Designing of a Refreshable Micromachined Braille Display for Electronic Messaging

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ABSTRACT

Visually impaired people are not sensitive to the input and output units available in communication devices such as smartphones, tablets, etc., and they are forced to use different communication interfaces as an intermediate medium to maintain their daily electronic messaging services. Thus, the use of intermediate media creates a risk regarding the safety and communication efficiency of their data, and the purpose of this research is to carry out preliminary studies on a communication device with touch-sensitive input and output that does not use intermediate media to maintain the communication activities of visually impaired people safely.

The primary purpose of this research is to study the use of micromachined refreshable braille display and braille keyboard together to maintain electronic messaging services more securely.

The validity of the initial hypothesis related to the above problem was scientifically verified by studying several research papers. Based on the qualitative data collected, a comprehensive study was conducted regarding the weaknesses of the current communication interfaces and the technical solutions that should be provided. Using the data and information gathered from the research, it was possible to present a technical design for a touch-sensitive communication device, and the technical accuracy of the relevant device was confirmed through an expert in the field.

The functions and model of a mobile touch-sensitive input and output communication device to carry out electronic messaging communication activities for visually impaired people have been presented here. The device is designed using Braille Grade 1 and a fingerprint sensor is installed in the device to provide security to electronic messaging and related data using bio-matrix authentication technology. There is also a braille keyboard to provide inputs to the system, which is equipped with a micro-machined refreshable braille display that can successfully capture electronic messaging and related outputs for visually impaired people. The above-mentioned braille keyboard of this communication device, designed as a mobile device, is made in slidable form. This communication device will be created to send messages to receive messages as well as to read email and SMS messages.

Through this communication device, touch sensitive input and output units including micro-machined refreshable braille display for electronic messaging are designed for the study of use in a communication system, so many functionalities related to electronic messaging have been neglected. That is, here the attention is focused only on sending reply to messages to the received messages as well as reading the email and SMS messages.

Keywords

Electronic messaging, Micromachined refreshable braille display, Biomatrix Authentication, Portable communication device

1. INTRODUCTION

1.1 Existing digital Methods for data communication for Blind community.

1.1.1 Problem context.
A study conducted based on a research report [1] emphasized that people with visual impairments use smartphones and tablets in large percentage to maintain electronic communication activities. It further states that the above type of communication equipment is used to provide communication services such as email and messaging and since visually impaired people are not sensitive to light, dependent software, and hardware such as screen readers, braille keyboards etc. are used to get outputs. However, in the use of dependent software and hardware to maintain communication activities, it was further emphasized from the studies that various problems arise in the fields of data security, communication efficiency and privacy. [2]

In order to resolve these problematic situations faced by visually impaired people in the communication of data and information related to modern electronic messaging, it is expected to be discussed in this research to create an electronic messaging system that can function as a smart unit equipped with a suitable touch sensitive braille display.

1.1.2 Objectives.
In this research, full attention is paid for designing a suitable system for visually impaired people to communicate with other people safely and efficiently through electronic messaging, and the objectives for the relevant system design can be listed as follows.

(1) Studying the combined use of micromachined refreshable braille display and braille keyboard operated by personal touch communication to maintain electronic messaging services more securely.

(2) Designing a secured existing electronic messaging system using Biomatrix authentication compared to other existing blind-electronic messaging systems.

(3) Designing a portable one-handed braille related keyboard for the relevant device.

(4) To introduce the use of a refreshable braille display with an innovative mechanism to efficiently communicate with visually impaired people.

(5) To propose a suitable portability hardware to achieve the communication activities of the visually impaired community.

1.2 System Features and Used Technologies of Existing Multi-modal Blind Communication Interface in Existing Applications.

Due to the lack of light sensitivity of visually impaired people, they have resorted to the use of multi-modal communication interfaces in conjunction with the communication devices to make inputs and outputs using communication devices such as smartphones and tablets. The facts obtained from a wide range of features and technical scope of these communication interfaces used by disabled people are summarized in the table below.

1.2.1 Features.
Although visually impaired people are not sensitive to light, they are more sensitive to touch and sound and the communication interfaces for visually impaired people are designed based on this theory, it is emphasized from the data study compiled below. This means that the characteristics they have are made to be observable and responsive to touch or sound. For example, Screen Readers, Text-to-Speech (TTS) and Voice Recognition interfaces are designed to be sensitive to sound, and Braille keyboards are designed to be sensitive to touch.

