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Design of A Single Electromagnetic Braille Cell

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Abstract – *Visually impaired usually use a universal code called a braille system for them to read and visualize images by using their haptic sense without using their eye. Over the few years, with the advent of technology, many assistive technologies have been developed and are widely accessible for the visually impaired community. However, educational braille-based and current assistive technology for visually impaired people to read and visualize, such as electronic braille display, is still lacking. This is due to the fact that most of the braille cell used in commercializing braille display is actuated by piezo bimorph actuator. This system is not the only complex due to the arrangement of the piezo strip, but it is also expensive to produce a braille display system. Moreover, its braille cell based on piezoelectric actuator also has the limited feature, where it can support to display single-line sentence only due to the arrangement and nature of piezo bimorph. This research aims to design a single braille cell based on electromagnetic actuator technology. The braille cell can support multiple lines of the sentence, is cost-effective, and has the same performance as a commercial braille display. In order to determine suitable design parameters and evaluates the performance of fabricated braille cells, an experiment is done with three levels of factors, one for a number of turns and the other is diameter which are 100, 200, and 300 turns and 0.1, 0.3, and 1.0mm. The result shows, regardless of wire diameter for coil, the minimum current required to lift the dot will remain the same for the same number of turns. The final number of turns and diameter selected is 300 turns, and 0.1mm and required minimum value of current 0.08A to lift the dot.*

Keywords - *Braille Cell, Electromagnetic Actuator, Cost-Effective, Stereolithography, Electrical discharge Machining.*

I. INTRODUCTION

In developing countries, lacking assistive technological solution for these community have made their learning process become very difficult, lengthy and complex as they are unable to receive visual information. Thus, assistive technology such as braille display can be used to help their learning process. Unfortunately, not every visually impaired people, especially those who lived in developing countries able to afford this commercialized braille as they are very expensive [1][2]. Typically, the price of an available electronic braille system is ranging RM 20,000 to RM 200,000 depending on the type of braille display, whether it is to display graphic or sentence. This is due to the most commercializing most of the commercialized braille display for sentences have limited features, where it can only display single-line sentences only and is difficult to display graphs or pictures. For commercializing braille graphics, however, they are very bulky due to their piezo strip orientation and size. While commercializing braille graphics are very expensive compare to regular braille display, it still not affordable. Therefore, the need to produce braille in a format that can be more easily stored, accessed, cost-effective, and reproduced is crucial in this field. [1][2][3]. This project focuses on the development of an electromagnetic actuator for braille display that will be used to assist the visually impaired in the learning process.

II. LITERATURE REVIEW

Braille system provides a means of a reading method for those who are visually impaired. It is first invented by a French inventor by the name of Louis Braille (1809 – 1852) by using the ‘night writing’ raised dots system, which is pioneered by Charles Barbara [9]. Each character in braille is depicted using rectangular cells/blocks that consist of 2 columns with 3 spaces for 3 dots in each (3x2 layout). The diameter of each dot is ranging from 1.4 mm to 1.5mm and has 2.5 mm spacing in between. Each cell, however, has about 6.0 mm spacing in between cells. It is important to note that, in braille technology such as electronic braille display, single-cell has 2 columns but with 4 spaces for 4 dots in each (4x2 layout) [10]. Two extra dots represent the typing cursor for braille users to type in the letter. The pattern in which the dots embossed are arranged in a cell to distinguish one character from another. Braille system is rather a code than language. Hence, a single pattern of braille code can be represented multiple letters in multiple languages.

Over the past few centuries and with the advent of technology, the learning process for visually impaired people has come a long way. The need to produce braille in a format that can be more easily stored, accessed, cost-effective, and reproduced has long been recognized in the braille display technology field [1][2][3]. Because of these reasons, many pieces of research have been published and actively exploring the technologies and actuators to be used as well as analyze their performance [4][5][11]. However, the diversity of these technologies and actuators does not reflect the array of devices currently available for purchase. In fact, most of the commercialized braille nowadays, piezo bimorph, is the only type of actuator to be found in the market. The table sections provide background information about all the research that explored braille actuators and current commercializes braille in the market.

Authors	The actuator used for developing braille cell
[3]	Micro servo
[4]	Ionic Polymer Metal Composite actuator
[6]	Electromagnetic actuator
[7]	Electromagnetic actuator
[8]	Hydraulic pressure actuator

Thus, the price of a single braille display or graphic is often expensive and not affordable due to the complexity of its system when using piezo bimorph. Numerous of paper has been publishing in the research field for the purposed of producing an improved version of this or developed entirely new braille system that used another alternative actuator [2]–[5], [12]–[14]. For this paper, however, it focused on the developing an electromagnetic actuator for braille cell.

