basically, the braille cell has been designed based on the specification of commercial braille cell-like size dimension, braille dots and hole on the cap. Two experiments have been conducted in order to test to test the functionality and to analyze the performance of developed braille cell.

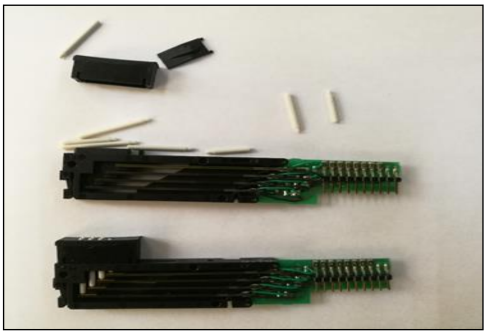


Figure 1: Metec braille cell

II. Related Research

Braille system provides a means of reading method for those who are visually impaired. Invented by a French inventor by the name of Louis Braille (1809-1852) by using the 'night writing' raised dots system pioneered by Charles Barbara [3]. The braille system used the following dimensions in Figure 2 as shown below. Each letter of braille is 6 dots in 3 x 2 dimension. The diameter of each dots is around 1.4 to 1.5mm, spaced evenly from other dots at 2.5mm. Each letter is separated with 6 to 6.4 mm horizontal spacing, and 10.4 to 12.7 mm vertical placing. Some braille employs a 4 x 2 layout with similar dimensions [4].

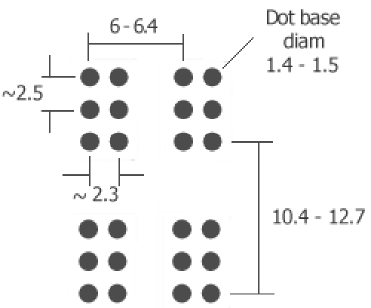


Figure 2: Braille cell system[4]

The braille letters permit 63 different patterns per cells, of which corresponds to specific letters of the Roman alphabet including punctuation marks. Without any contraction, the pattern-to-letter system is called Grade-1 braille, which is the basic braille language taught. Today, braille system is a generally well-known language employing the raised dots writing system replacing visual sensory with touch. The system had persisted and preserved well with time, and with the advance of science and technology, the system is also adapted to complement digital displays employed by numerous personal and work devices. Braille system no longer primarily relies on static raised dots pre-imprinted, but instead used a device named braille displays to variably show the information on the digital screen in braille characters [5, 6]. Figure 3 is an example of braille displays developed by Universiti Teknologi Malaysia (UTM) known as eBraille Quran [2]. Braille displays consisted of a set of braille cells, ranging from 20 to 40 stacked side by side. A singular braille cell is shown in Figure 2. Each of this braille cells represents one braille character, and together with the whole set of braille cells then displays the information. Each of this braille cells can change characters by manipulating the raised and lowered dots arrangement via all of its 8-dots per braille cell. To raise or lower each of these dots, the braille cells are manufactured with actuators that are accurate, responsive and precise, yet small enough to fit within the braille cells with widths not wider than the size of the human finger. For this purpose, braille cells employ pneumatic or piezoelectric actuators [7].

Figure 3: Braille display eBraille Quran[8]

The concept of piezoelectric effect is derided based on the certain materials ability to generate an electric charge when mechanical stress [7]. The term piezoelectricity is derived from the Greek word "piezein" which means to press. The discovery of piezoelectricity started in 1880 when early experimentations demonstrated the connection between macroscopic piezoelectric phenomena and crystallographic structure, originally published by Pierre and Jacques Curie [9]. The experiment established a relationship between mechanical stress and conclusive measurement of surface charges on specially prepared crystals – quartz, topaz, tourmaline, cane sugar and Rochelle salt [9]. This phenomenon was later confirmed to be true for the reverse – when an electrical charge is applied on the materials exhibiting piezoelectricity properties, mechanical stress was seen to develop. With this information, the use of piezoelectricity as transducers saw its first use in World War I in the ultrasonic submarine detector, made using a mosaic of thin quartz crystals glued between two steel plates. The piezoelectric concept then began gaining attention for applications such as sonar transducers, circuits, actuators and systems [10]. Piezoelectric actuators are a common mode of applying mechanical movement of the dots in braille cells due to its accuracy, precision, responsiveness, and small-scale size. The piezoelectric actuators typically consisted of thin, medium length piezoelectric strips attached to a power source in one end and the dots held at the opposite end. When a high voltage is applied onto the piezoelectric strips, based off piezoelectricity concept, will cause it to bend upwards or downwards. This bending motion will then prompt the dots to lift up or sink down. Multiple piezoelectric strips are required for a single braille cell that is governed by a control unit. The common controlling circuit is shift register circuit. Multiple braille cells are then controlled by the central processing unit embedded into the braille display device that translates visual output (text from computers) into physical braille characters output [11].

