Design and Construction and Testing of a Low-Cost GSM-Based Electronic Braille System

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Abstract: **This describes the design, construction and testing of a low-cost electronic braille system that is capable of converting text message (SMS) from mobile phones to braille and vice versa so as to enable visually impaired person to receive and read SMS via braille and to Arduino software that can make SMS and braille convertible and the installation of a system of rivets, servo master, and stepper motor for converting SMS to braille.**

Keywords: **GSM-based braille, Arduino, Visually Impaired, SMS-braille Conversion.**

1. INTRODUCTION

1.1 Background of the Study:

Blindness is a condition of poor visual perception which comes to the extent of vision loss. In a strict sense, the word "blindness" denotes the inability of a person to distinguish darkness from bright light in either eye. The terms blind and blindness have been modified in the society to include a wide range of visual impairment. Blindness is frequently used today to describe severe visual decline in one or both eyes with maintenance of some residual vision.

Vision impairment, or low vision, means that even with eyeglasses, contact lenses, medicines or surgery, the person can't see well. Vision impairment can range from mild to severe. According to the Medicine Net (2014), between 300 million and 400 million people are visually impaired due to various causes. Of this- group, approximately 50 million people are totally blind. Approximately 80% of blindness occurs in people over 50 years old which has been drastically increasing worldwide. It has been said that a person goes blind every five seconds and a child (5 y/o or below) goes blind every minute worldwide.

In the Philippines, 478,969 out of 68.4 million Filipinos are blind according to World Health Organization (WHO). Cataract (77% of blind), Glaucoma and uncorrected Aphakia were the most common causes of

blindness according to the National Survey of Blindness survey conducted in year 1995.

Because of the huge number of blind people and the difficulty in preventing blindness, Louis Braille invented the Braille system in 1824. Braille is a tactile writing system used for the blind and for the visually impaired people. It is a big help for blind people enabling them to learn how to read and write using embossed dots. Braille has been improved in many ways to enable the blind to cope in the modern world. Some people have come up with innovative braille accessories which include watches, keyboards, note takers, books and many more so that blind people won't be left out of the innovative technologies of the modern era.

According to the American Foundation of the Blind (AFB), the cost of Electronic Braille Display ranges from $3,500 - $15,000 (154,873.25Php - 663,742.50Php). In a regular household, it is costly for blind persons to purchase these braille products. So for the benefit of blind people, the authors have thought of developing a low-cost GSM-based Electronic Braille System which converts SMS to braille using an Arduino Software and vice versa.

After going through the GSM Module, the text messages will be converted to braille with the use of Arduino Software. Braille will then be embossed through the use of rivets, servo motors for driving the rivets and stepper motor for discrete steps.

1.2 Glossary:

The following terms are defined operationally:

Acrylic Glass. A transparent plastic used as a substitute for glass Arduino. It is an open-source platform used for building electronics projects.

Arduino. an open-source platform used for building electronic projects. Arduino consist of both a physical programmable circuit board and a piece of software or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board (https://learn.sparkfun.com). It is used to convert the received text messages to Braille system using a coded program.

Arduino GSM Shield. It connects to the Arduino Board and allows the system to receive and send messages.

Arduino Mega 2560. It is a microcontroller board that has 54 digital input/output pins of which 15 can be used as PWM outputs, 16 analog inputs, 4 UART, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button (https://arduino.cc). It serves as the main controller of the system that will regulate the servo and stepper motors and transforms a text message to braille and vice versa.

Braille Keypad. It is a keypad where the letters are converted into braille codes that will allow the blind to type their message using the six dots of each braille cell.

Braille System. It is a series of raised dots that can be read with the fingers by people who are blind or whose eyesight is not sufficient for reading printed material. It is a code by which languages may be written and read (http://www.afb.org).

Effectiveness. It is when the original message is converted to braille and vice versa. It is the capability of producing Desire result.

Efficiency. It is when the device is working properly in sequence with each part of the system that includes the GSM Module, Arduino Mega and Motors (Servo and Stepper).

Fidelity. It outputs an exact replica of the original message from the converted message.

Grade 1 Braille. It is the type of braille used as basic literacy of the blind.

Microcontroller. It is a small computer on a single integrated circuit containing a processor core, memory, and programmable input and output peripherals.

Printer head. A component in a printer that moves back and forth to print the characters from which the images are transferred to the printing medium.

Real-Time. It is the time that ranges from the first character to the last character of the message received.

Rivet. A short metal pin used for holding together two plates of metal.

Rubber. A tough elastic polymeric substance that holds the rivets in place.

Slate. It is a rectangular frame that maintains the alignment of the braille pins.

Servo Motors. These are self-contained electric devices that rotate or push parts of a machine with great precision (http://sciencebuddies.org).

Stepper Motor. An electromechanical device that converts the movements of printerhead into discrete mechanical movements.

1.3 Preview:

The next section**, Section 2,** presents th**e Statement of the Problem, after which Section 3** states the **Objectives of the study. This is followed by** an explanation of the **Significance and Scope of the Study in Section 4, while Section 5 gives the Review of the Literature. Section 6 t**hen discusses the **Methods used in the study, while Section 7 presents the Results and Discussion. The Conclusion** is then presented **in Section 8, while Section 9 presents the Recommendations. Section 10 gives the Acknowledgement, while the final Section contains the References.**

2. STATEMENT OF THE PROBLEM

The problem that the researchers wanted to address was whether it would be possible to design and construct a cost-effective GSM-based electronic braille system that would enable blind people to receive text messages (SMS) from mobile phones, convert the messages to braille and let them create text messages through a keypad using the Braille system as well.

3. OBJECTIVES OF THE STUDY

General Objective:

The study mainly aimed to design and construct an electronic Braille system that is cost-effective for the purpose of enabling blind persons to use SMS for communication. The improvement of braille technology in the Philippines.

The study is for blind people to receive messages and also reply to those messages through the use of GSM Module. The text messages sent will be transmitted to the GSM module which will be used as a medium to send and receive messages

More specifically, the study aimed to attain the following s**pecific objectives:**

1. Create a program to convert a text message to Braille system and vice versa.

2. Construct a Low-Cost Electromechanical Braille that will be used to interpret the converted message to the visually impaired.

3. Test and evaluate the efficiency, fidelity and real-time characteristic of the transmitted message when converted to braille and vice versa.

4. SIGNIFICANCE AND SCOPE OF THE STUDY

4.1 Significance:

This research is important because it will benefit the following:

- **Blind People.** It will be easier for them to socialize. It will develop their communication skills through the process of text messaging. They will be able to practice and improve their reading and writing ability.
- **Relatives of the Blind.** They can easily monitor and contact their blind relatives for security purposes, even if they are far from each other.
- **Future Researchers**. The study will help the future researchers to gain knowledge in such research by using this study as their reference and innovate this study for a better device.

4.2 Scope and Limitations:

The study covers the transmission of an SMS to the GSM Module and its conversion to the Braille system through the use of Arduino software. Arduino software will convert the entered message from keypad to braille and decode into characters before delivering the message to mobile phones. The study designed an Audible tone for alerting and signaling the user in cases such as: incoming message, message failed, next line and message sent. Maximum of 160-characters message could be transmitted. Once the message is received and read, it will automatically be deleted. There are buttons for the following functions: (1) push button switch for moving on to the next line; (2) toggle switch for sending and receiving; (3) rotary/selector switch for storing maximum of 6 contact whom the blind wishes to send messages to; and (4) push button switch for reset. The user may respond to a message from the six buttons that correspond to six dots of braille cell that will be converted to alphabet and an enter button that will consider the entered cell as an input character. The user sends the message by pressing all the six buttons together with the enter button. The user may send message to six contacts provided in the selector switch.

The research study has its following limitations;

1. The study will use Grade 1 braille,
2. The system covers only all the letters, numbers and common by used punctuation marks for sending and receiving,
3. The researchers cannot control the wireless network when there is low sign coverage,

4. The system will not operate if there is power failure,
5. The system can only store up to 6 contact numbers to send its message,
6. The system cannot control the traffic in a simultaneous receiving message, and
7. The device may transmit a message only if the SIM has a sufficient load balance.

4.3 Circumstances of the Study:

The research was conducted at the research section of the Library of Lyceum of the Philippines University-Cavite, Gen. Trias, Cavite, Philippines. Gathering of components were carried out from December 2014 to February 2015. E-gizmo supplied the necessary equipment such as the GSM Module, Servo Motors and the Laser Cutting for the Acrylic Glass. Some parts such as capacitors were purchased at Deeco, while the transformer and buttons were bought at Johnz Electronic and Electrical shop.

The prototype was made at Deloverjes' Residence in Golden City, Dasmarinas City, Cavite, and was completed at Reyes' Residence in Metrogate Village Dasmarinas City, Cavite between December 2014 and January 2015.