The concept of the electromagnetic actuator is any device that provides working motion as a result of force produce by the current-carrying wire and permanent magnet. When there is current flow through the loop of wire, a magnetic field accumulates around it, causing a permanent magnet to attract or repel. The direction of the permanent magnet also depends on the direction of current flow through the coil. This concept involves the theory of electromagnetic magnetostatics law. There are two principles involves, which are Lorentz law and Faradays Law. Below is the equation of magnetic field, B.

$$\vec{B} = \vec{\nabla} \times \vec{A} = curl\vec{A} \quad (1)$$

Consider a straight wire positioned along the x-axis; the x-component of the magnetic field B $^{\rightarrow}$ is zero (B $^{\rightarrow}$=0) due to the 90-degree angle of cross-product in equation 1. Thus, leaving only two other vector components, which are:

$$B_y = \frac{\partial A_x}{\partial z}, \; B_z = -\frac{\partial A_x}{\partial y} \quad (2)$$

For the wire segments that have a length of l_1 and a length of l_2 with a current i_1 current i_2, respectively, an attractive force or repelling force is created if there is current flow in both wires. If the current in each wire flow in the same it produces attractive force, while the current that flows in different direction produce repelling force. If the current flow in wire 1, only y and z components of the force will be acting on wire 2 due to the current flowing in wire 1. This repelling force produced between the wire can be determined from the general equation of Lorentz's force:

$$\vec{F} = \oint i \cdot \vec{dl} \wedge \vec{B} \; \frac{\partial A_x}{\partial z} \quad (3)$$

Where $\vec{dl}$ is an element along the length of the conductor, F_y and F_z are expressed as follows:

$$F_y = \int_{-l/2}^{l/2} i_2 B_y dx \; ; F_z = \int_{-l/2}^{l/2} i_2 B_z dx \quad (4)$$

Using these formulae, the resulting force of a magnet and a coil can be calculated. These formulas, however, consider force acting between two current-carrying wires, and according to Faraday's law, a permanent magnet can be represented by a coil, with a certain number of turns of one single [15].

Therefore, for this project, it is a case of full balance (which is a permanent magnet and coil are coaxial). This resulting the force acting in the y-direction between two parallel wires cancel. Leaving the sum of forces along the z-axis F_{act} gives the force generated by the actuator. Below is the expression summation F_z for F_{act}, as well as the general equation.

$$F_{act} = \sum F_Z$$
$$F_{act} = BIL \quad (5)$$

Whereas F is produced resulting from magnetic field B, current I, and L.

III. BRAILLE CELL DESIGN

In order to design a braille cell, it is required to design two parts, one for permanent magnet and another for the copper coil. The design should be able to support the main components such as coil and permanent magnet (NdFeB in this case). This design required less number of parts, as well as easy to assemble. Furthermore, it also has a screw thread mechanism to constrain the movement of magnet and dot inside dot holder. Next, it also has line embossed at each end of the dot holder so that the coil winding process is easy and have cleaner coil arrangement. Dot length is design with an extra 2mm to compensate the thickness of casing/cap (where total length is 2.7 mm).

Figure 1 below shows the basic concept design of an electromagnetic braille cell.

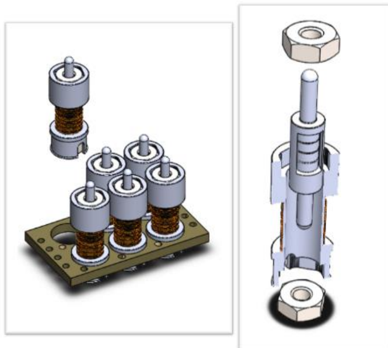

Fig.1: Basic concept design

However, there are many disadvantages to this basic design, first it consumes large space between dots as the number of turns increases. Second, there will be electromagnetic interference as the coil is too close to each other which then will affecting the movement of adjacent dot. Finally, it will need continuous current supply in order to maintain the dot to stroke upward. The next design is called concept 1, as shown in Figure 2.