1.2.2 Used Technologies.
The technology contributed to the creation of communication interfaces will be emphasized based on the recorded data in a way that varies depending on the sensory ability of the visually impaired person targeted by the respective communication interfaces. Examples of sound-sensitive communication interfaces i.e. Screen Readers, Text-to-Speech (TTS) and Voice Recognition are created using IVR technology, and touch-sensitive communication interfaces are created using mechanical technology. Also, communication interfaces being hardware and software, its technology can change as above.

Table 1. : A summary of the features and background technologies in multi-modal communication used by visually impaired people for communication

Interface	Features	Used Technologies
Screen Readers	Navigation shortcuts and commands. [3] Text to Speech conversion. (IVR) [2] Customizable speech settings. [4] Support for multiple languages. [4]	Text to Speech Engines. [2] Accessibility APIs. [3]
Text to Speech (TTS)	Conversion of written text into synthesized speech in real time. [5] Text to Speech conversion. (IVR) [5] [6] Natural language processing for Adjustable speech parameters, e.g. speed, pitch, and emphasis [5] [6]	Speech Synthesis Technology. Digital Signal Processing (DSP). [5] [6]
Braille keyboards with braille display	Dynamic refresh rate for real time updates and navigation. [7] Compatibility with computers, smartphones, tablets, and other devices. [7] [8] Multi-line Braille displays for enhanced content readability. [7]	Piezoelectric Actuators, Bluetooth and USB Connectivity. [7] [8]
Voice Recog:	Speech to text conversion. (IVR) [9] [10] Command recognition, Multi-language support for international users. [11] Integration with smart home devices,automotive systems, and mobile assistants. [11]	Speech Recognition Engines Natural Language Processing (NLP) [9]

1.3 System Challenges and limitations of existing multi-modal blind communication interfaces

The current limitations and challenges of these communication interfaces, which are designed to maintain the communication activities of visually impaired people using smartphones, tablets, etc., by targeting multisensory abilities and through various technical methods, are presented in the table below.

1.3.1 Limitations.
In the study conducted on the limitations of communication interfaces used by visually impaired people for electronic messaging, it is emphasized that the relevant limitations are based on the technologies that have been contributed to their creation. Screen Readers and Text-to-Speech (TTS) communication interfaces are commonly used to create IVR technology, and the existence of similar limitations can be mentioned as an example.

1.3.2 Challenges.
In the study of the qualitative data obtained from the research reports, it is emphasized that the limitations of the communication interface related to the challenges have been affected in some way. For example, there is a challenge called Limited Functionality for Voice Recognition and it is due to the Vocabulary limitation of the relevant communication interface.

Table 2. : A summary of the limitations and their challenges in multi-modal communication used by visually impaired people for communication.

Interface	Limitation	Challenges
Screen Readers	Learning Curve, [4] compatibility issues with certain software applications, websites,multimedia content [2]	Complexity, Compatibility Issues, data privacy issues while being in public [2]
Text to Speech (TTS)	Speech Synthesis Limitations, Language Support [5]	Speech Quality, Pronunciation Accuracy, data privacy issues while being in public [5] [6]
Braille keyboards with braille display	Line Length Limitations [7]	Cost, Size and Portability [7] [8]
Voice Recog:	Accuracy Issues [9], Limited Vocabulary [10]	Speech Recognition Accuracy [9], Limited Functionality, data privacy issues while being in public [10] [11]

2. METHODOLOGY

The identified problem that was properly mentioned in introduction was initially evaluated by using published research papers. Accordingly, what are the communication interfaces used as support media, their features, used technologies, limitations and what are the challenges that arise in their use were studied. In this way, a tabular summary was made to present the qualitative data collected by conducting secondary research.

Based on the qualitative data collected through secondary research, the general process of the braille based electronic communication device that can perform inputs and outputs using appropriate touch sensing to provide a solution for the limitations and challenges related to communication interfaces was finalized.

It was explored as to which optimal technical resources should be used to design the input, processing, and output units of the following communication device in such a way that can perform the relevant functional and non-functional requirements of the finalized general process. Attention was drawn here on the optimal technical resources to be used in both the hardware and software aspects of the relevant communication device.

