



## DEVELOPMENT OF A PROTOTYPE OF A SINGLE-CELL REFRESHABLE BRAILLE DISPLAY

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### ABSTRACT

*The modern era has witnessed significant advancements in information technology, which have to be incorporated into our everyday lives. These technological developments are revolutionizing our daily routines, enabling everyone, including those with physical disabilities, to benefit from them. For instance, Braille-based devices have made it possible for people who are blind or visually impaired to acquire literacy skills by learning the Braille system. This paper proposes a refreshable braille display that is innovative and easy to use. It is a single-cell device that can be of immense help to blind and visually impaired users.*

### Introduction

Braille is a writing system designed for people with visual impairments or blindness. It is a tactile system that uses raised dots arranged in specific patterns to represent letters, numbers, punctuation marks, and even musical symbols. Each cell in Braille consists of six dots, arranged in two columns of three dots each.

In recent years, interest in conducting research in the development of Braille-based gadgets and devices has increased around the world, including in Uzbekistan [1-7].



In the last decade, several studies have been conducted on Braille-based devices and systems around the world. It is described a project that aims to provide low-cost assistive technologies to the visually challenged in Barbados in [8]. The cost of the prototype was about one-half that of a commercially available device, and it can be used without a screen reader. It is analyzed product architectures of pin array technologies for tactile displays in [9]. The study discusses the design of technologies that use arrays of pins to create tactile interfaces that can be refreshed. The authors used both qualitative and quantitative methods to explore the various mechanisms that have been developed to enable this interactive surface technology. They also created a new morphological landscape of the solution space to highlight the key functions of this technology. It is discussed [10] the development of a dynamic/refreshable Braille display that presents Braille points by the up-and-down movement of pins using a Cam actuated mechanism with just two actuation points instead of the standard 6 used by every single refreshable Braille board.

Another interesting study found in [11]. In the study, it is developed a refreshable Braille display called “BrailleRing” that allows blind people to read tactile characters on the inside of a rotating ring. In [12], a new mechanism for a refreshable braille display was proposed. The display used a single-actuated slider to refresh braille cells made of simple and passive ferromagnetic pins. In [13], it is developed a Braille reading system based on electrotactile display with flexible electrode array. The proposed system is composed of a six-channel electrotactile stimulator, a flexible electrode array for Braille display, and a graphical user interface (GUI) for monitoring and control. In [14], it is aimed at giving a brief overview of the available braille printers and Braille generators, along with a comparative study of their endurance, cost, and durability. In [15], it is summarized and compared trends in braille display where there is a deviation from the standard presentation of braille. In the study, various aspects of alternate braille designs in terms of relative cost, convenience, and reading speed are reviewed.

Another interesting study was found [16]. In the study, it is focused on the working principle of devising a display board and introduces a working model of a single unit of a novel prototype of a computer display board for blind people. [17] describes a methodology to effectively convert multimedia contents to braille using a 2D braille display. The study also proposes the transformation of Digital Accessible Information SYstem (DAISY) and electronic publication (EPUB) formats into 2D braille display. In [18], it is designed a controller for refreshable Braille displays used by Blind or Visually Impaired people. The controller manipulates the ASCII 64 printable character set in order to stimulate 6 dot combinations in Braille language. In [19], it is given a survey on innovative refreshable braille display technologies. In [20], it is developed the prototype of an e-book reader, which is a low-cost electro-mechanical system aimed at assisting the visually impaired to access the e-books. [21] presents an open-source text-to-braille scanner along with a unique low-cost refreshable braille display.

The above-mentioned studies were related to general Braille systems. In this study, we aim to develop a prototype of a single-cell refreshable braille display.

The rest of the paper follows this structure: The “Related work” section is dedicated to the overview of existing research on the topic. The “Modeling and Design” section proposes a



design approach for single-cell refreshable braille display. The “Development of the Proposed Display” section presents the development process of a single-cell refreshable braille display. The section “Conclusion” concludes this paper.

