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RESEARCH ARTICLE

An innovative idea for low cost Braille e-reader

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Abstract

Background/Objectives: The aim of this study was to implement the rotating cubes for designing the Braillerefreshable display. The rotating cube Braille display has many benefits i.e., compact size, low cost etc. **Methods/Statistical analysis**: refreshable Braille display is an electro mechanical device which forms Braille charactersby raising pins through holes on flat surface. The raising of such pins is accomplished by complex and costly systems like solenoids or piezo-electric crystals or EAP (Electro Active Polimer). We developed the prototype of e-book reader, which is a low cost electro mechanical system aimed at assisting visually impaired to access the e-books. **Findings**: Many design concepts were proposed earlier and prototypes were built, and were tested successfully in thepast by using three simple rotating cubes. The main parameters like dot spacing, overall dimension, touching force and operating voltage obtained are discussed. Dot spacing 2.5 [mm] with reference to International standard has been maintained. Regarding overall dimension, the display unit is designed to have dimension of 120mm width to 150mm height adhering to NLS standard of Braille dot spacing, and the tactile surface will feature 13 lines with 14 characters per line. The touching force of 0.32N and operating voltage below 25 V was obtained and used. **Novelty/Applications**: The Solenoid is used for positioning the faces of individual cubes, which can be arranged in different positions thereby forming all Braille characters. The high power consumption which remained the major head ache in solenoid electromagnetic actuator models was a major challenge we faced initially, which we overcame with our unique innovative design combining cubes that can rotate to form Braille dots and electromagnetic actuator which can be positioned at various places to run this cubes. So Keeping Occam's Razor Principle in mind, we went ahead to design a multicell/multi-line electronic refreshable Braille display as a technology demonstrator by using three simple rotating cubes.

Keywords: Braille cell; Rotating cubes; Actuators; Refreshable Braille displays

1 Introduction

An estimated 253 million people live with vision impairment in which 36 millions are totally blind and 217 millions have moderate to severe vision impairment; 89% of people who are visually impaired lives in under -developed and developing countries. Globally, chronic eye diseases are the main cause of vision loss. The vision impairment is caused by uncorrected refractive errors, age-related macular degeneration, glaucoma, diabetic retinopathy and un-operated cataract. Implementation of eye care services can give promising results for infectious eye diseases, such as cataract, trachoma and onchocerciasis. Even though 80% of all vision impairment can be prevented or cured[1] but it can increase due to population growth and ageing.

Braille is a communication medium which assists visually impaired individuals to read the information. All information needs to be learnt first and then to be converted to Braille manually. It takes handsome amount of time and main inability being millions of books to be transferred to Braille. Hence there is the need for refreshable displays which automatically converts e-books into tactile or audio output through electronically controlled micro controllers.

Refreshable Braille Displays (RBD) also assist in accessing illustrations, maps, graphics and millions of e-books. The above said facilities are enabled only through multi line refreshable displays. At present only single line displays with text access alone is available. Since multi-line needs tight package of actuators, it is costly and bulky in size.

RBD displays contain movable pins of six or eight dotted Braille cell arranged in two rows of three or four columns each. Each pins should be raised up and down in-order to display Braille characters in a tactile device. Currently single line RBDs are available at affordable cost, but it is used to access only text information. There is a need for going to multi line display incase to access graphics. Braille dots on the RBD are raised using either mechanical pins or actuators. The number of actuators used should be more in case of multi-line display which is the main reason for the high cost of the device. Various actuators used are piezo actuator, Pneumatic actuators, Electro-magnetic actuator, Electro Active Polimer (EAP) actuator, Electro rheological Actuators and shape memory alloys. Each actuator has its own limitations which makes it not suitable for a cost effective device. In this paper we propose electro-mechanical rotating cube mechanism operated by solenoids for actuating the Braille pins.

Electromagnetic micro actuators are developed and manufactured to drive the tactile Braille screen. It has the permanent magnetic spindle in the middle of two electromagnets which will pop up or go down , when the electromagnets are powered because of magnetic pull and push. But while implementing practically, as the space between two successive Braille dots are too small, the magnetic forces created by neighboring electro magnets will interfere with each other and hamper its operations. Since it is of large size, the Braille display implementing electromagnetic actuator is limited to single line[2].

In any pneumatic system, the source which is powering the system, example an oil pump can be remotely placed and powered. When Pneumatic/hydraulic system is used in Braille system, we need to run tiny pipe lines to the actuators, which let us place more actuators in small place there by giving us freedom to place individual actuators forming standard Braille dot structure. But the addition of valves and controls to control individual pipe lines adds enormous complexities to the system[3]. Pneumatic actuator in Braille displays suffer from friction and low tip displacements[4].