A touch-sensitive braille communication device consisting of identified functional and non-functional requirements in the general process was designed using optimal technical resources which were finalized from research papers found through google scholar and various web sources. For this, more accurate hardware and software arrangement were designed by protecting the principles and concepts of electronic, software and computer science.

An evaluation was conducted to confirm whether the designed touch-sensitive braille communication device can provide successful solutions to identified problem scenarios based on the limitations and challenges of communication interfaces currently used for receiving inputs and outputs by visually impaired people. In addition to this, a financial evaluation for Materials and Manufacturing under the research evaluation and a technical evaluation was also done to confirm the safety of the design.

3. PROPOSED SOLUTION

To fulfil the communication needs of the visually impaired people with the outside society through electronic messaging services, the functions of a mobile communication device using the Micromachined braille method using the full sense of human touch and its model are to be presented here.

3.1 General Process

As mentioned above, the primary purpose of this mobile communication device, which is designed using the sense of human touch, is to present the use of a refreshable micromachined braille display that can work independently for the electronic messaging of visually impaired people. The complete process of this device can be presented as follows according to the following activity diagram. (Figure: 1)

Here, when the visually impaired person receives an electronic message, the system identifies the type of the message (email/SMS) and vibrates the device according to the type of message. It is expected to make the visually impaired person aware of the type of message using the sense of touch. Afterwards, the user's identity is verified through a fingerprint-based biomatrix authentication process. After the identity is confirmed, the content of the electronic message obtained through the API is processed in the system with the necessary actions (E, F, G) to be output by the refreshable braille display. Pagination option can be used to handle more than 126 characters (including word spaces), and space is provided here to send a replay message. It will be done according to the actions K, L, M and N in the above diagram. (figure: 1).

3.2 Hardware Arrangement of the proposed solution

This mobile communication device is 8.5cm in length and 16cm in width, designed to make inputs and outputs more efficient and closer to visually impaired people in electronic messaging communication using braille: Grade 1 method. Using Micromachined Refreshable Braille Cells [12], this display is made in a 6 * 21 matrix type format and is capable of providing a maximum output of 126 braille characters at a time. (Figure: 2)

As mentioned in research papers [13] [14], it has been mentioned that braille: Grade 1 is used for fast reading and writing, and Grade 2 and 3 are relatively slow. Thus, in order to provide the user with the opportunity to read and write electronic messaging efficiently using this device, and to maintain the user experience at a high level, braille: Grade 1 was used for the communication purposes of the device. Furthermore, Micromachined Refreshable Braille Cells [14] were used for display design based on the basic principles of being able to easily handle electrical signals and the cost to be borne for one cell being very minimal.

Based on braille Grade 1 [13], this sliding keyboard contains 6 keys to create braille characters easily. There are 3 keys for handling pagination in this keyboard designed in an area of 5cm x 15cm. Furthermore, there are 4 separate keys for various types of inputs such as confirming confirmations, putting space between words, removing previous entered words and spaces, entering dots and commas, and 10 separate keys for inputting numbers from 0 to 9 are also available in this keyboard.