### **Related work**

In recent years, various refreshable braille displays have been developed due to recent advancements in science. In [22], it is presented a one-character refreshable braille display, implemented with electromagnetic relays and control logic implemented on an FPGA. In [23], a new model of a refreshable braille display that uses micro servos instead of solenoids or lead screw actuation has been proposed. This model is capable of creating various patterns of braille symbols, each representing an alphanumeric value or a contracted word. In [24], it is designed and implemented a digital braille system for the visually impaired. The system is operated through push-pull solenoids that are powered by electromagnetism. These solenoids are linked to an Arduino Uno board for control and management purposes. In [25], it is designed a single braille cell based on electromagnetic actuator technology. The braille cell can support multiple sentence lines, is cost-effective, and performs like a commercial braille display.

Another interesting study found in [26]. In the study, it is created an integrated solution of hardware and software, based on the concept of one Braille cell using only open-source components. The proposed system was evaluated by blind volunteers with different Braille knowledge and computer experience. In [27], it is designed three-dimensional model of the multi-line Braille display. In [28], a single cell refreshable Braille display was designed. It features six custom-made electromechanical flapper actuators and includes speech functionalities to aid self-learning and independent operation. The cell size can be adjusted by moving the actuators to suit the preferences of the learner. In [29], it is developed a novel refreshable braille display based on the layered electromagnetic driving mechanism of braille dots. In [30], it is aimed at designing and developing a one-character refreshable braille display that is affordable and easy to use through the Internet of Things (IoT) technology. In [31], it is proposed a linear Braille alphabet, which is a novel method to represent Braille characters using the vibration engine of a mobile device operated via vibro-tactile signal sequences.

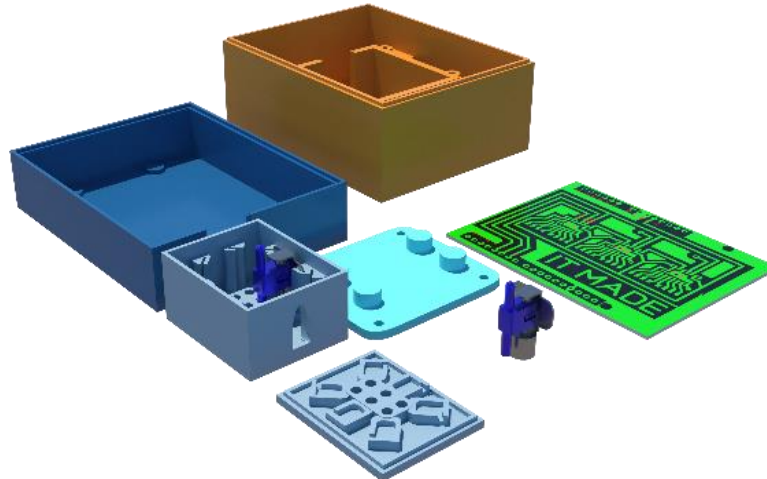
In [32], it is proposed a prototype of an affordable Braille display for blind people to read when input is given through a computer. In the study, electromagnetic solenoids are used to facilitate the vertical movement of the dots on the Braille display controlled by an Arduino Uno. The proposed device could guide blind people to read certain patterns of dots in the Braille cell known as braille alphabets. In [33], a BrailleCursor was designed and developed, which is a full-size Refreshable Braille Display with 40 Braille cells. It is based on an innovative method that uses a single actuated cursor to refresh Braille cells that are composed of passive pins. In [34], a learning tool was developed to teach the Braille alphabet, numbers, and alphanumeric characters to the visually impaired using a digital input file. Finally, it is designed and validated a readable device that can perform as a single-cell electromagnetic refreshable braille display in [35].

To summarize, the overview of the previous contribution mentioned above on refreshable braille displays is based on different existing approaches. However, none is based on the design presented in this work. In this study, a single-cell refreshable braille display specialized for the 6-dot braille standard is designed and developed.