Electro- rheological fluid-based actuator increases the viscosity of fluid by applying electricity. The main disadvantage is being large and it needs mechanical energy externally for displacement[5]. ERF actuator responds very fast but the large size remains to be its limitation[6].

A refreshable Braille display with vertical pin movements was developed with Shape memory alloy coil along with magnetic latches. When electricity passes through the coils of SMA coil, they become rigid pushing the pins up and the electricity is stopped, they become flexible to let the pin down. Thus, the up-down movement of individual pins are achieved[7]. When the dots are raised, the hydraulic force can resist the pressure applied the finger while the user reads Braille. Even though SMA actuator is able to produce large strokes and forces, it suffers from high cost and high power consumption[8].

A hybrid technology combining Hydraulic and Magnetic latching mechanism was designed by a group of researchers from North Carolina University for implementing in Refreshable Braille display. An oil cavity was designed beneath each cell and is filled with oil. An actuator for each cell is made with electro active polymer material which has the property to deform when an electric current is applied. This mechanical deformation is used to apply pressure on the fluid in the cavity. The fluid in turn raises the pins to form a single Braille dot. Sufficient pressure is applied to the fluid so that the pins can withstand the applied pressure of a human finger. It only takes 30 milliseconds to raise or lower a pin in the display[9].

EAPs are lightweight, inexpensive, energy efficient, and generally exhibit fast responses. However the latching mechanism was very good but it too had drawbacks like the user need to remove hands from display whenever text was changed, and if any pressure was given on dots then it prevents from being set and proper latching. Dielectric elastomers exhibit high performance in strain and energy efficiency[10].

In piezoelectric Braille display unit, the Piezoelectric crystals mechanically expand and contract when an electric force is applied. This mechanical deformation is used to raise the pins up and down to form Braille characters. Actually it is very fast but when used for multi line Braille display it becomes bulky and too costly[11].

A Braille dot display module that uses a PDMS membrane driven by thermo pneumatic actuator develops a Braille display device. However, it consumes high electricity and slower[(12)]. The thermal expansion and phase transition property of thermo pneumatic actuator makes it very slower and consuming high power[(13)]. In general, the electromechanical devices are complicated and expensive and the difference between them is as listed in [Table 1].

Table 1. Actuator types and its limitations

Actuator	Pros and Cons
Electromagnetic	• large size of the actuators • fast response time • high power consumption
Pneumatic	• Low viscosity • low mass, high availability • friction as well as low tip displacements
Electrorheological	• dimensionally large and require encapsulation • high power consumption
Shape Memory Alloys	• change their shape when heated • high cost
Thermo-Pneumatic	• slower • high power consumption
Piezoelectric	• very fast, bulky • costly for multi-line • low power consumption

2 Materials and Methods

Our proposed research is to develop a prototype which is a software- controlled Braille e-book reader which would be at low cost for the visually impaired people. Our plan is to create a model using rotating cube technology. Three rotating cubes with different combinations of Braille dots are stacked together and are rotated by servo motors controlled by microcontroller. Braille Character generator, under the touch pad dynamically generates characters with the help of a microcontroller. User might get true reading experience just like a hard copy Braille material.

2.1 International Braille standard

The tactile display of the device consists of Braille cell which electronically display the Braille symbols. A standard Braille cell has one to six dots. Each dot position is arranged in two rows of three column each. 63 different dot patterns were obtained by various possible dot positions. Whenever an input is given on a computer platform (Arduino IDE), the solenoids move vertically up and the dot positions are changed. The user can easily detect the alphabet, numbers or symbols by touching the cell with their finger tip. The Braille can be reset by using the "space" key of the keyboard. A reading system for the visually impaired, invented by Louis Braille of France, called Braille is a code system to read scripts of various world languages like English, Tamil, Hindi, etc. This system consists of systematically arranged 6 raised dots to represent a character. One character is represented in a single cell. These dots have standard dimensions and are recognized/followed internationally. By arranging six dots with various combinations in 64 different ways, a cell can be arranged to represent 64 unique characters as explained in [Figure 1). The international unified standard will be implemented/followed in this project. Each cell dimensions and spacing will be adhered, to make sure that there will not be any confusion when the device is handed over to a visually impaired person for reading.