5. REVIEW OF THE LITERATURE

According to Chen (2008), the embodiment of the utility model discloses a braille movable termination and a touch device. A braille mobile terminal, comprising: input information receiving module for receiving input information; a conversion module for converting the received information in the receiving module into braille; a touch module for displaying the converted braille. A touch device comprises of display, recognition, and retransmission unit. The function of display unit is to show the input information converted braille coming from mobile terminal. The recognition unit is used to display the input information to the mobile terminal and sends confirmation. The retransmission unit displays and transmits the input information to the mobile terminal to request for retransmission in accordance with the content of the input information. As mentioned by Schramm (2009), the Braille Mirroring can be accessed by multiple users and can receive content from the same computer. Each user can receive the content through a braille display configured to accommodate the user's needs or preferences. This allows students in a classroom, collaborators on a project, or audience members at a presentation to each experience content in a way best suited to their individual needs. Control of the computer can be monitored so that only a primary braille display can control the computer, or all braille displays can control the computer. This allows a single user to retain control of the computer when appropriate (e.g., when the user is teaching a classroom of students), and allows users to collaborate together when appropriate (e.g., when they are working on a collaborative project). In line with Wong (2013), the blind people can write braille on the first surface of the braille reading-writing device, and they can touch to read the written braille on the second surface thereof. Therefore, in the invention, the functions of writing and reading braille are integrated into the same device, and operation habits of the blind people are greatly conformed to. According to José Antonio Borges and Dolores Tomé (2013), Music study recently became a compulsory subject in elementary schools in Brazil, aiming to provide children with their first deep contacts with the musical universe. A methodology for teaching music to blind children, based on the interaction with the Musicbraille software was presented to which specific functions were added so it can support the activities of basic music education. The Musicbraille Project is the structure that will disseminate nationwide the proposals and methodological ideas contained in the paper, ensuring that it were widely distributed throughout the country. With the hope that the human network that has been created, interconnecting Musicbraille users and teachers , will be able to support these ideas, allowing that quality inclusive music education for blind children quickly become reality across the country. The future of this research involves the evaluation of this technology and methodology to disseminate braille Music education in different languages.

As for the study of Norio Takatsuji, Koutarou Shiraishi, and Tetuo Yanase (2014) entitled "Effect of two-layer simple die on Braille Embossability to boxboard", used experimental device like cam-toggle press machine, metallic mold, Urethane rubber and processed material. A cam toggle type precision pressing machine is a pressing machine that highly precise positioning and maintenance are possible in a bottom dead center by cam and toggle. The toggle which changes from horizontal movement to movement of the up-and-down direction can take out big power according to an enlarging mechanism, the cam changes rotational movement to a straight-line motion is stable.

The material of this simple metallic mold is stainless steel, and is given durability with high hardness. The size of a male type convex part should be 1.4mm and 0.5 mm in height and the size of the hole of a negative form is 1.6mm. Thickness of a male type and the negative form are 0.3 mm and the size is 15×60 mm. Urethane rubber is inserted under the simple metallic mold, and it becomes two-layer simple metallic mold structure. Urethane rubber is excellent in dynamic intensity, and wear resistance is also good. Processed material is white board. It is usually used a package of medicine, and the thickness of that is 0.27 mm. The foundation and plywood for height control are installed on the table of a pressing machine, and the negative form and urethane rubber of a simple metallic mold are installed on Die Bode. Next, the male type of a simple metallic mold is carried in the state where it combined with the negative form, double-stick tape is pasted up on the male type back side, and a table is moved under a top plate. A top plate is dropped and a male type is made to fix to a top plate. The distance which a table moves was decided in the case of processing, and since it can always moves and stops at the same position, the braille-points emboss process can be carry out. As an experiment procedure, a processed material is first placed on the negative form of a simple metallic mold, and a table is moved under a male type. Then, a male type descends towards a negative form with a top plate, a male type convex part enters the hole of a negative form, and braille-points emboss processing is performed by a processed material being inserted and crowded in the hole of a negative form. After processing, and when the top plate goes up, a table returns to the original position. This operation of a series of is performed automatically.

Ying (2010) stated that their invention is to provide a relatively simple structure, fully-featured, and highly reliable. Its primary features is to receive automated messages printed in a braille device so that the blind people can independently receive and read the text message. Their invention is composed of GSM Module, a Braille Printer and a Controller Module. The GSM Module receives the text messages, braille printer will then print out messages in braille, and the controller module will be responsible for the management and coordination of GSM and the Printer.

On the research study of Fields and Khan (2009), the portable electronic device can be operated in both a braille-input mode and a non-braille-input mode.

In the braille-input mode it can be selected by using either the trackball or thumb navigator. In the non-braille-input mode, a user can use the device's input keys to input text, numbers and symbols into the device. Alternatively, the user may use a specific input key or may use the thumb navigator or trackball to select a default setting indicating the type of character each input key normally generates.

According to Kway, Salleh, and Majid (2010), they have made an alternative tool for braille writing with its Slate and Stylus. The A-J+3+6 Method emphasized on the concept of braille writing with slate and stylus and no mental reversals are required as the dots numbering position or “dot calling” begin from right to left instead of left to right as the writing with slate and stylus from right to left. This enabled students to write braille with slate and stylus without doing mental reversal of the braille code before writing. Since most of the blind students had learned writing with braille machine, they have no difficulty in writing with slate and stylus. They just need to switch the dots 1, 2 and 3 instead from left to right when writing from right with slate and stylus. A-J+3+6 method is more effective in braille writing than the conventional method because the students who used conventional method tend to do more mirror errors than the students who used A-J+3+6 method. It is better to use the A-J+3+6 Method in braille writing with Slate and Stylus than the Conventional Method.

As for Xu Min (2011), they invented a Braille Display Cellphone, a utility model phone that has a mobile phone body which is provided with a braille display. The braille display is divided into several modules. The body of the phone also features an internal baseband chip and voice processing module. The baseband chip is connected to the voice processing module and the braille display. Braille displays the utility model phone then the user can enter the text, numbers, letters, etc. into braille dots and can be performed while the voice module declares the entered text.

In relation to the study of Jia (2013), system and method to capture and translate braille embossing include a sensor, an output system, a processor coupled to the plurality of sensors and the output system, and a memory. The memory stores instructions that when executed by the processor it receives a signal from the sensor then interpreted as letters, numbers, symbols or punctuation commands as the first braille cell and send a signal corresponding to the first braille cell to the output system. The output system may include a visual display and at least one audio system.

In Chen’s study, it has similar function compared to the current research in receiving text messages and likewise converts the received messages into Braille system. Their study did not use GSM Module unlike this research. One of the advantages of this research is that it has an additional feature that can send information using a braille keypad. Moreover, the blind people can check his text message before he sends it.

In Ying's research, it also converts the message to braille but its output is different from the research study. Instead of using a device to emboss the converted braille, he used a printer for embossing dots while the study used a braille device that will emboss series of rivets on braille pins.

In Schramm's study, the only similarities between their study and the research study is that it converts a provided content to braille displays. For braille mirroring, it is the computer that provides the information and multiple users can receive the content from the same computer while in this study the source of information comes from mobile phones and only a single user can receive the content.

In Wong's study, its similarity to the research study is that the user can simultaneously read and write. There is also the reading and typing portion combined in one device. The writings of the user will be projected in the reading portion of this device therefore allowing the user to check what he has typed. The pressing buttons, the keypad and the touching buttons, are the braille dots or pin. The pressing and the touching buttons surface were enhanced so that the user can easily distinguish which is which.

In comparison to the research of Jia, this system of capturing and translating process in the Arduino software then display the converted messages into braille.

Similar to the research of Khan, the portable electronic device provides opportunities for the blind to experience the life of an ordinary person. The difference is that the portable electronic device is that it lets the user to choose from braille-input mode to non-braille-input mode while the research has a braille keypad that let the us in the Braille Display Cellphone from Xu, it is a device that has a braille display and the user can enter text with braille dots and has a voice module that complements the entered text. The only difference of the braille display cellphone from the research is that it is a portable device and it has a voice processing module.

The Music Braille by Borges and Tome is similar to the research in such a way that it aimed to improve the way of living of the blind people. The difference is that in Music Braille it incorporates facilities with educational purposes to teach children and creates an interaction between the basic music educations while the GSM Based Electronic Braille is for blind people to have long distance communication with the use of mobile technology.

As for Yanase, Takatsuji and Shiraishi, they have used different materials to emboss braille characters. In the research study, the use of acrylic, rubber, rivets, spacer, frame, microcontroller, GSM Module, servo motors and stepper motor provides a low-cost braille. Acrylic was laser cut as a braille slate. Rubber as a stopper for the braille pins once embossed. Rivets act as braille pins. Microcontroller works as the brain of the whole device. GSM Module receives and transmits messages. Servo motors push the designated braille pins. Stepper motor moves the servo motors from left to right.

Kway, Salleh and Majid's study has a different function in the research project because it uses A-J+3+6 method in braille writing while the current research uses 7 switch buttons to write message. Each switch buttons are programmed with different combinations that is equal to the letters that visually impaired uses based on Grade 1 braille standard.

6. METHODS

6.1 Research Design:

The researchers used the experimental research method in which they designed, constructed, and field tested a prototype among blind persons. The hardware of the device was designed appropriately, specifically the platform of the braille pins and reliability of the message transmitted.

All the data gathered in the research method were used in building the device. After applying an experimental method, the researchers were able to know what the setup will be of the circuit and the components needed, and the theoretical information to be used and came up with a defined and reasonable GSM based electronic braille. To understand further how the device will function, the researchers created a flowchart design in **Figure 1**. It represents the arranged operation of a GSM Based Electronic Braille. The creation of the braille mechanism is the challenge for the researchers. The concept of the old versions of printer were used when the printing of letters was still the same as the embossing of braille pins and it also moves from left to right which is also similar to that of braille. For the frame of the mechanism, the researchers created a flexi glass that holds the mechanism in place. The rivets acts as the braille pin of the system. The printer head serves as the base of the braille system and supports the servo motors. The servo motor will push the pins upward and downward while the stepper motor moves pulses from left to right. The rubber plate will serve as a stopper for the rivets. Both the stepper motor and servo motors will obtain pulses from the Arduino.