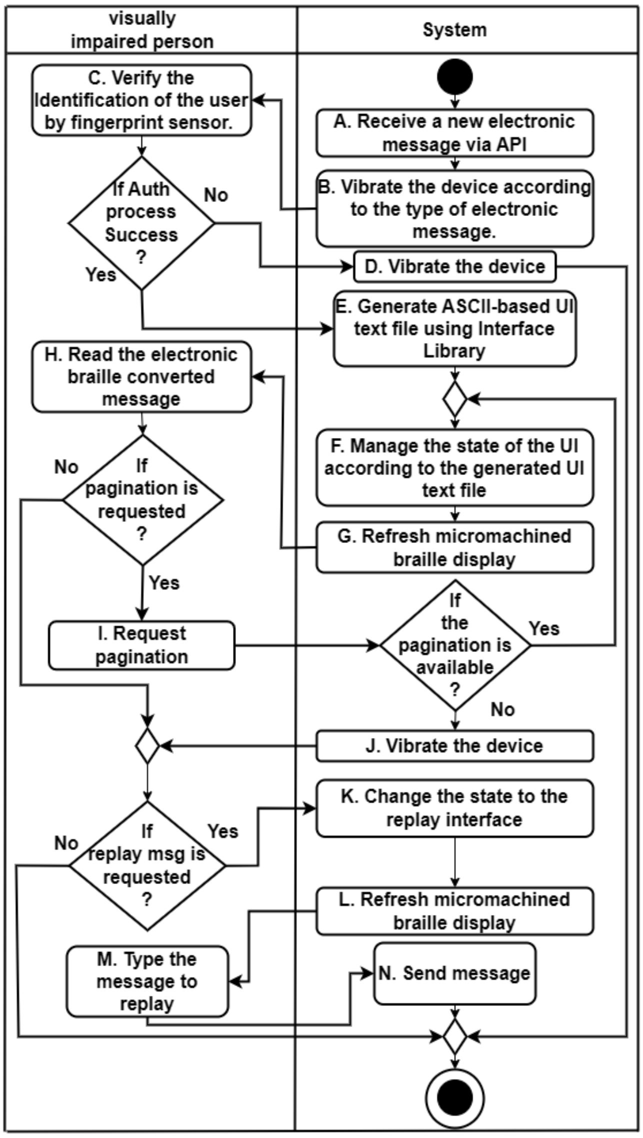

Fig. 1: General Process of the System

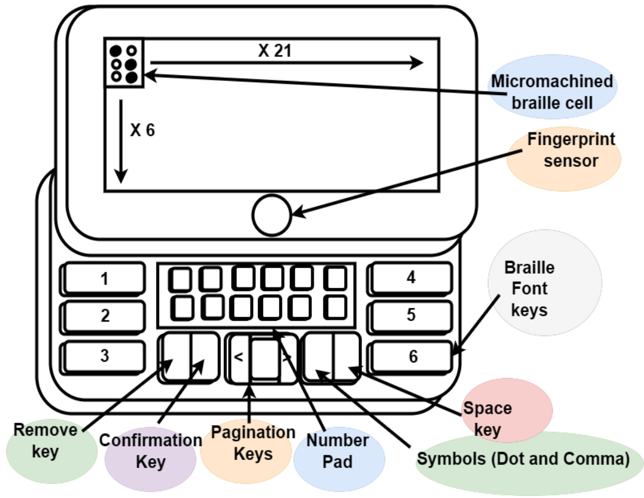

Fig. 2: Overview of the Device

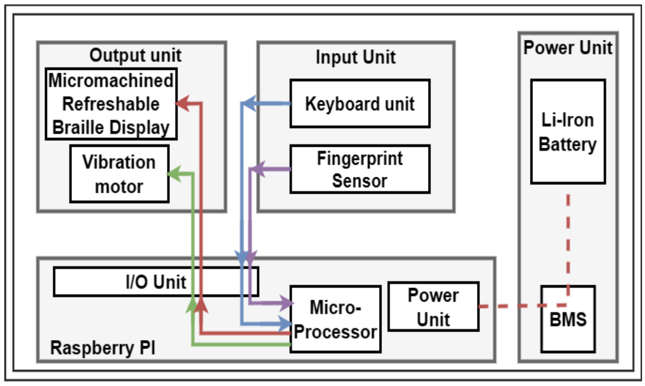

Fig. 3: Proposed System Architecture

A vibration motor is installed in this device, and it provides touch sensitive outputs according to various vibration patterns. Fingerprint sensor module will be installed here for the purpose of using biometrics authentication technologies. Accordingly, it will be possible to prevent unauthorized access and protect the privacy of visually impaired people.

Since this mobile communication device is also a kind of computing device, its architecture is based on the basic computer model, and can be seen as input, output, control and memory as usual. (Figure: 3)

”Display Unit” is the main unit of output. In addition to this, the vibration motor also outputs various vibration patterns, and all inputs and outputs are touch sensitive. Data input is done through keyboard, access controller, fingerprint module and all units are connected to control unit through I/O unit through Address bus and Data Bus. A Raspberry PI micro-controller is used to control all the hardware in the system, and a Li-iron battery and BMS are used to provide the electricity required for the system.