## Modeling and Design

Autodesk 3ds Max software was used to design the 3D model of the proposed display. Autodesk 3ds Max is a professional software used for 3D modeling, animation, visualization, and game design [36].

A 3D model of the proposed display was designed in the following figure sequence. Figure 1 shows all the 3D components of the proposed display.



**Figure-1.** 3D components of the proposed display

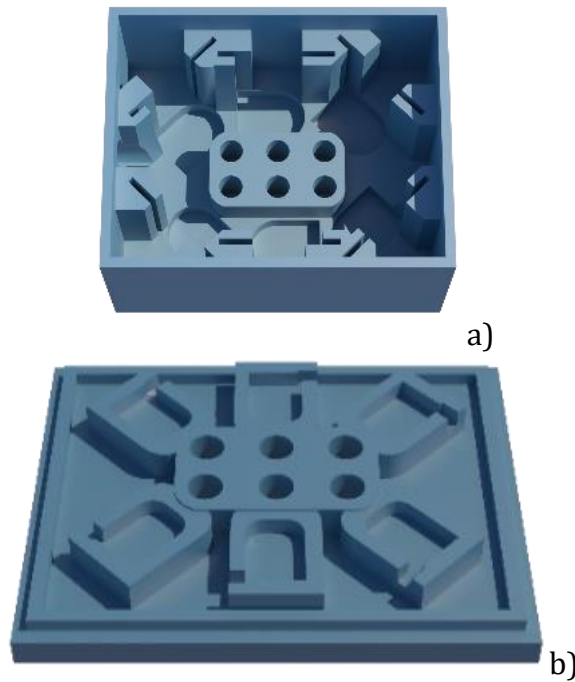
The proposed display includes the following units: a single-cell display unit and a control unit.

Figure 2 shows one of the components of the single-cell display unit.

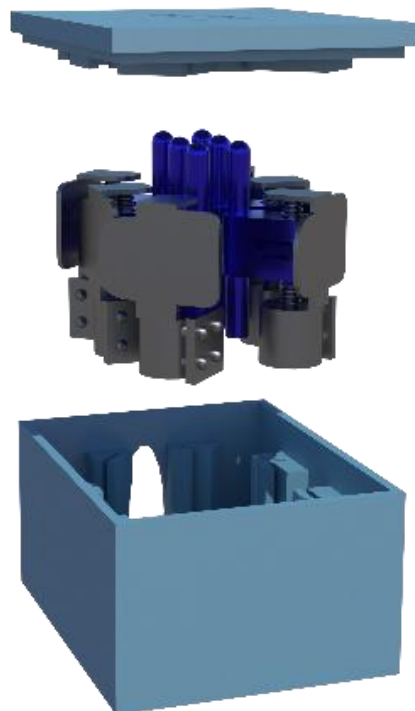


**Figure-2.** 3D model of the micro stepper motor

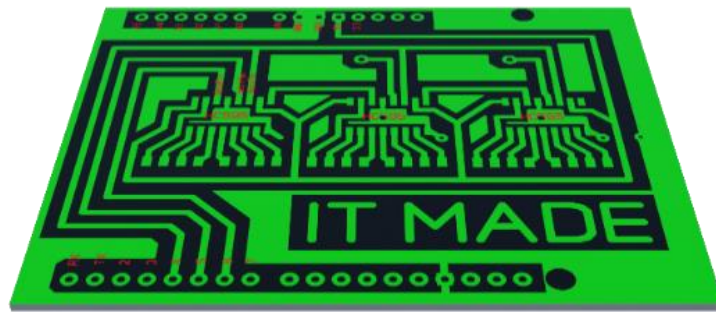
Figure 3 shows the 3D model of the top part and the inside part of the shell of the single-cell display unit.