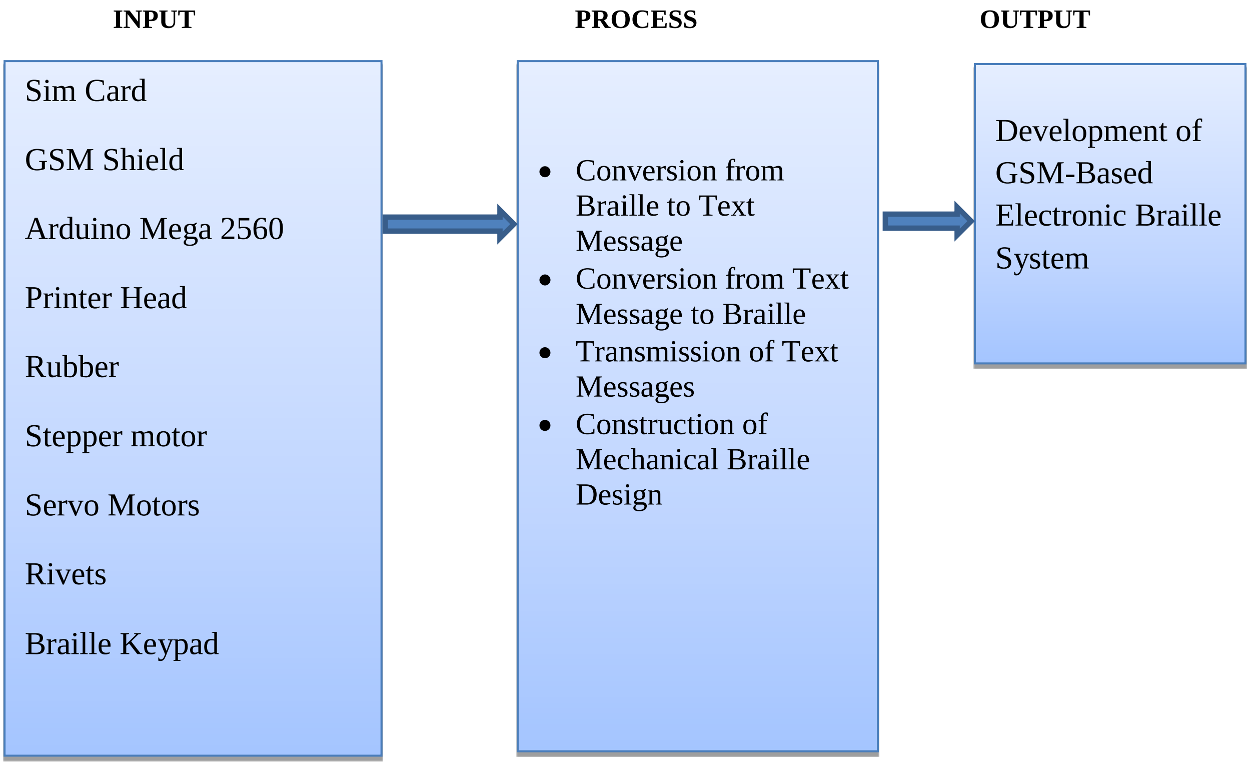
With the software, the researchers used the Arduino Mega with the GSM Shield that enables the GSM program with the Arduino. The conversion of the text message to braille and vice versa and the pulse of the stepper motor and servo motors were covered by the software of the system.

In knowing the whole process of GSM Based Electronic Braille System, its control system model can now be determined. **Figure 3** shows the control system of the devices. The GSM Module was be connected to the Arduino (for converting) and Electronic Braille (for receiving the converted message).

In this study, the researchers tested the fidelity, efficiency, and real-time characteristic of the device to be constructed.

6.2 Research Design Framework:

In terms of receiving, the input stage is the text message transmitted from a mobile phone. After this process, the GSM modem will receive the text message and convert it to braille using Arduino by means of a coded program. The blind people will then be able to read the received text message. For the process of sending, the input is the braille keypad where the blind people will type their message. Following this process is the conversion of text message to Braille system then the mobile phone will receive the text message.



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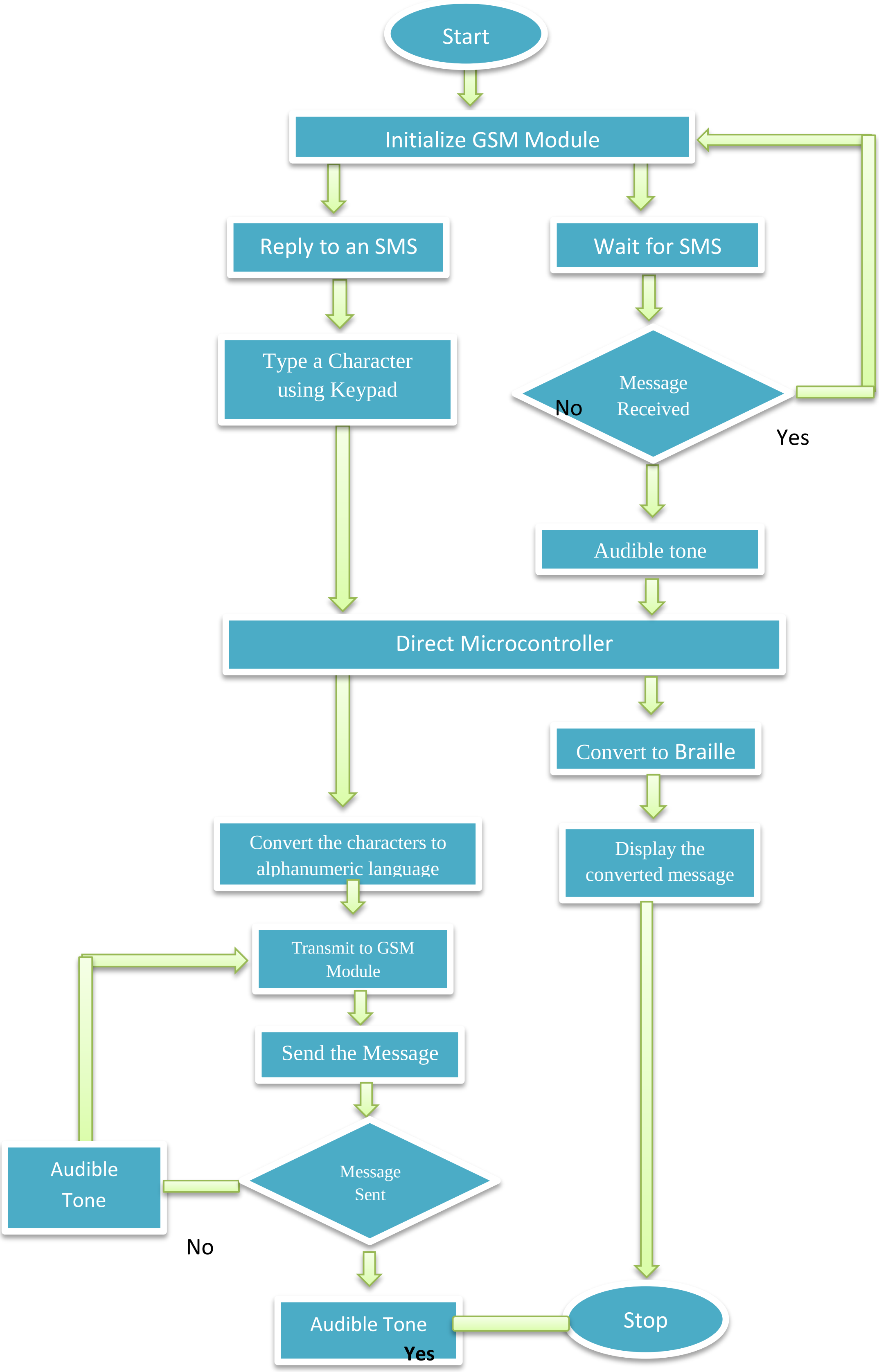

Figure 2: Process Flowchart of the GSM-Based Electronic Braille

The flowchart of the research study is displayed on Figure 2. In the device, there are two main functions: Transmit and Receive. In transmitting message, there are six buttons that will be equivalent to the Braille (six dots) and the seventh button would be the ENTER key. These buttons can be used to input text message in every character typed. To send the message created, the seven buttons must be pressed all at once. In receiving message, it will be up to the GSM Module to receive the message transmitted by a mobile phone. Once the message has been received by the device, it will automatically be converted by the program uploaded on the Microcontroller and the motors will start to move and push the pins to emboss and let the blind person read the message.