2.2 Methodology

The design of the proposed refreshable Braille display using rotating cubes for a dynamic full page e-book reader is shown in [Figure 1]. In this section, working principle of a multiline, multi-cell of the proposed Braille e-book reader is explained. The text that is to be converted into Braille format is either stored in an SD card or fetched from Wi-Fi/internet. A micro controller unit powered by 8bit AT Mega 328 AVR chips is the heart of the proposed system. This micro controller unit acts as a bridge controlling the data/memory area, and mechanical tactile display controlling various parameters. The pre-formatted text data is fetched from the storage section by the micro controller and it processes the data to the pre-defined Braille matrix. The Braille coded data is fed to stepper and servo section which in turn controls the Braille display unit. The Braille display consists of three rotating cubes stacked by a central shaft. One set of three cubes represents a single Braille cell. Rotation of each cube is initiated by a solenoid whose position is controlled by a stepper motor. One cube has four combinations of Braille dot formation in its four faces. A single Braille cell is horizontally split into three sections viz., upper, middle and lower which are represented by three cubes. By rotating these three cubes we can have sixteen different Braille combinations, thereby achieving an entire range of Braille text for a single cell.

These basic Braille cell structure can be scaled to n number of characters and n number of lines to form a multi-cell multiline refreshable Braille display.

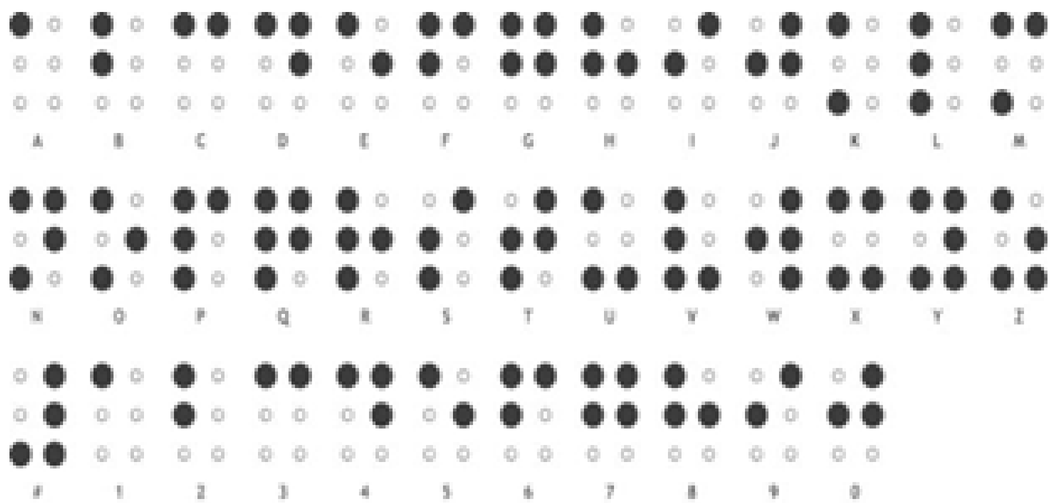

Fig 1. Standard Braille cell dimensions

2.3 Design overview

2.3.1 Electronic interface

The Solenoids and servo motor, featuring in this basic mechanical design, is controlled by a CPU containing an 8 Bit AVR micro controller like ATMega328. The Micro controller is programmed to remember the position of individual Braille cubes and rotate them to desired combinations to form different array of characters on the tactile surface. CPU accesses memory card via SPI interface where display data(e-book) is stored as shown in [Figure 2]. Suitable format for files will be standardized like txt or pdf or any other unique extension and text matter are formatted to device specific format and stored. Books which fall under different titles will be stored and indexed in an user-friendly way for the user to select a specific topic with ease.

Fig 2. Proposed e-Braille structure

The micro controller used is Arduino mega 328 board. The operating circuit includes rotating cubes, a stepper-motor, servo motors, solenoids, and electrical components such as resistors, diodes and transistors. PCB layout was designed in ExpressPCB Version 7.3.4 and printed out. Electronic components along with Microcontroller AtMega328 were soldered on the PCB board. [Figure 3] below show the physical PCB.