A micro-controller or a micro-processor can be used as the controlling unit in the design of this type of system. However, in order to handle electronic signals related to 126 braille cells, SMS and email APIs related to electronic messaging and sensor-keyboard readings, the relevant controlling unit must have a high memory capacity and a high level of power management. Micro-processor raspberry pi is used for the purpose of providing memory capacity and power management required for the system. [15] [16] LI-Iron battery is used for this system based on High-performance Energy Storage, low-weight and being able to maintain the cost at a minimum value. It was decided that a LI-Iron battery should be used for the system, and a research paper [17] [18] emphasized that a BMS should be used to confirm the battery’s existence and safety during charging.

3.3 Hardware arrangement of refreshable micromachined braille display

The hardware arrangement of the display, which is the primary output unit of the system, can be presented as follows.

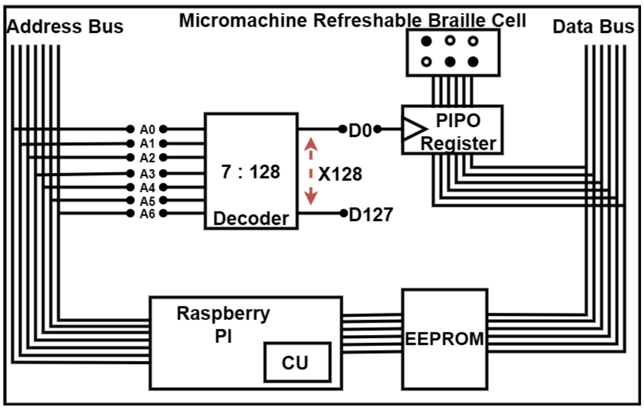

Fig. 4: Hardware Arrangement of Refreshable Braille Display

There are two separate bus lines to handle control signals required by the control unit and to handle data signals, and an EEPROM is connected to the data bus. A 7:128 type decoder is connected to the Address bus, and on the other hand it is connected to 126 PIPO Shift Registers. All PIPO Shift Registers are associated with 126 Micromachined braille cells. According to a research report [19], a study was conducted on the use of decoder to reduce the bus width, and as a practical application, the decoder was used to reduce the address bus width. Also, for the braille cell, the corresponding character and the associated binary code must be temporarily stored in a non-destructive memory, so a data shift register has been used for that. And also, PIPO shift registers [20] were used for parallel data input.

However, to design the aforementioned circuit (Figure: 4), a unique integrated circuit must be made because the 7:128 decoder integrated circuit is not readily accessible on the market. For this, an organization with appropriate technical knowledge should be contacted and it is quite a lengthy process. However, the 3:8 type and 4:16 type decoders that are commonly found on the market can be used to produce a 7:128 decoder for this purpose. This process is known as decoder cascading and 74LS138 IC can be used for 3:8 type decoder and 74HC154 IC for 4:16 type decoders. Using above mentioned ICs, a 7:128 type decoder can be designed by following the decoder cascading procedure.

Refreshing braille cells in the display is done in a first come first serve manner and Queue algorithm is used for that. (Figure: 8 - D) When the opportunity to refresh braille cells comes, the control unit selects the address line according to the address bus. Thus, the PIPO Shift Register is active for reading data, and when it remains active, the required data is released from the Data bus. Then, since only the relevant PIPO Shift Register is active, only the relevant register is captured the released data. Since the register has the corresponding binary value saved, the corresponding braille character will be output using the braille cell module.

According to a research report [21], it was studied that it is possible to store data in EEPROM non-volatile, and in this case, an

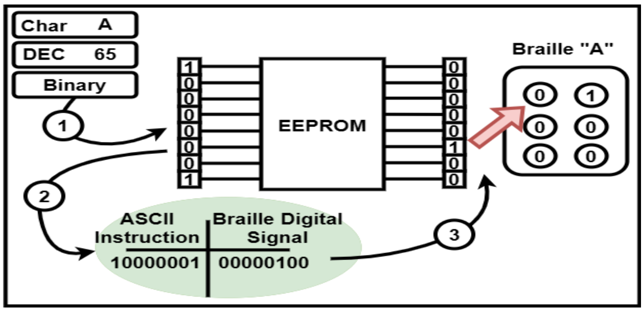

Fig. 5: EEPROM Functionality

EEPROM is used to store data signals structured in a non-volatile manner. That is, the Braille signals corresponding to the ASCII code are stored in binary form. This makes it possible to simplify the scripting process and is used to refresh the braille cells faster. The related process can be presented as follows. (Figure: 5,6)