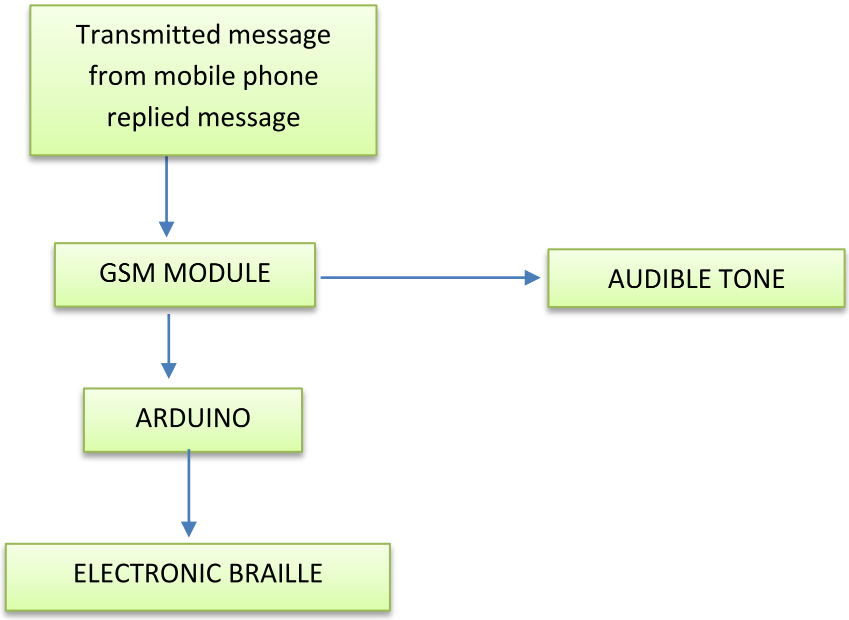

Figure 3: Control System Model of the GSM-Based Electronic Braille

In Figure 3

The Control System Model for the study is displayed. The system simply transmits and receives which is the primary function of the device. It will neither receive nor transmit without a GSM Module. GSM Module is responsible for recognizing the phone numbers and the device's own number, too. Arduino is a microcontroller that sets every component used at its right sequence and pace. Electronic Braille is done by gathering the necessary components together such as the switches, servo and stepper motors, rivets and printer head. Audible tone was used to alert the blind user of the message status.

6.3 Design Considerations:

Design Parameters of the Braille Mechanism:

There has been a lot studies and researches that were made for the development of braille.

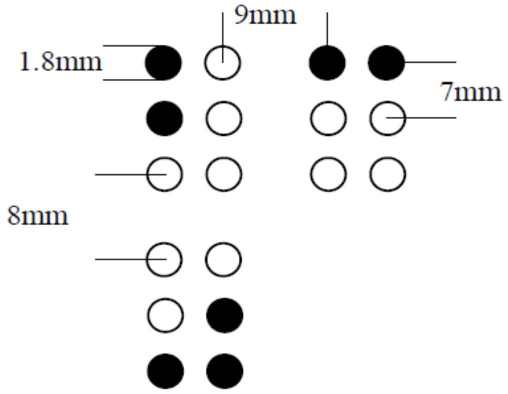

Figure 4: Parameters of an Electronic Braille Pin

Grade 1 Braille:

There are three grades in a braille. The Grade 1 Braille is the most simple of the three. In this research study, the researchers consider the Grade 1 Braille as their converted output. The Figure 5 shows the following letters, numbers and symbols that the research project covers. Each possible arrangement of dots within a cell represents only one letter, number, punctuation sign, or special braille composition sign. Individual cells can't represent words or abbreviations in this grade of braille. Grade 1 Braille is typically used only by those who are new to learning the grades of Braille.

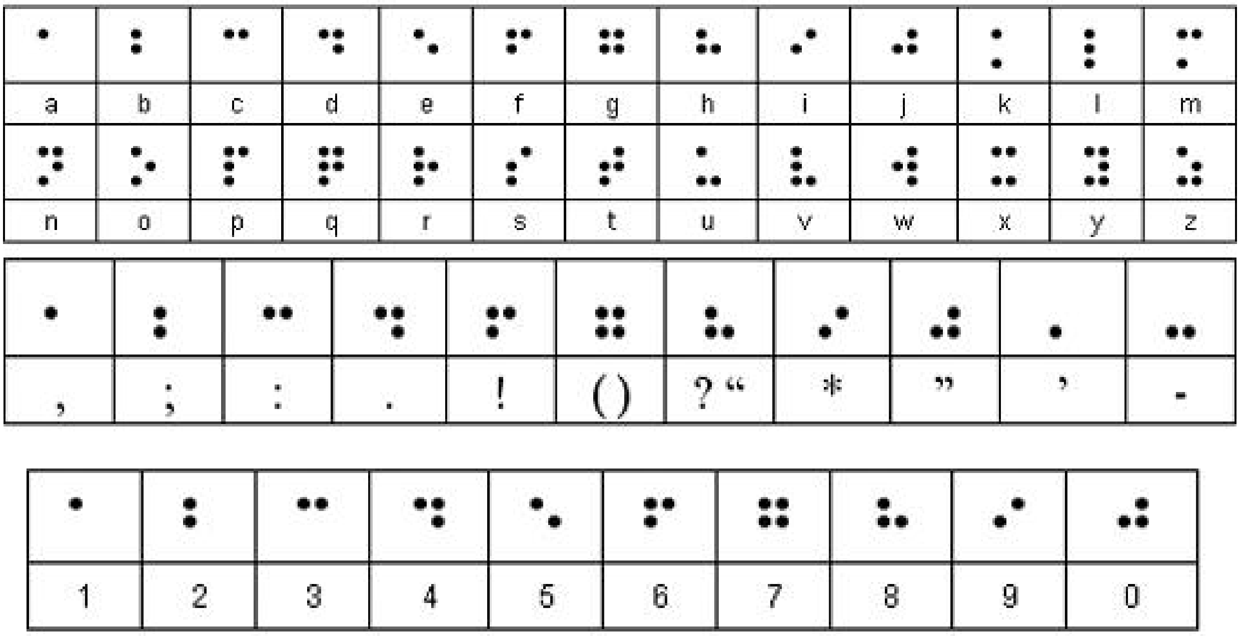

Figure 5: Grade 1 Braille Symbols

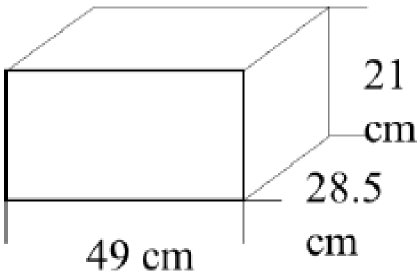

Figure 6: Casing Dimensions

The casing of the study should have these dimensions to contain all the components in one box. With its dimensions, everything is going to fit perfectly even though it is not a portable device to carry to places.

Arduino:

The Arduino software must also be considered during the design as it will be the main controller of the whole system. The converted message must be accurate to the message sent. The control of the different buttons of the user and the embossment of the braille will all depend on the software created in Arduino.

Microcontroller:

The program cannot be done without a microcontroller. It will be the medium for controlling the whole system using the Arduino software. The researchers consider the memory of the microcontroller. The microcontroller should also has a large memory to store large amounts of code in a program.

6.4 Components Used:

Table 1: Components Used in the Study

Materials	**Items**	**Quantity**
Microcontroller	Arduino Mega 2560	1
GSM Module	SIM 900	1
Sim Card	Smart	1
Capacitor	100uF, 50V	1
Diode	In4001	4
Acrylic Glass	4.5 mm	1
Rubber	Bicycle Tire	0.50 meter
Resistor	10KΩ	13
Rivet	1/8 x 1/2	96
Switch	Push	2
	Push DPDT 2MM Lead pitch	8
	Selector	1
	Toggle	1
Buzzer	22mm piezo electric	1
Electrical Wire	Solid Wire	2 meters
Motor	Stepper	1
	Servo SG-90	6
Printer	Lexmark	1
Spacer	M3 x 15	4
	M3 x 25	4
	M3 x 25	4
Screw	3 x 6	16
	3 x 20	8
	1/8 by ½ with knots	4
Paper	Sand	2
Stepper Motor Driver	A4988	1
Wires	Stranded (1m)	4
	Solid (1m)	4
Shrink Tube	3mm	1 meter
	3.5mm	1 meter
Lead	Solder	2 meters
Relay Module	Sainsmart (2pair)	1
Printed Circuit Board	EGPC-03	3
Connectors	Female Header	15
	Male Header	15

6.5 Testing and Debugging:

The research underwent testing to verify the efficiency, effectiveness, real-time and fidelity of the device.

Efficiency:

Efficiency will be measured through the conversion of the message. The message sent and converted by the Arduino should be the message that will be displayed in the braille. A maximum/limit of 160 characters per page must be received and displayed through the braille. When a message was received, sent or failed, there should be an audible tone to notify the user.

Fidelity & Efficiency:

Fidelity was assessed through text received being converted to braille and it showed exactly the same as the original text.

Real Time:

The sending and receiving of message must be in real time. The time sent from the phone must also be the time received by the braille system and vice versa.

SIM (Subscriber Identity Module) Card:

It is a portable memory chip used mostly in cell phones that operate on the Global System for Mobile Communications (GSM) network. These cards hold the personal information of the account holder, including his or her phone number, address book, text messages, and other data. SIM cards are convenient and popular with many users, and are a part of developed cell phone technology. The GSM Module will not send and receive a message without the SIM Card.

GSM (Global System for Mobile Communications) Module:

It is a specialized type of module which accepts a SIM card and operates over a subscription to a mobile operator, just like mobile phone. A GSM Module exposes an interface that allows applications such as to sending and receiving messages over the modem interface. The research study uses a GSM Module to allow the blind to send and receive messages from mobile phones and vice versa.

Arduino Software:

The Arduino converts the message received by the GSM Module to Grade 1 Braille. It is designed around a relatively low power microcontroller that gives the user complete control of its hardware. Through the use of Arduino IDE, one can write programs (<32Kb) that can interface with almost limitless hardware including switches, sensors, LCDs, other microcontrollers, the internet, etc.