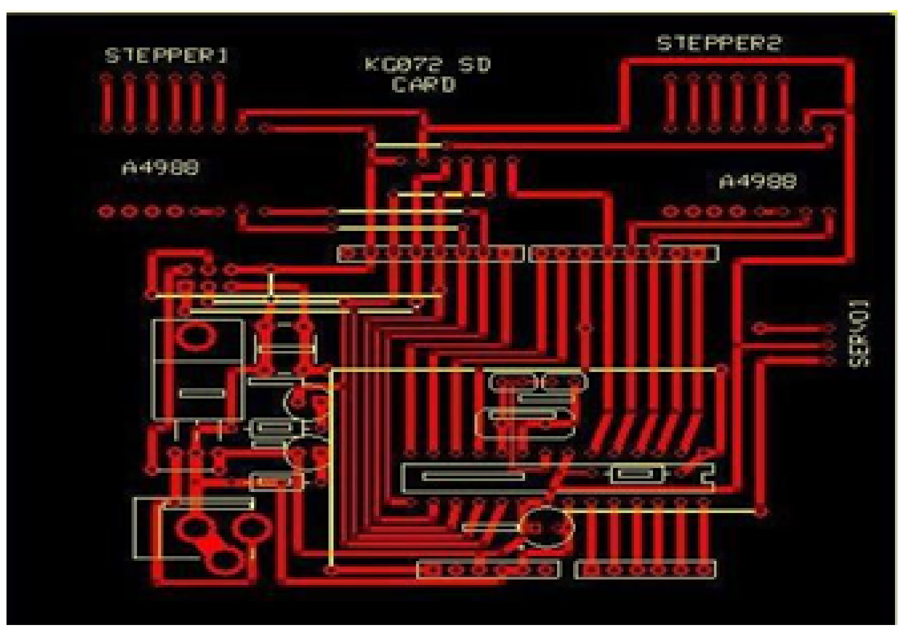

Fig 3. Schematic diagram of physical structure of PCB

2.3.2 Display Interface

One set of three rotating cubes representing single Braille character is arranged into various different combinations of Braille dots as in [Figure 4]. Four magnetic tips are moulded at four corners of individual Braille cube. Individual Braille character cell is formed by stacking 3 magnetically tipped cubes, horizontally one over the other guided by central shaft. With 5mm square, 2.5mm thickness, three such cubes form individual Braille character within 5mm width, 7.5mm height spacing. A solenoid with a leaf spring rotates each cube in its axis by pushing it at one particular corner. When the pushing force overcomes the magnetic lock generated by the corner magnet, the cube rotates and latches on to its immediate next phase. By repeatedly pushing single cube four times, four different combinations of two Braille dots (zero dot, one left dot, one right dot, two dots) are achieved.

In this work, the display unit is designed to have dimension of 120MM width to 150MM height adhering to NLS standard of Braille dot spacing, and the tactile surface will feature 13 lines with 14 characters per line.

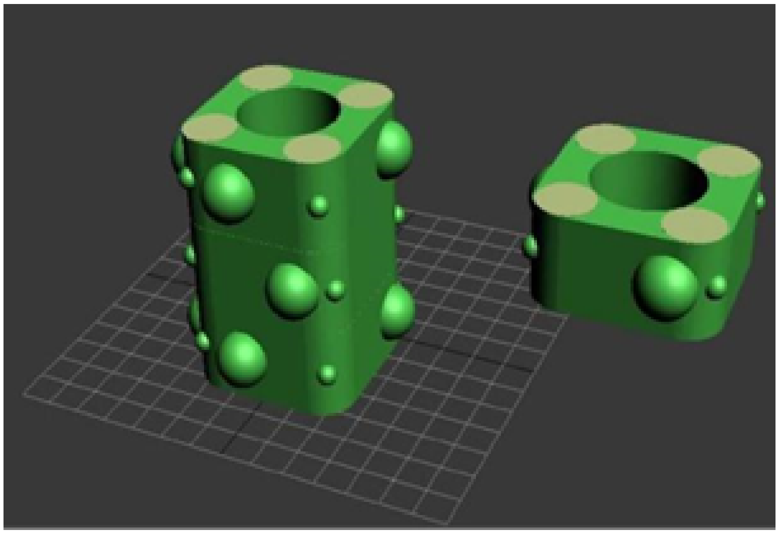

Fig 4. Rotating cube structure

2.3.3 Control mechanism

The rotation is activated by an electromagnetic solenoid and a plate spring. The cubes are held together by their magnetic tips moulded at their corners. Once the solenoid/plate spring overcomes the force of this magnetic hold, the cube rotates and snap attaches to the next set of magnetic corners. All the 14 solenoids are attached to a solenoid mount horizontally which is fixed on a screw rod and a guide rod for its vertical movement. This solenoid mount is moved behind the Braille cubes and positioned at the required place by a precision servo motor as shown in [Figure 5].