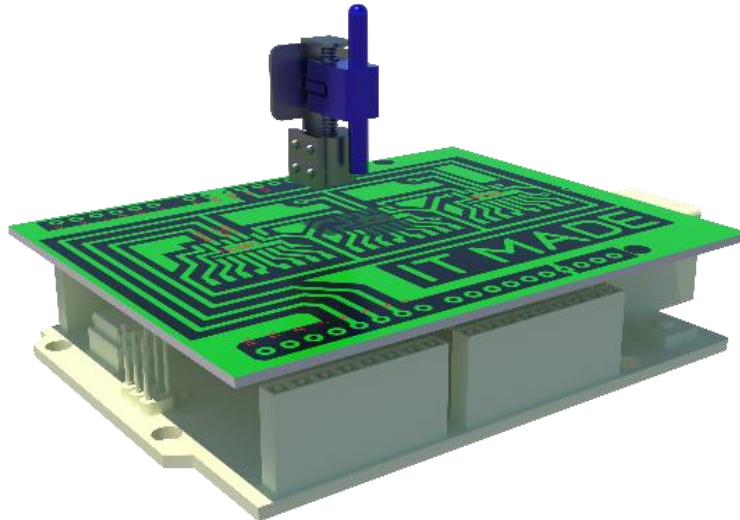
**Figure-3.** Components of the single-cell display unit: a) 3D model of the inside part of the shell of the single-cell display unit; b) 3D model of the top part of the shell of the single-cell display unit



**Figure-4.** 3D model of all components of the single-cell display unit  
Figure 5 shows one of the components of the control unit.



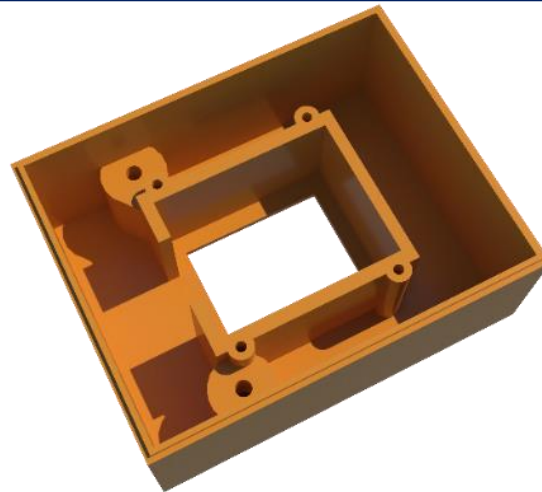
**Figure-5.** 3D model of the electronic circuit board



**Figure-6.** 3D model of the components of the control unit

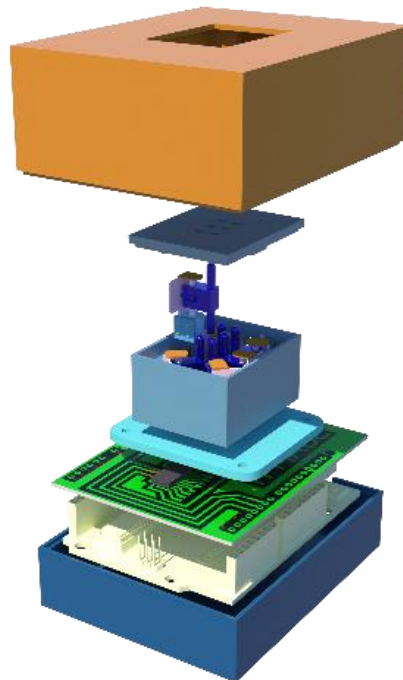
Figure 7 shows the 3D model of the top part and the inside part of the shell of the control unit.





b)