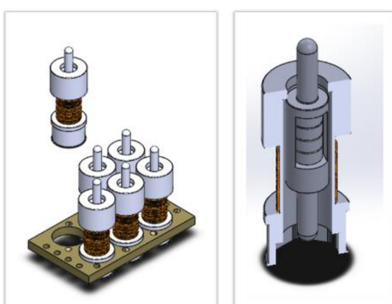

Fig.2: Concept 1 design

This design solves the problem to the previous design, where coils consume a lot of space in between the dots. Therefore, the diameter of the middle section is reduced to provide extra space for the coil. Not only that, with this design, it is able to minimize the chances of electromagnetic interference between dots. Furthermore, previous dot design is redesigned so that it able to contain magnet inside, this design is now called magnet holder. So that more stable stroke can be achieved. Although this design is relatively simple as there are no parts added but with slight change to the prior design, yet, it still needs continuous current supply. The third design is just a slight improved from the concept 1, where some feature is remains unchanged such as space for coil as shown in Figure 3.

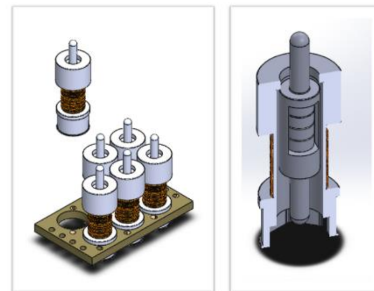

Fig.3: Concept 2 design

However, in this new design, new components such as M2 nut are added, where the purpose of this M2 nut is to maintain the dot in their position by pulling the magnet of the dot (up or down). This new design adds more parts to the previous design, where two M2 nuts are added to attract the dots upward and downwards in order to maintain the dots stroke regardless of any current supply when it is already stroke upward. This addition will increase the cost of material. Furthermore, this design will be prone to manufacturing faulty, as the design needs to fit perfectly with the M2 nut. Figure 4 below is the summary of initial concepts and final concept of braille design.

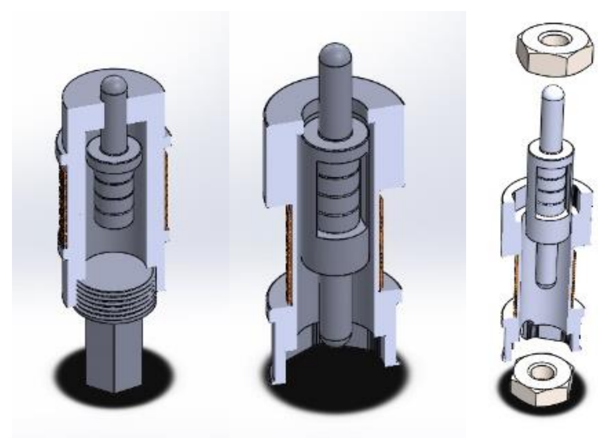

Fig.4: Initial concepts (basic concept - left, concept 2 - center, concept 3 - right)

Based on these three concepts, a comparison is made in order to select final concept for braille cell which as shown in Table 1:

Concept 2 is selected for final braille cell design. This is due to that it consumes less space and does not required continuous current supply. Although the number of parts has been increased however it is for the sake of no continuous current supply needed (refer to Table 1).

Table 1: Design Comparison

Criteria	Basic Concept	Concept 1	Concept 2
Manufacturability	Simple	Simple	Complex
Continuous Current Supply	Required	Required	Not Required
Space Consume	More	Less	Less
Number of parts	3	3	4
Lock Mechanism	Snap Fit	Snap Fit	Snap Fit

IV. BRAILLE CELL FABRICATION

The method of fabrication to fabricate braille cell has been decided, which is using Stereolithography 3D printing (SLA) and Electrical Discharging Machine. Standard resin produce from SLA 3D has high stiffness, however it is brittle. Especially during the winding process, if the winding is very tight, standard resin is deformed and breaks. Other than this, the quality of printing is noticeably unsatisfactory, as some component appeared to be smaller and bulkier. These problems causing some component to be reduce, for example, number of neodymium magnet that can be used is reduced from four to three as shown in Figure 5.