III. Research Methodology

A. Braille Cell Design

The method of fabrication has been determined by using predominantly 3D printing technology named Maker-Bot 3D that is available in UTM labs. The material used to print 3D objects is the type of plastic material named Acrylonitrile-Butadiene-Styrene (ABS). One of the limitations of using 3D printer is a 3D object can only be printed in one direction at one time. Trying to print the whole braille cell body in one go will create a number of structural problems such as overhang and deformed dots. By considering this limitation, the braille cell has been designed part by part and was assembled afterwards. Figure 4 shows a design of braille cell at four different views; side, top, isometric and exploded view. Basically, the braille cell contains braille dots, cap, actuator holder, upper and bottom slot. Those are designed using designs using Solidworks software. The overall size of braille cell for this design follows the standard size of Metec braille cell which is about 84 mm x 17mm x 7mm. As illustrated in Figure 4, most of the braille cell design is modified only to the cap. There are two lock mechanisms are added to the design where both could lock the cap together with the upper and bottom part. By having this lock mechanics, it can resolve the cap breaking loose issues that were happening in Metec braille cell that is mention earlier in this paper.

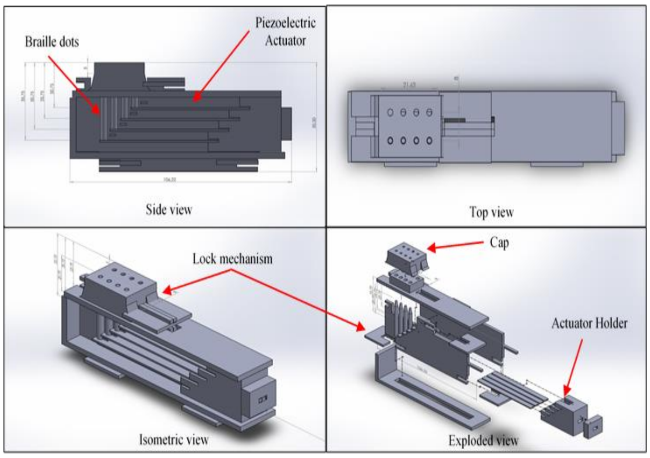


Figure 4: Braille cell design

B. 3D Printing

The 3D printers used for this research are the ones available in UTM design lab. The printer model is Maker-Bot 3D with a build volume of 24.6 cm x 75.2 cm x 15.5 cm. The 3D printer's specification is tabulated in Table 1. The printers are roughly two years old and capable of feeding PLA or ABS filaments.

Table 1
Maker-Bot 3D specification

Properties	Specification
Build Volume	24.6 cm x 75.2 cm x 15.5 cm
Layer Resolution	100 microns
Filament Diameter	1.75 mm
Filament Type	ABS, PLA
Nozzle Diameter	0.4 mm
Nozzle number	2
Max Dimension	24 cm x 15 cm x 15 cm
Min. tolerance	0.4 mm

IV. RESULT & DISCUSSIONS

This section will explain the result of fabricated braille cell using predominantly 3D printer technology in term of quality of fabrication, problem found and proposed a solution. This section also explains the functionality test that has been done on fabricated braille in order to find out whether it functions. Finally, some discussion on analyzing the performance of fabricated braille cell and its comparison with Metec braille cell also presented in this section.