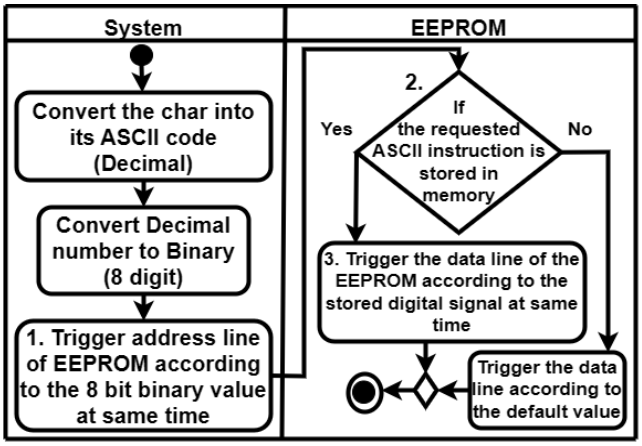

Fig. 6: Activity Diagram on ASCII and EPPROM

3.4 Hardware arrangement of braille keyboard

The hardware model of this sliding keyboard, which is based on braille to enter user inputs related to the system, is as follows.
The high-low states of electricity are used to identify the inputs of this keyboard separately, which can only make one input at a time. A 5bit input is obtained using a 32:5 type encoder and converted to a structured input using EEPROM. Thus, the purpose of using an encoder is to reduce the data bus width of the keyboard from 32 to 5. [21]

The conducted studies [22] emphasized that there is no 32:5 type encoder related IC circuit in the general market. It is possible to create a suitable IC circuit for this through an organization with special knowledge, and CPLD - Complex Programmable Logic Device can be used as an alternative to get the 32:5 encoder function.

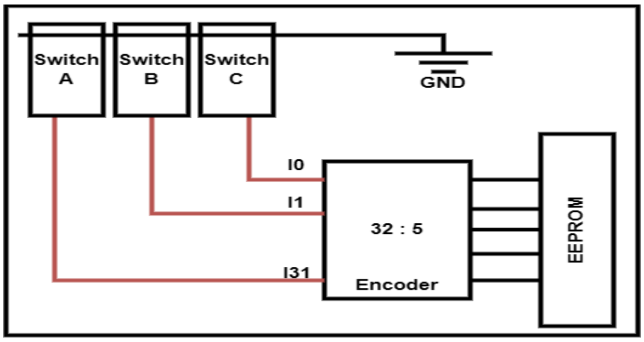

Fig. 7: Hardware Arrangement of Braille Keyboard

3.5 Software arrangement of the proposed system

In order to maintain the operation of the above system (Figure:1), it is necessary to logically align the necessary instructions to the micro-controller. Python programming language and its multi-threading method can be used for this. Since data structures and algorithms are used in the programming, python was chosen as the programming language, and multi-threading method is used in order to increase the efficiency of the display.

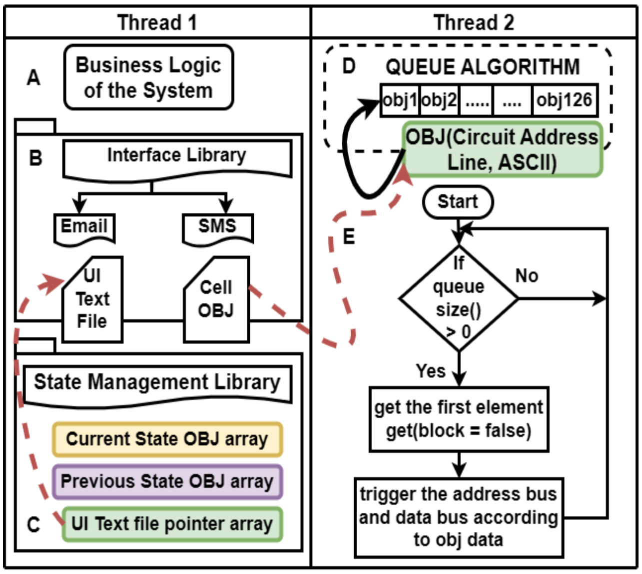

Fig. 8: Multi threading Performance

Basically, the instructions for business logics are executed in thread 1 and the related processes are indicated by A in figure 8. The process for setting the outputs to be given by the refreshable braille display in various cases also takes place in this tread 1. A text-based UI file is used for this, and an interface library is used to generate the UI file. 3 global array variables are used for managing display state-management. In this way, at the end of each business logic, a comparison is made with the previous state and the generated current state, and the object data related to the changed data is inserted into the queue in thread 2. The third global array variable stores two pointer values as start pointer and end pointer related to generate UI file and those pointer values are used for pagination. This method is used to increase the refresh ability of the display.