Rivets were used as braille pins that will come out as different combination of braille symbols. A braille cell consists of six raised dots/pins arranged in two parallel rows having three dots. A single cell can represent an alphabet letter, number, punctuation mark, or even a whole word.

Braille Keypad:

The braille keypad is an input device that allows the user to type and enter text or instructions for the computer in braille. The use of braille keypad lets the blind to create a message while checking the entered message with the braille. 6-8 push-button switches were used to create a Braille Keypad.

Printer Head

It is used to carry the six servo motors that will be used to push every cell from left to right. Using this, a cost-effective device was provided.

Stepper Motor:

It is used to move the printer head from left to right (and vice versa) carrying the microsolenoids and the sliding crank mechanism to push the pins in an upward motion.

A4988 Stepper Motor Driver:

It is used for a bipolar stepper motor. It features an adjustable current limiting, over-current and over-temperature protection, and five different micro-step resolutions (down to 1/16-step). It operates from 8 V to 35 V and can deliver up to approximately 1 A per phase without a heat sink or forced air flow.

Servo Motor:

It is an alternative for a microsolenoid. It is used to push the braille pins up from left to right.

Rubber:

It is used as a stopper for the pushed pins by the stepper motor. It will be activated by another stepper motor by pulling the rubber, tightening the rivet with the aim of avoiding collapse while it is embossed upward. The rivet will maintain its position with the use of Rubber Plate.

Acrylic Glass:

It is used as a slate that will hold the rivet (braille pins) together. The braille slate was laser cut for precision of holes for the rivet to emboss without no hindrances.

 ISSN 2348-6988 (online)
Vol. 4, Issue 1, pp: (27-50), Month: January - March 2016, Available at: www.researchpublish.com

7. RESULTS AND DISCUSSION PRESENTATION OF THE PROJECT DESIGN

This chapter contains the presentation of the "Development of GSM-Based Electronic Braille System". The functions of each elements of the Braille system will be clarified. The actual design will only work with the mechanical device working connected to the Arduino. Each part of the device are essential to have a comprehensive system. The flowchart of the program allows the device to work at its desired output. The results of the study will also be discussed.

7.1 Presentation of Data of the Actual Design:

The Electronic Braille System is divided into two major sections: the hardware and the software. The hardware consists of the mechanical design of the braille system and the software contains the program of the overall system.

The input and output devices are interfaced in the Arduino that controls the step and regulates the angular position of the stepper and servo motors respectively. The stepper motor is required to have a stepper motor driver which consists of the following inputs primarily, the Vmot or the Motor Supply Voltage. It operates in a current of 600 mA and a voltage of atleast 29 V. It was supplied with 24 V/2A power supply. The servo motors were connected to Arduino to have a uniform power supply and to lessen consumption of power for each servo. The GSM Module of SIM900 needs an external input supply of 9 V. Once powered up, the GSM Module initializes and loads the program while connected to the Arduino board.

Figure 7: Main Controller (External)

Figure 8: Main Controller (Internal)

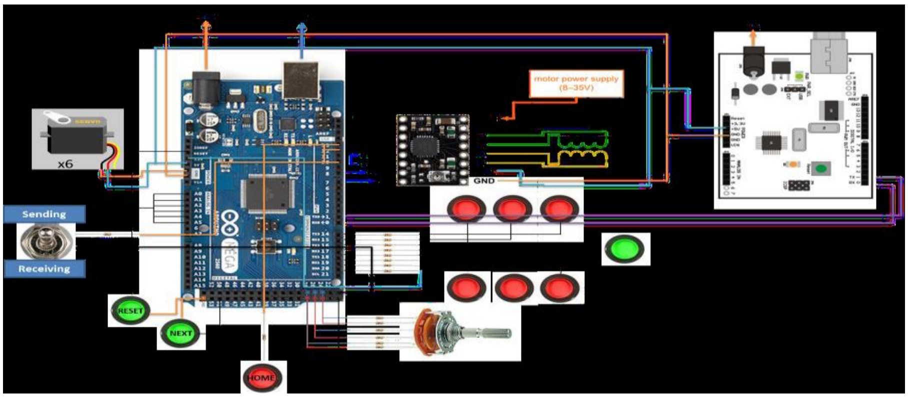

Figure 9: Wiring Diagram of the Study

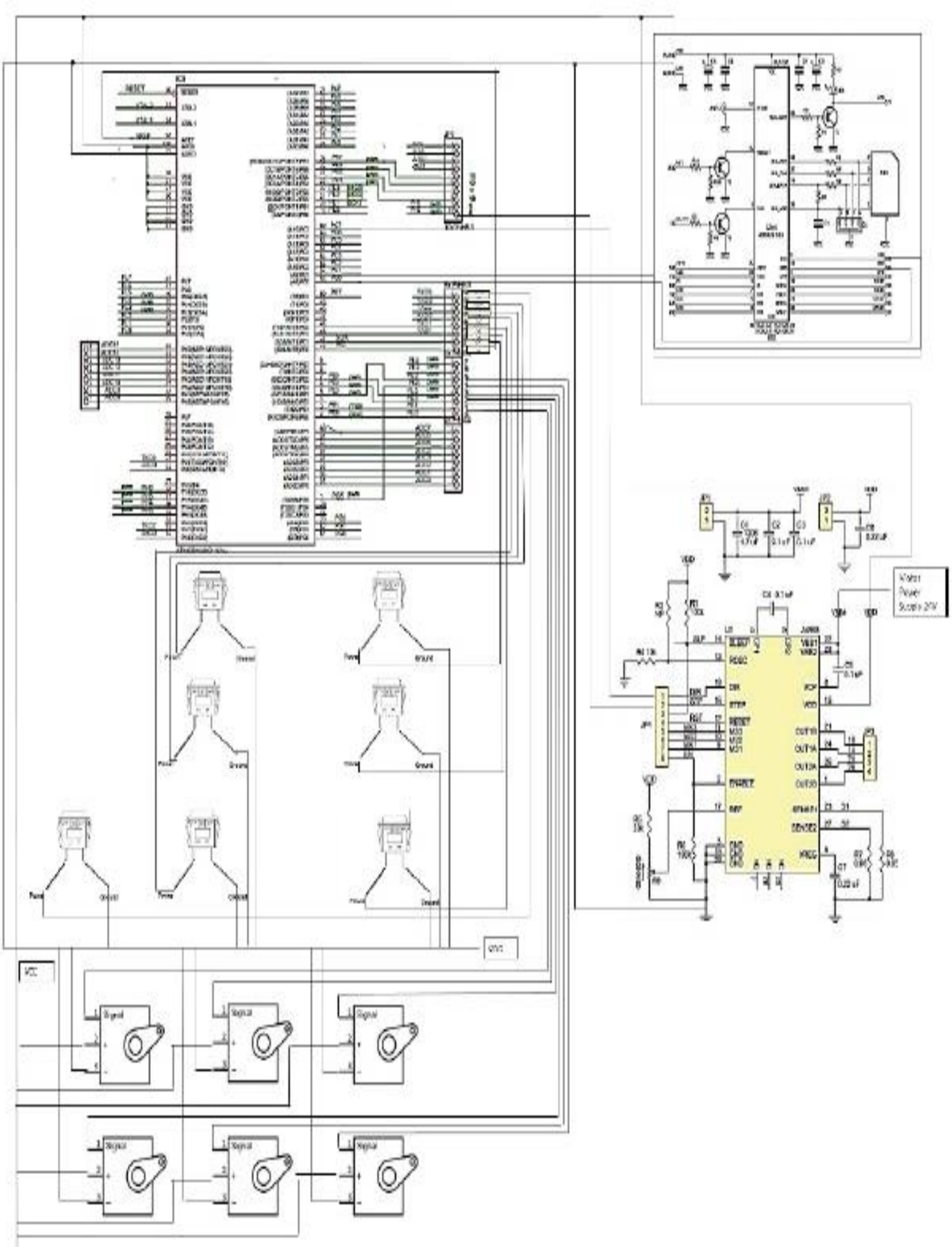

Figure 10: Schematic Diagram of the Study

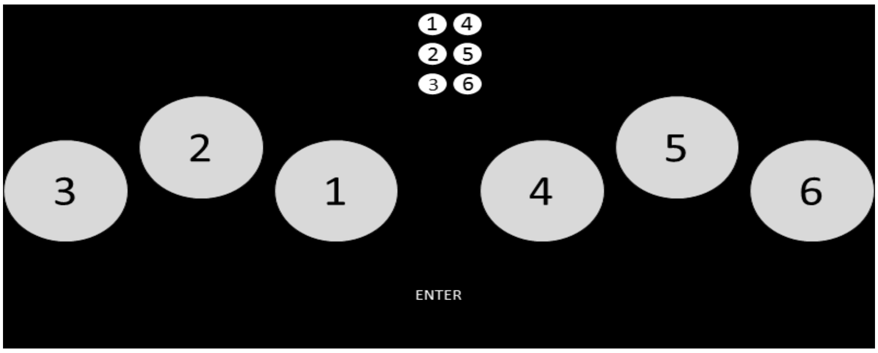

Figure 11: Six Switches (Keypad) Input to Braille Cell Output

The buttons and special purpose switches were also connected to the Arduino. There were six buttons that corresponds to each rows and columns of the standard braille and an enter key to input the entered character to Arduino for conversion. Figure 11 shows how the six switches are used to output a character on a single braille cell. The special purpose switches contains the reset, next line, reply and send buttons.