A. Braille Cell Fabrication

As being mention before, the design of braille cell is fabricated using the Maker-Bot printer. All parts were printed simultaneously in one printer. Early prints noticed that the filament could not stick to the printing bed due to its small size. The solution to it was by creating rafts to provide a more stable platform for the filaments to stick onto. Figure 5 below shows the result of a fabricated braille cell. As the design is printed with very small dimensions (60 mm x 27mm x 7mm), the quality of the print is noticeably unsatisfactory. There is a noticeable crack on the cap of the braille cell and the holes on the caps are practically blocked. This is due to how thin the caps are made. Part of this is also because the design requires the 3D printer to create supports on the cap's sides, which upon scraping it from the printing bed, further weakens the cap's walls.

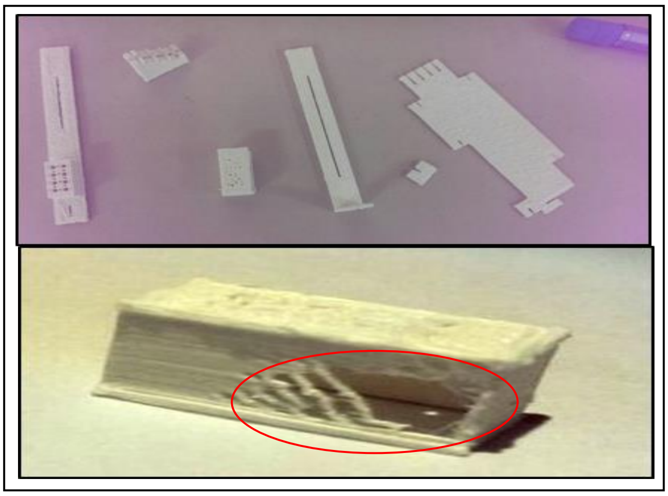


Figure 5: Result of the fabricated braille cell

Based on the issue, the braille cell has been resized to be a little bit larger compared to the small design in term of its thickness. All part like braille dots, cap, actuator holder, upper and bottom slot were made to be larger with 1mm – 1.5mm tolerance to ensure that all the mating parts would fit. Figure 6 shows the size comparison of resizing design compared to first and commercial braille cell. As it could be noted, the resized design had to be fabricated noticeably larger than the commercial size. The print quality for the small design is unsatisfactory and the slot tolerance between parts are too small to be printed for this size. The resized design has produced the cap in good quality. The wall of the cap became thicker compared to small design and thus providing more strength to it. The cap also fits its mating and secured firmly with additional locks, and most importantly has a firmer grip than the commercial ones. Further designs may simplify the design further and remove the cap locks entirely. The hole dimension for the resized design is enlarged from 1mm to 1.5mm. The holes are less blocked as illustrated in Figure 6. It is shown that by increasing the thickness of braille cell design can produce a good quality of fabricated braille cell when using 3D printer technology. Several drop tests have been conducted at a different height and the results show that the cap did not come out and it is tight with the body.

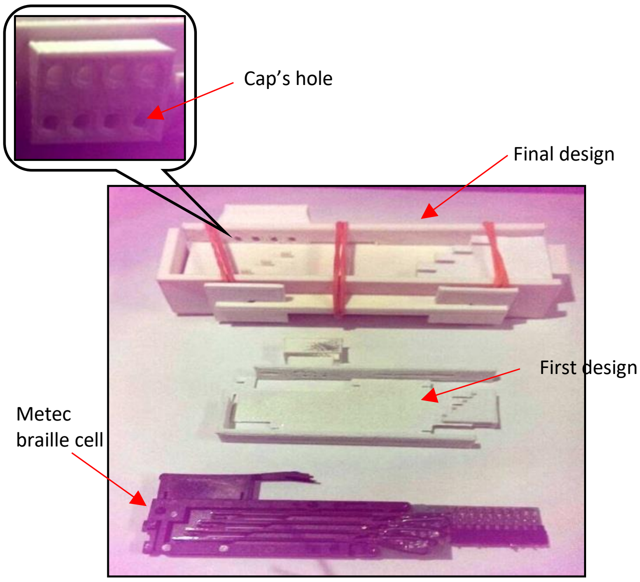
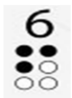
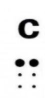
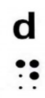