Thread 2 contains the cell object queue and is processed in FIFO mode. The process is done as shown in E and in Thread 2, the control signals and data signals required for the display are always handled. (E)

3.5.1 Text-based ASCII UI file.
As mentioned above, Text-based ASCII UI is the file that helps to create various interfaces in braille display. In this file created by the interface library, the ASCII code store corresponding to the character to be output by each braille cell happens. Interface library will have 2 interfaces for email reading and replay email and two similar interfaces for SMS. Below is how the corresponding interface is created after receiving an SMS message.

Basically, the SMS related data is captured through the relevant APIs in JSON format as shown in A. After that, the captured data is processed in the form of an array as shown in B (Figure: 9) according to the relevant interface library. Finally, all the characters in the array mentioned in B will be written in ASCII code form in the file. (C) Finally, as shown in Figure 10, the state of the system will be updated and then braille cells will be updated as shown in Figure 8 - E.

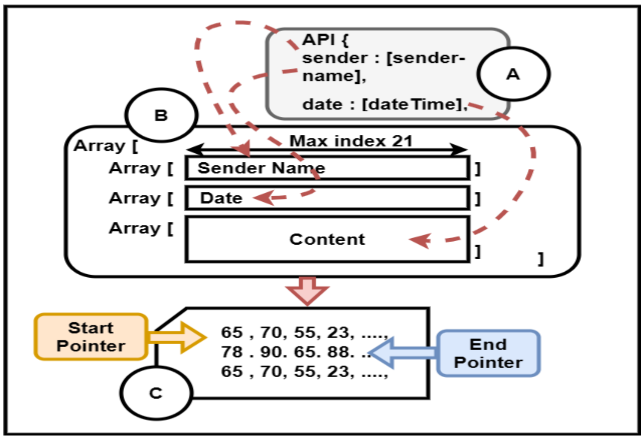

Fig. 9: UI Functionality for Receiving Message

3.5.2 Pagination process.
The refreshable braille display used to create can give a maximum output of 126 characters at a time and in some cases the content of electronic messages can be more than 126 characters. This pagination facility is provided to handle such cases. The related processes can be presented as follows. (Figure: 10)

4. EVALUATION

4.1 Usability of the designing

In the above literature review, several problem scenarios based on the communication limitations and challenges faced by the visually impaired people based on the communication interfaces used to meet their daily communication needs have been discussed. The overall interaction design offered by this design research can be