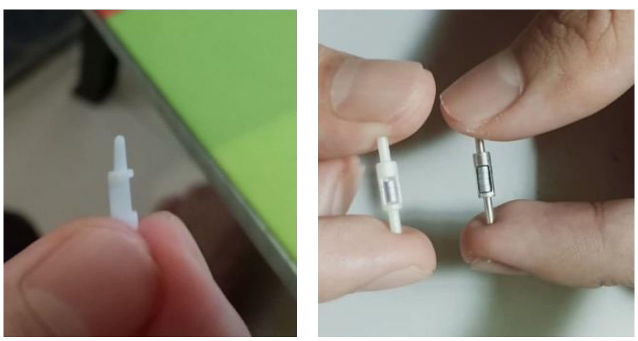

Fig.5: Results of bulkiness printing

Therefore, another material along the new fabrication method is proposed and used, which is Electrical Discharging Machine (EDM) and Aluminum Alloy. However, the height has been increased 1mm (dot holder and magnet holder), wherein the previous design, the bottom part (where it attached to PCB design) very small and easily fall off if attach to PCB. Figure 6 below is the new look of new material in comparison to previous material.

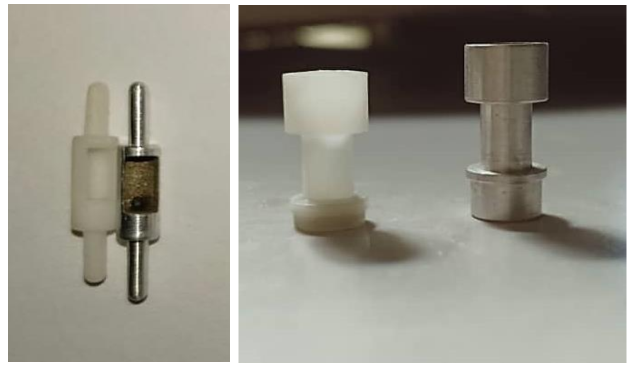

Fig.6: Previous material and new material

V. RESULT & DISCUSSIONS

This section will explain the result of each data obtained from the experiment that has been setup to determine the correct number of turns and diameter. Other than that, this section also justified the decision in selecting specific number turns and diameter for final braille cell. The challenges of using an electromagnetic actuator is that, number of turns and diameter must be selected appropriately. This is due that if choosing an inappropriate number of turns and diameter it will affect the overall size of the braille cells. Another reason is that, number of turns will affect the value of force it produced while the diameter will affect the resistivity of wire, which then affect the value current can flow. Besides that, current value must be lowest as possible to avoid rather complicated electronics or danger to operator or user. For this reason, an experiment is setup to determine the suitable number of turns (able to produce high force) and diameter (able to operate at low value of current) without consuming large space consumes. Diameters and number of turns selected as factor of this experiment is 0.1mm, 0.3mm and 1.0mm and 100 turns, 200 turns, and 300 turns. For each number of turns and diameter, is connected to voltage regulator and tune the voltage value until the dot is lifted up. Stroke is then measure using photogrammetry technique.

Due to dot stroke is very small to measure using measuring tools, a photogrammetry technique is applied. Actual length stroke is estimate using relative size (in unit of pixel) of 2x2mm cell of graph paper to the length of dot stroke (in unit of pixel). Then by using pixel to metric ratio, an actual length of stroke in unit of millimeter is calculated. Software used to measure length in unit of pixel is photoshop. To illustrate the process and calculation to obtain the actual length of stroke in millimeters, a sample of calculation for 300 turns and 0.1mm (refer to Figure 7 and Figure 8).

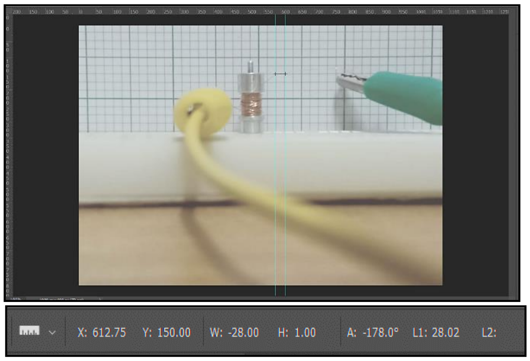

Fig.7: Pixel length of 2x2mm cell

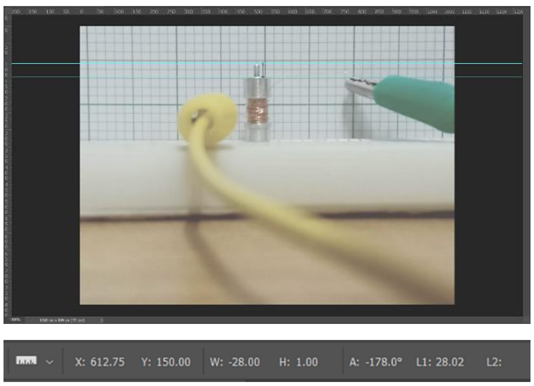

Fig.8: Length of stroke in pixel unit

By measuring the size of 2mm x 2mm of graph paper and dot stroke in pixel unit. Actual size of stroke can be calculated as shown below.

$$\frac{Pixel}{mm} = \frac{28.02}{2} = 14.01 \text{ pixel per milimmeter};$$

$$Height = \frac{38.00}{14.01} = 2.71 \text{ mm} \quad (6)$$

The dot stroke height is measure from an image for each set of experiments. Below are the data collection table for 0.1mm and 0.3 mm coil diameter based on number turns.