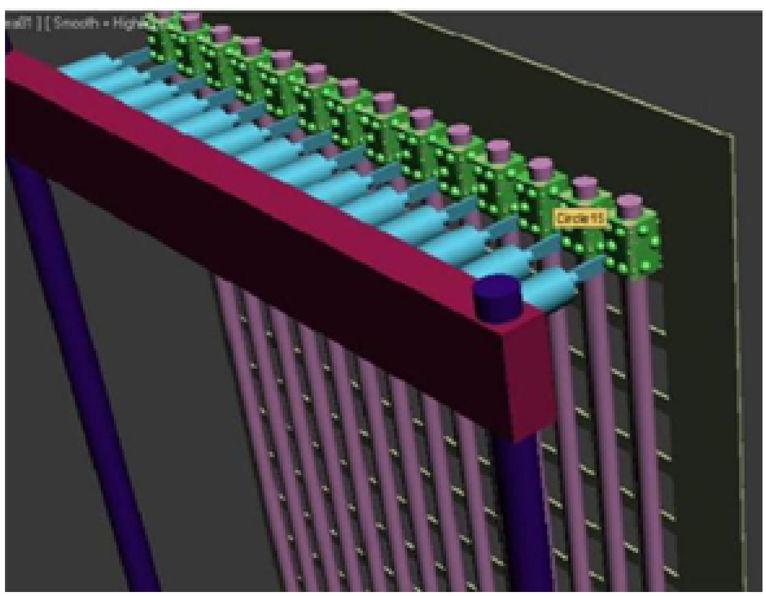

Fig 5. Solenoid in action

The solenoid which rotates one single cube that is top queue is again positioned at the middle cube to rotate it. Once the desired combination is achieved at the middle section, the solenoid is positioned behind the bottom cube and the same process is repeated. Thus, a single Braille character is achieved. The same solenoid is again positioned at the top queue of second cell and the next line to achieve full scale Braille display. This positioning of the solenoid is achieved by a rapid movement stepper motor. The major factors considered for tactile display to be validated are like cost, blocking force, vertical displacement, operating voltage and power consumption were checked and implemented.

3 Results and Discussion

3.1 Integration and functional check

Functional check of PCB board was carried out by interfacing it to PC Via serial communication. PCB Board was finally interfaced with TD-01 to check the units functional capabilities. When initialized, Microcontroller fetched the text data stored in the Micro SD memory card and deciphered it to braille code. The Stepper and Servo motors were activated and Braille characters were punched by rotating cubes thus forming raised Braille dots and creating a refreshable Braille surface. New characters are again printed on the flattened surface for reading. With this, the validity of the design and basic design objectives were successfully met.

3.2 Parameter validation

Braille refreshable display using rotating cubes meet the standard parameters like dot spacing, overall dimension, touching force and operating voltage obtained are discussed. Dot spacing 2.5 [mm] with reference to International standard has been maintained. Regarding overall dimension, the display unit is designed to have dimension of 120mm width to 150mm height adhering to NLS standard of Braille dot spacing, and the tactile surface will feature 13 lines with 14 characters per line. The touching force of 0.32 N and operating voltage below 25 V was obtained and used.

4 Discussion

The piezoelectric technology remains to be the most expensive but widely used in Braille display devices and costs $35 to $38.84 per cell[14,15]. The Shape memory alloy costs $200[16] for full page Braille display. The Electromagnetic actuator may cost up to $8 per cell[17]. Thermo-pneumatic actuator[13] usage makes the device to be sold at $5000. EAP technology cost up to $5 for each cell[18]. Our proposed technology based on rotating cubes will cost $0.5 per cell resulting in $91 for full page display which is very competitive when compared to other technologies. The cost wise comparison was also listed in [Table 2].

Table 2. Actuator types and its limitations

Actuator type	Cost per cell of full display
Piezoelectric	$35 to $38.84 per cell
Shape Memory Alloy	$200 for full page display
Electro magnetic (Solenoid)	$8 per cell
Thermo-pneumatic	$5000 for full page display
Electro Active Polimer	$5 for each cell
Our proposed method	$0.5 per cell $91 for full page display

5 Conclusion

Any advancement in science is useful only if it is within the reach of a common man, including the visually impaired. So it is the responsibility of the researcher to make such devices, particularly at low cost to be made available in various fields. In this paper, study we have addressed how to overcame various challenging hurdles including power consumption, cost reduction, and standard Braille cell dimension which are achieved by using cheaper solenoid with simple mechanical rotating cube technology for making a full page refreshable Braille display. We have also clearly outlined how the existing expensive multi line Braille displays can be replaced with our innovative technology.

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