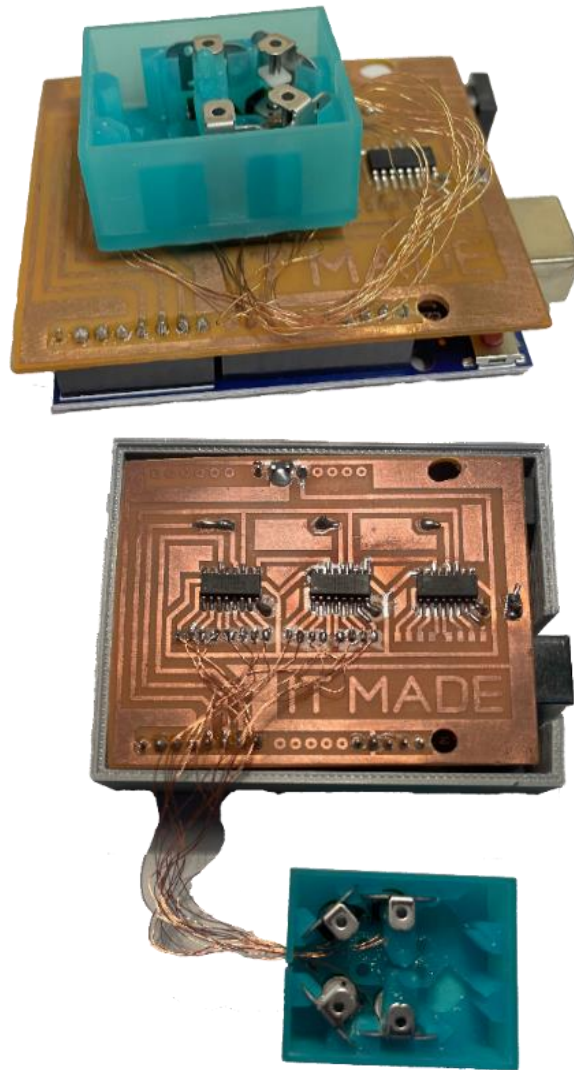
**Figure-7.** Components of the control unit: a) 3D model of the inside part of the shell of the control unit; b) 3D model of the top part of the shell of the control unit



**Figure-8.** 3D model of the proposed display

### **Development of the Proposed Display**

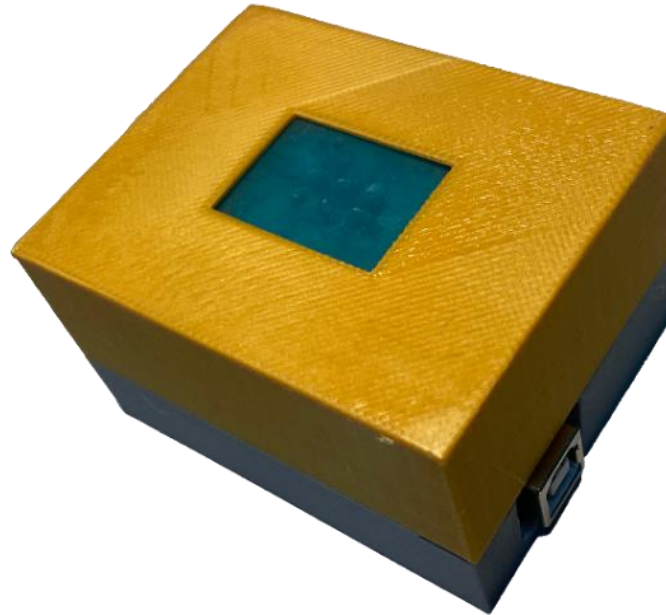
The development process of the proposed display was carried out in several stages. First, a 3D model of the device was designed (See Figures 1–8 above). A 3D model of the display was printed using a 3D printer. The electronic circuit of the device was designed, and a special board was made for the proposed display. The electronic circuit was placed inside the component printed from a 3D printer. Finally, the proposed display is ready for operation (See Figure 11).



**Figure-9.** Connecting process of a single-cell display unit and a control unit of the proposed display



**Figure-10.** A single-cell display unit and a control unit for the proposed display



**Figure-11.** The final prototype of a single-cell refreshable braille display

### **Conclusion**

As the number of blind and visually impaired individuals is expected to increase globally, it has become increasingly crucial to develop accessibility tools for daily communication and learning. In this paper, we have created a prototype of a single-cell refreshable Braille display that is innovative and straightforward in design. This display can be highly beneficial for users in their daily communication and education.

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