System Design:

The researchers have structured an outline with regards to how the system of study works. The system design flowchart is shown on Figure 12. Since the researchers are familiar with the whole process, they ultimately decided to study "The Development of GSM-Based Electronic Braille System".

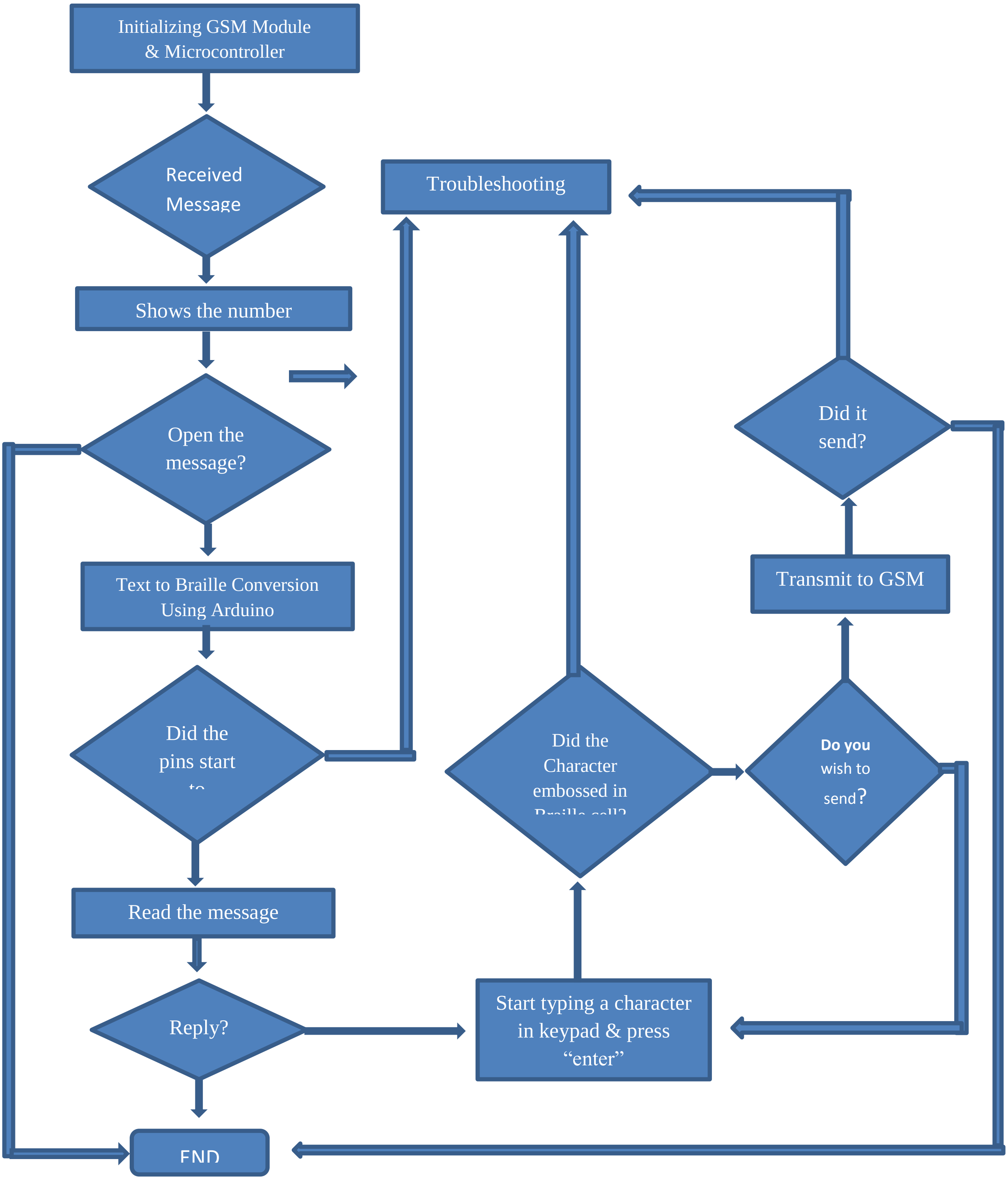

Figure 12: System Design of the Study

Source Code Development:

The step-by-step process of working with the program for the study was programmed with the use of Arduino MEGA 2560 using AT Command as language for sending and receiving through the use of Gizduino's GSM Shield. C++ Language was used for controlling servos, steppers and switches of the device.

1. Using the serial monitor of the Arduino software, the Arduino will have access to the GSM Module. A mobile phone shall text the device. If it has received the message, it is ready for the next step. All materials used in the study will be connected to the Arduino even the stepper and servo motors to be controlled.

2. In the programmed system, the text received will be converted to bits and this will allow the stepper motors and servo motors to interpret it and work with its necessary steps and position angles.

3. Once the servo and stepper motors work, the rubber plate will be pulled by a servo motor sg5010 that will act as a stopper. The servo motor sg90 will push the rivets (braille pins) upwards making a braille symbol.

4. The special buttons (up, down, left, right) are programmed in Arduino that includes the RESET and SEND button, NEXT & PREVIOUS page and message buttons respectively.

5. If the user desires to reply back, a keypad is necessary. The keypad consists of 7 switches that are likewise controlled by the Arduino Software. The switches are for inputting one character at a time. Each character is converted into bits for the Arduino to interpret it digitally and pass the data to the motors to push the required rivets for a designated character.

8. RESULTS AND TESTING

Actual Testing (sending):