Table 2: 0.1mm coil diameter

For 0.1 mm, N = 300turns

Voltage,V	1.1	1.1	1.2	1.3	1.3	1.5
Current,I	0.08	0.08	0.09	0.07	0.08	0.09
Height,mm	2.7	2.7	2.7	1	2.7	2.7

N= 200 turns

Voltage,V	1.4	1.2	1.1	1.0	1.0	1.0
Current,I	0.13	0.12	0.11	0.11	0.11	0.10
Height,mm	2.7	2.7	1	1	1	1

N= 100 turns

Voltage,V	1.6	1.5	1.5	1.4	1.4	1.6
Current,I	0.22	0.20	0.20	0.19	0.19	0.25
Height,mm	2.7	1	1	1	1	2.7

From the observation, for 300 turns, it is required at least 0.08 A to lift the magnet holder up to attach to M2 nut to reach 2.7 mm dot height while for 200 turns, required at least 0.12A. Next, for 100 turns, the minimum current to lift the magnet holder to reach 2.7 mm is 0.22 A. It should be noted 1mm is when the magnet (inside magnet holder) floating in the center of the dot holder.

Table 3: 0.3mm coil diameter

For 0.3 mm, N = 300turns

Voltage,V	0.11	0.10	0.12	1.1	0.10	0.10
Current,I	0.09	0.08	0.09	0.08	0.07	0.08
Height,mm	2.7	2.7	2.7	2.7	1	2.7

N= 200 turns

Voltage, V	0.09	0.10	0.10	0.09	0.10	0.10
Current, I	0.10	0.11	0.10	0.11	0.12	0.12
Height, mm	1	1	1	1	2.7	2.7

N= 100 turns

Voltage, V	0.10	0.09	0.08	0.10	0.09	0.09
Current, I	0.22	0.20	0.20	0.23	0.20	0.21
Height, mm	2.7	1	1	2.7	1	1

Based on the observation, both values of current for each turn however remain the same regardless of the diameter of wire copper. Other than that, when using 0.3mm diameter, it is found that coil and uncoil wire copper causing the dot holder to deform. In other words, when winding is too tight, it causes the dot holder to be deformed, which then interrupt the motion of the magnet holder. Hence, standard resin is then replaced with another material which aluminum alloy. For 1.0mm, the copper wire appeared do not have protective enamel layer, therefore it is rejected as part of this experiment.

Based on the result, it is observed that electromagnetic force is only affected by N and I, whereas electromagnetic force is related to the product N (number of turn) x I (applied current). Hence, an actuator of electromagnetic element can extent to higher force just by keeping content or lowering the current and also by increase the number of turns. Next, it is important for the current, I to be lowest as possible in order to avoid rather complicated electronics and danger for the operators or user, hence in this project developed a system with the by increase N (number of turns) while reducing keeping a reduced space and as well as keeping the overall size under or same as commercialize braille cells. Another reason 300 turns and 0.1 mm is selected is that we can maintain low current flow while the voltage supply increased, for example this project used 1.5V supply from motor driver. This is due to increasing of resistivity of wire copper when length (number turns) and diameter increased. To summarize, the final design parameters are 0.1 mm diameter of wire copper with 300 turns and lowest possible current at 0.08A, which as shown in Table 4.

Table 4: Final design parameter

Design Parameters	
Number of turns	300 turns
Diameter of copper wire, mm	0.1mm
Current, I (A)	0.08 A

VI. CONCLUSIONS

This study was carried out with the purpose to develop and design an electromagnetic actuator for braille cell. A suitable number of turns and diameter of copper wire has been optimized in order to achieved low space consumptions, low current flow and produce high electromagnetic force by increasing number of turns. The result also shows that by using a specific number of turns, regardless of diameter it used, the same amount of current flow is required to actuate the dot. By using 300 turns and 0.1mm, minimal space can be achieved and able to produce a consistent stroke if the current supplied is constant at 0.08A.