Figure 6: First and final design with Metec braille cell

B. *Functionality Test*

The functionality test can be done by test the ability or functionality of fabricated braille cell to display a certain braille's alphabets. In order to test the functionality of fabricated braille cell, a testing circuit is developed. The circuit is powered up by a 12V DC adapter. A DC-to-DC converter is used to convert the 12V input voltage to 200V output voltage that is used to activate the piezoelectric actuator. Eight relays are used as a switching device between piezoelectric actuator for each braille's dots and I/O of Arduino the microcontroller. The electronic circuit is controlled with Arduino UNO. Controlled by using I/O pins ranging from 1 to 8 for each individual relays. Switching each pin as output will activate the relay to close the circuit connecting the 200V input to the piezoelectric strip, allowing it to lift the dots upwards. In the functionality test, the microcontroller is programmed to send several alphabets and numbers. Table 1 shows the result of the braille cell that displayed certain braille's alphabets and numbers such as 'a', 'b', '5', '6' and so on. It shows that the braille cell work and function correctly to the microcontroller's command.

Table 1
The result from functionality test

Alphabet	Alphabet in Braille	Alphabet Output	Number	Number in Braille	Number Output
'a'			'5'		
'b'			'6'		
'c'			'7'		
'd'			'9'		

C. *Performance Test*

To test the performance of between fabricated and Metec braille cell, an experiment is conducted to measure each dot's stroke for both braille cells. The measurement of each dot's stroke is measured by using Verner Calipers. The dot's stroke can be obtained by measuring the differences between two dot heights: peak height (when the dot raised up) and base height (when the dot falls down). The result for all dots is shown in Table 2. It is observed that most of the dots for fabricated braille cell produced a minimum and maximum stroke of 0.71mm and 0.75mm respectively. Each value of dot's stroke was not same due to the dot's furnishing issue or piezoelectric actuator that may be not properly installed. However, based on the table, it is shown that the fabricated braille cell obtains a larger stroke length compare to the Metec braille cell at 0.75 mm against 0.7 mm respectively [ref]. This indicates that the fabricated braille cell dots would be more distinguishable for the blind people fingertips when they are reading the braille alphabets or characters. It also indicates that although the fabricated braille cell use the same size piezoelectric actuator with commercial braille cell, it is able to give the stroke which is sufficient with the commercial braille cell.

Table 2
Dots stroke of the fabricated and commercial braille cell

Dot	Stroke (mm)	
	Fabricated braille cell	Metec braille cell
1	0.75	0.68
2	0.71	0.69
3	0.75	0.68
4	0.71	0.71
5	0.74	0.69
6	0.74	0.70
7	0.75	0.69
8	0.75	0.70

V. CONCLUSION

In this research, low-cost braille has been designed and fabricated by using 3D printing technologies. This braille cell has been developed with the purpose to improve and resolve the cap breaking loose issue of a commercial braille cell. The braille cell has been designed based on specification stated on the commercial braille cell. Most of the braille cell design is modified only to the cap. There are two lock mechanisms are added to the design where both could lock the cap together with the upper and bottom part. The result shows that by having this lock mechanics, it can resolve the cap breaking loose issues that happened in a commercial braille cell. On the other hand, the functionality test that has been done on fabricated braille in order to find out whether it functions. It shows that the fabricated braille cell work and function correctly to the microcontroller's command where it successfully displayed certain braille's alphabets and numbers such as 'a', 'b', '5', '6' and so on. Lastly, the performance and comparison in term of dots stroke between the fabricated braille cells were tested. It is observed that fabricated braille cell obtains a larger stroke length compare to the Metec braille cell at 0.75 mm against 0.7 mm respectively. This indicates that the fabricated braille cell dots would be more distinguishable for the blind people fingertips when they are reading the braille alphabets or characters. It also indicates that although the fabricated braille cell used the same size piezoelectric actuator with commercial braille cell, it is able to give the stroke which is sufficient with the commercial braille cell.

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