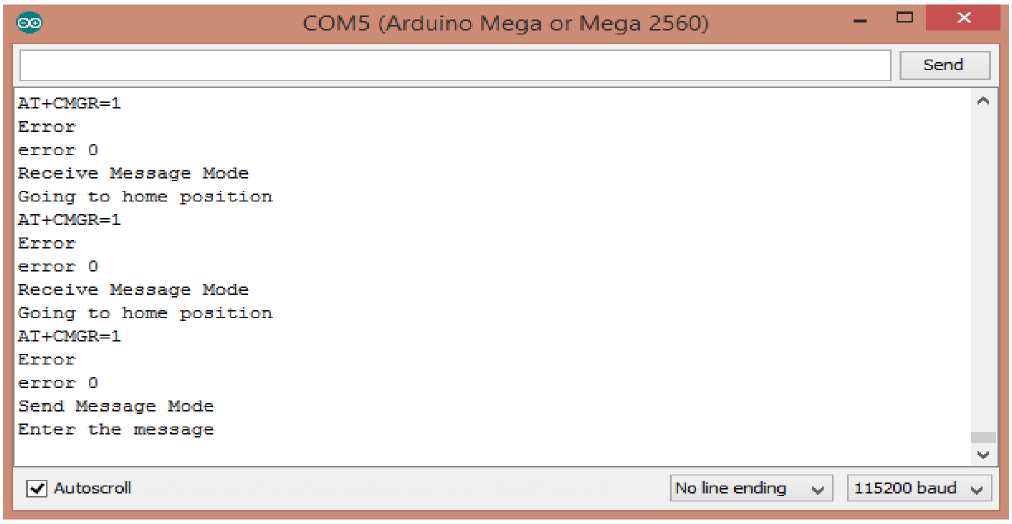

Figure 13: The device is in Send Message Mode

Figure 14: The user enters the message with the Keypad

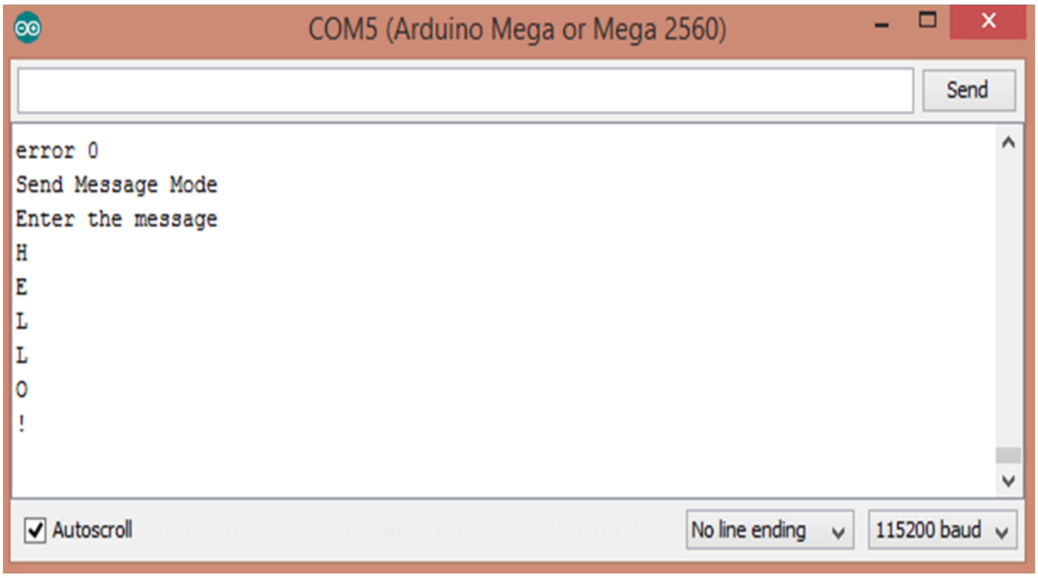

Figure 15: The serial monitor displays the entered character

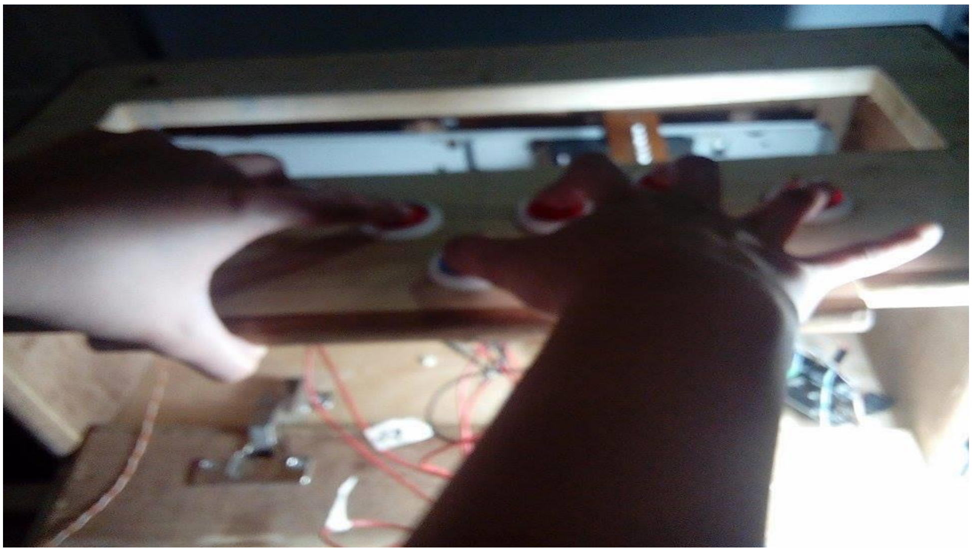

Figure 16: Pressing all the keypad together to send the message

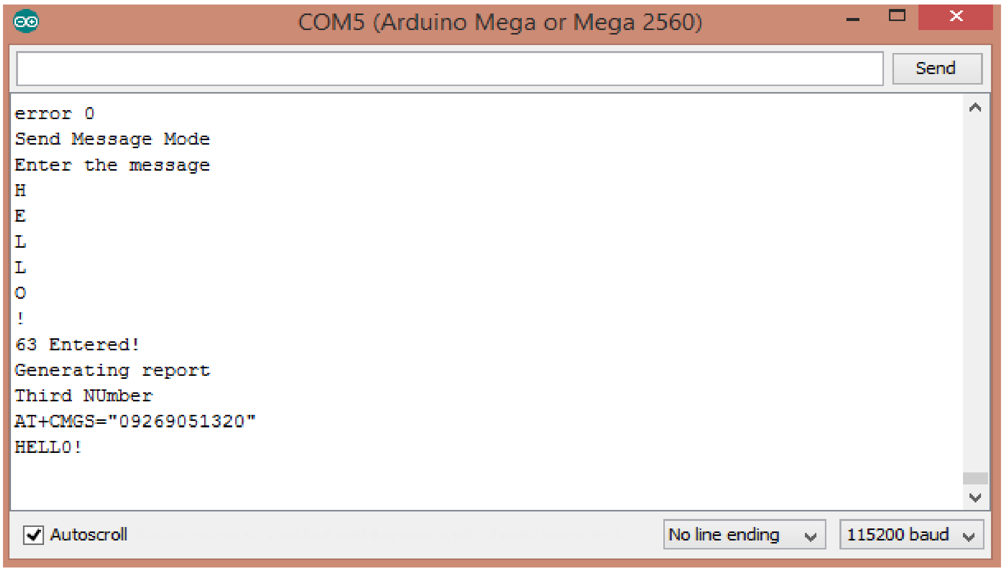

Figure 17: Message was sent to the mobile

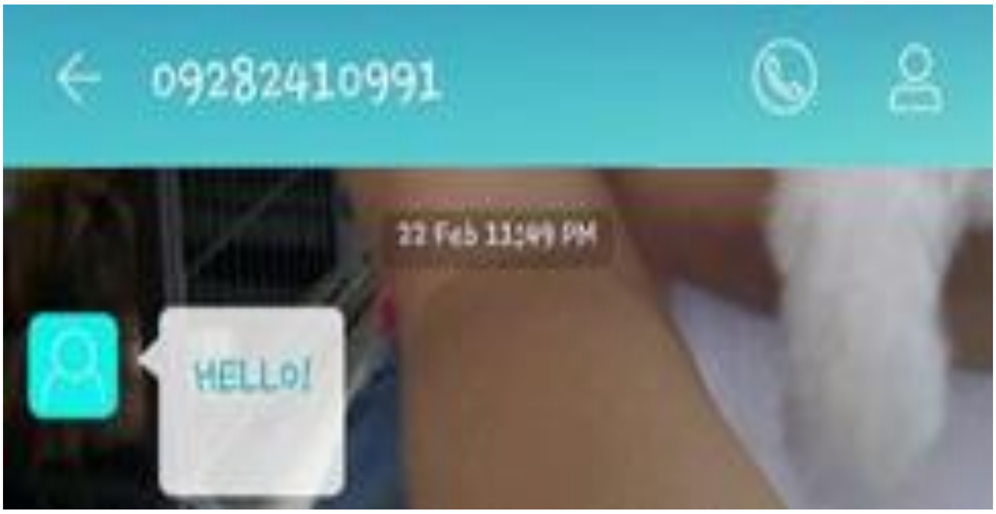

Figure 18: The message received by the mobile phone

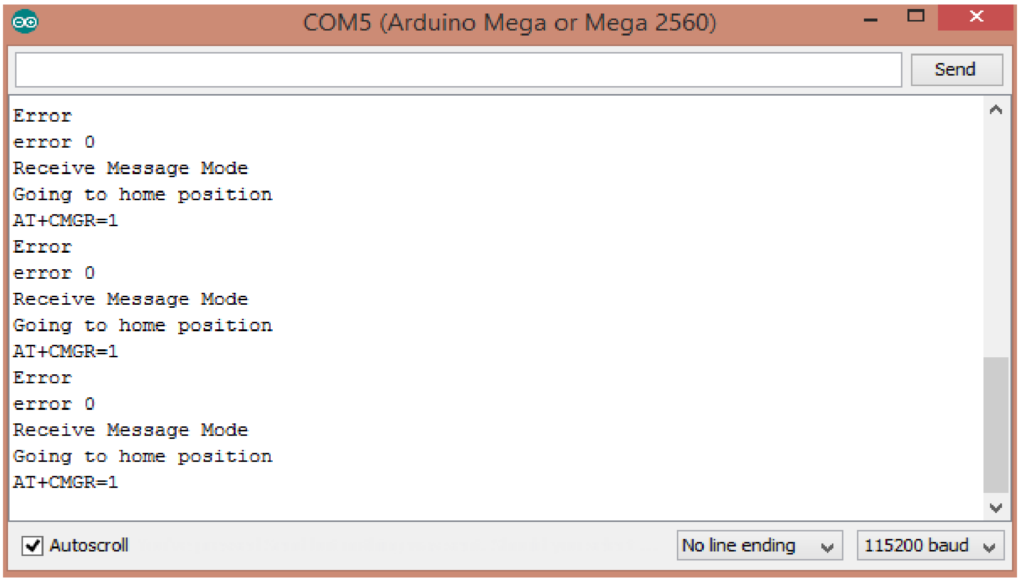

Figure 19: The device is ready to receive message

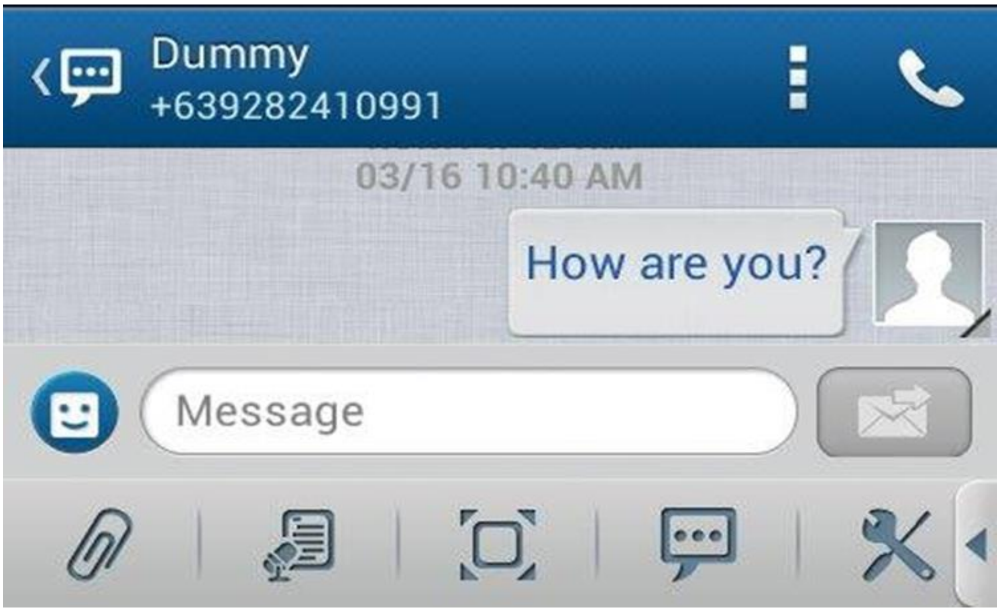

Figure 20: The message sent by a phone to the device

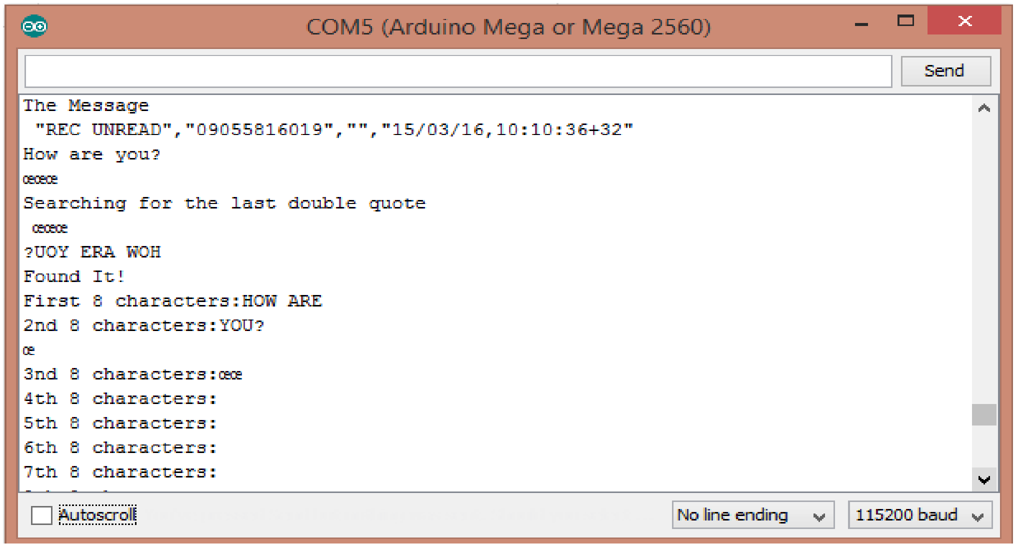

Figure 21: The message received by the device dividing the characters into 8 characters per line and excess to 16 characters will be output when the Next Button is clicked.

Figure 22: The message received to Braille

Efficiency Test:

Efficiency is acquired from achieving a specified function. The special function that must be accomplished is the ability of the Braille system to send and receive a message. It was achieved by testing the connectivity of Arduino to GSM, Sending and Receiving of the GSM. For the analysis of the efficiency of the system, ten (10) trials must be done.

Table 2: GSM to Arduino Connectivity Test

Trial	Result
1	Failed
2	Failed
3	Success
5	Success
6	Success
7	Success
8	Success
9	Success
10	Success

The GSM must be connected to the Arduino and it should be called in the Arduino Software through AT Command.

Table 3: GSM Sending Through Keypad Braille

Trial	Result
1	Success
2	Success
3	Success
5	Success
6	Success
7	Success
8	Success
9	Success
10	Success

Table 4: GSM Receiving Test

Trial	Result
1	Success
2	Success
3	Success
5	Success
6	Success
7	Success
8	Success
9	Success
10	Success

Table 5: Converting Message to Braille

Trial	Result
1	Success
2	Success
3	Success
5	Success
6	Success
7	Success
8	Success
9	Success
10	Success

Fidelity Test:

Fidelity happens when the device sends and receives message, converts the message and the message sent must also be the message received by the receiver. Therefore, The conversion of the message must be identical to the message send and vice versa. The fidelity of the device will be tested with recurrence to validate the accurate conversion of each character.

Real Time Testing:

The testing of the device in real time must also be evaluated. Real time will be assessed from the time the message is converted to Braille to the time the user finished reading the message. This will be tested in repetition to get the average time for reading in different character length. In this case, the stepper and servo motors must be in precision to have an ease of contact with the rivets.

Table 6: Converting the Receive Text Message to Braille

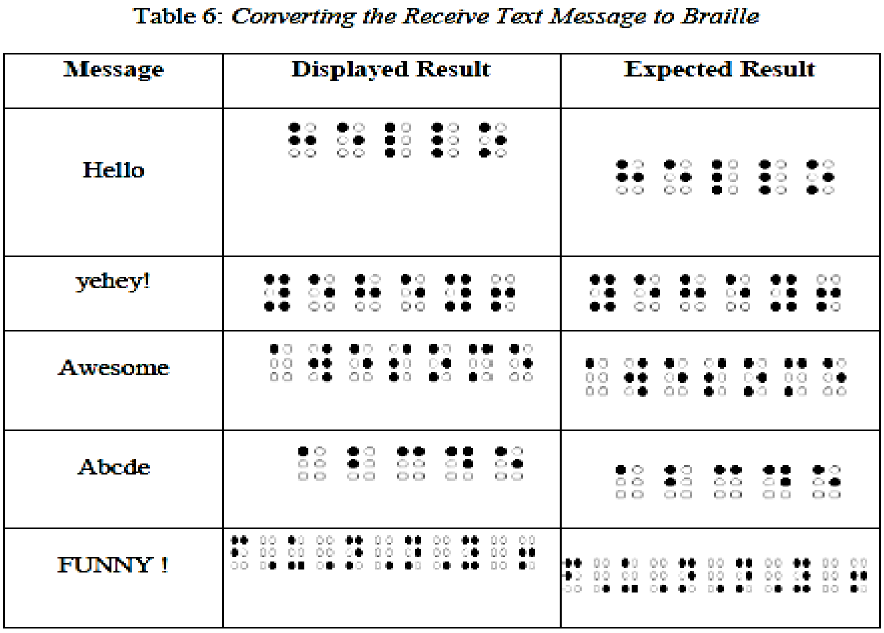
Table 6: *Converting the Receive Text Message to Braille*

Message	Displayed Result	Expected Result
Hello		
yehey!		
Awesome		
Abcde		
FUNNY !		

Table 7 Time of Text to Braille Conversion

Character Length	Result (s)
2	*2.4*
4	*4.8*
6	*7.2*
8	*9.6*
10	*12*
12	*14.4*
14	*16.8*
16	*19.2*

9. SUMMARY OF COSTING

Table 8: Total Costing of the Study

Component	Unit Price	**Cost**
1 GSM Shield	1,995.00	1,995.00
1 Lenmark Printer (old Version)	300.00	300.00
1 Sim Card	35.00	35.00
6 Servo Motor 90	175.00	1,050.00
1 A4988	300.00	300.00
20 minutes Laser Cutting	25.00/ min.	500.00
1 Acrylic 4.5 mm	223.00	223.00
1 Selector Switch	25.00	25.00
1 Toggle Swicth	15.00	15.00
13 10K Ω	1.00	13.00
1 Capacitor 100 micro Farad 50V	1.50	1.50
Buzzer	15.00	15.00
3 Push Button	35.00	105.00