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REFERENCES

[1] A. Russomanno, S. O'Modhrain, R. B. Gillespie, and M. W. M. Rodger, Refreshing refreshable braille displays, IEEE Trans. Haptics, 8(3) (2015) 287–297.doi: 10.1109/TOH.2015.2423492.

[2] M. E. Adnan, N. M. Dastagir, J. Jabin, A. M. Chowdhury, and M. R. Islam, A cost-effective electronic braille for visually impaired individuals, 5th IEEE Reg. 10 Humanit. Technol. Conf. 2017, R10-HTC 2017, 2018(2018) 175–178. doi: 10.1109/R10-HTC.2017.8288932.

[3] A. M. Muntasir Rahman, S. Mahmud Khandaker, N. N. Saleheen, T. Nobi Afee, N. Afrin, and M. A. Alam., A portable braille refreshable display using micro servos, Jt. 7th Int. Conf. Informatics, Electron. Vis. 2nd Int. Conf. Imaging, Vis. Pattern Recognition, ICIEV-IVPR (2019) 212–217. doi: 10.1109/ICIEV.2018.8641028.

[4] M. Benali-Khoudja, M. Hafez, and A. Kheddar, VITAL: An electromagnetic integrated tactile display, Displays, 28(3) (2007) 133–144. doi: 10.1016/j.displa.2007.04.013.

[5] G. H. Feng and S. Y. Hou, Investigation of tactile bump array actuated with ionic polymer-metal composite cantilever beams for refreshable braille display application, Sensors Actuators, A Phys., 275 (2018) 137–147. doi: 10.1016/j.sna.2018.04.007.

[6] Md. Ehtesham Adnan, Noor Muhammad Dastagir, Jafrina Jabin, Ahmed Masud Chowdhury, Mohammad Rezaul Islam, A cost effective electronic braille for visually impaired individuals, IEEE Region 10 Humanitarian Technology Conference (R10-HTC), (2017) 1–6.doi: 10.1109/R10-HTC.2017.8288932.

[7] Dimitar N. Karastoyanov, Lyubka A. Doukovska, and Vassia K. Atanassova, Electromagnetic Linear Micro Drives for Braille Screen: Characteristics, Control and Optimization, Third International Conference on Telecommunications and Remote Sensing, (2014) 1–6.

[8] Jun Su Lee; S. Lucyszyn, A micromachined refreshable braille cell, IEEE Journal, (2005) 673 - 682.

[9] F. Başçiftçi and A. Eldem, An interactive and multi-functional refreshable Braille device for the visually impaired, Displays, 41 (2016) 33–41. doi: 10.1016/j.displa.2015.11.001.

[10] H. Parekh, S. Shah, F. Patel, and H. Vyas, Gujarati Braille Text Recognition : A Review, 5–10. doi: 10.090592/IJCSC.2016.003.

[11] C. Jayant, C. Acuario, W. A. Johnson, J. Hollier, and R. E. Ladner, V-Braille: Haptic Braille Perception using a touch-screen and vibration on mobile phones, ASSETS'10 - Proc. 12th Int. ACM SIGACCESS Conf. Comput. Access., (2010) 295–296. doi: 10.1145/1878803.1878878.

[12] J. S. Lee and S. Lucyszyn, A micromachined refreshable Braille cell, J. Microelectromechanical Syst., 14(4) (2005) 673–682. doi: 10.1109/JMEMS.2005.845415.

[13] D. N. Karastoyanov and V. K. Kotov, Electromagnetic Linear Microdrive for Braille Screen: Control and Circuit Test, Int. J. Mater. Sci. Eng., 3(1) (2015) 1–6. doi: 10.12720/ijmse.3.1.1-6.

[14] M. Karpelson, R. Pena, and R. J. Wood, "Low-Cost Electromechanical Actuator Arrays for Tactile Display Applications, Proc. - IEEE Int. Conf. Robot. Autom., (2018) 471–476.doi: 10.1109/ICRA.2018.8460909.

[15] M. Benali-Khoudja, M. Hafez, J. M. Alexandre, A. Kheddar, and V. Moreau, VITAL: A new low-cost vibro-TActiLe display system, Proc. - IEEE Int. Conf. Robot. Autom., 2004(1) (2004) 721–726. doi: 10.1109/robot.2004.1307234.