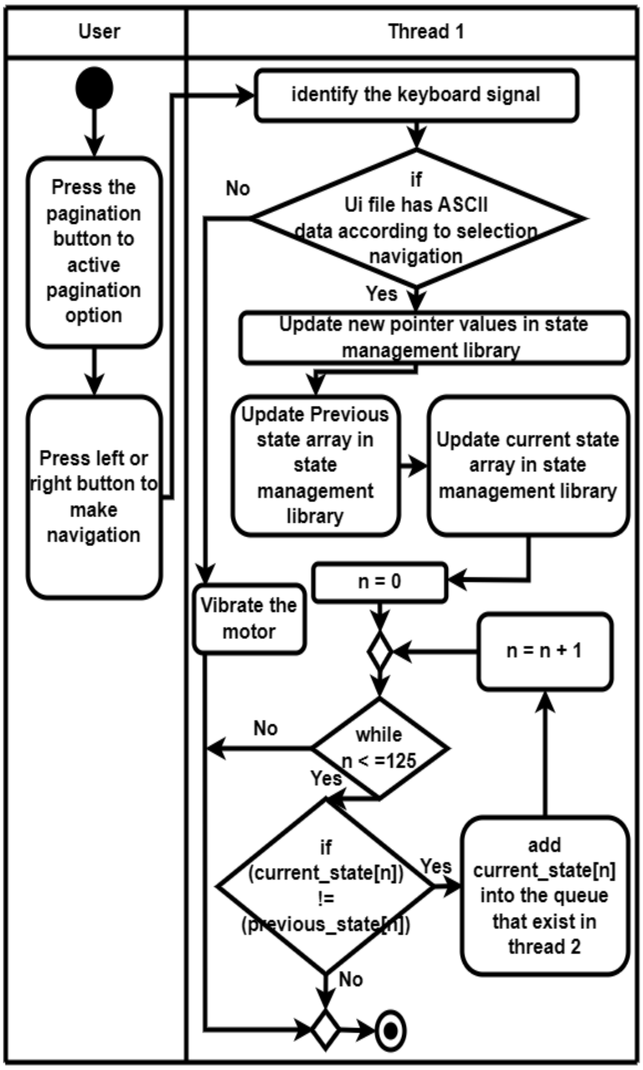

Fig. 10: Pagination Process Workflow.

summarized as follows to evaluate whether it is possible to provide effective solutions for the problem scenarios identified above.

4.1.1 Data privacy issue while being in public [2] [5] [6] [10] [11].
The output units of this communication device have been designed in such a way that the touch sensing ability of the visually impaired people is used and thus by providing outputs based on touch sensing, it has been possible to protect the privacy of sensitive data in public places.

4.1.2 Portability [7] [8].
By designing a unique portable sliding keyboard layout with an area of 5cm x 15cm to input braille characters, pagination, numbers, etc., it has been able to solve the portability problem of the traditional braille keyboard.

4.1.3 Compatibility issue [5] [2].
By designing the input and output units of the communication device in such a way that it does not depend on intermediate media and fully uses the braille method, it has been possible to completely avoid the existing compatibility issues of the input and output of traditional communication interfaces.

4.1.4 Line length limitation [7].
By designing the hardware and software arrangements in the communication device in such a way that it is suitable for the pagination process and by designing a braille display according to the 6*21 matrix format, it has been possible to solve this problem completely.

4.2 Materials and Manufacturing

The expected cost for manufacturing processes including materials, electronic components used to design the following communication device can be stated as follows. Costs for components are given according to AliExpress e-commerce web related to 2024/04/16.

Table 3. : Financial Evaluation

Component Name	Quantity	Price (USD)	Total (USD)
Raspberry Pi 4 Model B	1	53.00	53.00
PIPO Shift Register	126	00.37	46.62
74LS138 IC	1	00.61	00.61
74HC154 IC	8	02.66	21.28
CPLD core board	1	09.87	09.87
Switches	24	-	00.99
BMS	1	00.69	00.69
Li-Iron	1	18.4	18.4
Vibration Motor	1		00.99
3D Printing	1	33.33	33.33
Total Cost			185.78

5. ACKNOWLEDGMENT

We would like to take this opportunity to thank Mr. M. Kulathunga (lecturer in IOT, Computer Architecture, Software Engineering, Networking) who contributed to the technical evaluation of the electronic setup of this design research and confirmed its reliability.

6. CONCLUSION

The main objective of this research paper is to engage in a comprehensive study on the combined use of a micromachined refreshable braille display and a braille keyboard, which is operated by personal touch communication, in order to maintain the electronic messaging services of visually impaired people more safely. To achieve the above objectives, the hardware models and its basic functions related to a mobile communication device that uses braille have been presented in this research paper.

However, under future enhancement, other messaging functionalities related to electronic messaging can be included in this touch sensitive braille communication device and they can be mentioned as follows.

(1) Incorporating the facility of sending new email/SMS electronic messages to another party.
(2) Introducing the attachment facility in such a way that when sending email/SMS messages to other parties, the relevant message can be sent with attachments such as voice recordings, location sharing etc.
(3) Received email/SMS search facility and organization options such as flags, stars are included in the system.
(4) Identifying spam email/SMS using machine learning algorithm (K-Nearest Neighbor) and automating the system in such a way that they undergo filtering.

It is essential to have suitable user interfaces to bring electronic messaging services closer to all the above options to the visually impaired people. For that, all the user interfaces of the communication device should be designed in command line interface format.

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