8 Push button	30.00	240.00
4 LN4002	1.50	6.00
96 Rivets	.50	48.00

2 Sand paper	8.00	16.00
4 M3 x 15 Spacer	4.50	18.00
4 M3 x 25 spacer	6.00	24.00
4 M3 x 45 spacer	11.50	46.00
16 pcs. 3 x 6 Screw	2.00	32.00
8 pcs. 3 x 20 Screw	2.50	20.00
4 $^{1}/_{8}$ x ½ screw with knots	25.00	100.00
Arduino Mega 2560	1,950.00	1,950.00
2m Soldering Lead	16.00/ meter	32.00
1 meter 3 mm shrink tube	23.00/ meter	23.00
1 meter 3.5 shrink tube	25.00/meter	25.00
	Total Cost	1,157.50

10. SUMMARY, CONCLUSION & RECOMMENDATIONS

Summary:

The purpose of this study is to design a device that will benefit the blind people. To accomplish such goal, it became necessary to reach some prerequisite goals. This includes how it should work with quality, what materials are they going to use that will be cheaper than any other and how to create the mechanical and programming part of the device. The device is divided into two parts: Electronics and Mechanical. Mixing these two fields together is a challenge.

In Mechanical system, the typically used for Electronic Braille are the Piezoelectric which is an expensive one that is why there are only embossed printers in the Philippines since it is not a cost-effective device. The researchers of this study managed to provide a low-cost braille with the use of rivets, re-used printer with its attached stepper motor, servo motors instead of solenoid coils. This further improved the study by making it not just an innovative device for the Philippines but also can be bought by anyone for it is low-cost.

In Programming, the researchers divided it into three parts: Sending, Receiving and Translating. Each of these has a huge impact on our design and also it covers a lot. Receiving works from a mobile phone to the electromechanical braille by using an Arduino Software and then using AT Commands for the electromechanical braille to receive messages. Sending is the next part which allow the users to reply back to the mobile phone with the use of the 6 keypads and an enter button. The braille pins, however, will give an output of what the user is typing for which helps them to correct necessary characters. The translation process is simply converting the characters to braille and should be displayed using the electromechanical braille.

As for testing the device, the researchers asked two blind person to test the device if they can actually read from the device. The researchers also verified the symbols for assurance.

Conclusion:

The researchers have discovered that there are ways to create a low-cost Braille system by avoiding microsolenoids or any piezoelectric braille but by the use of motors. The researchers attained their goals to make the device an affordable and useful device for every people who wants to avail for their blind relatives.

In Efficiency Test, the proponents tested the connectivity of GSM and Arduino, and GSM Sending (with the use of the Keypad) and Receiving. The researchers have done at least 10 trials to prove that these tests can sync and work coordinately. All of the tests passed since it has a correct program and connection between switches and Arduino with GSM.

In Fidelity Test, the researchers tested the precision of the Text-to-Braille Output which can only be accomplished with the right data input. Researching how to use and read Braille was required for the proponents to achieve its precise output. Servo motors and Stepper motors were also vital in fidelity of the device for it is required to push and embossed the pins in equal level. To test the system, a message of different character lengths (2-16) is sent from the mobile phone. As for the result, it received the text message immediately and able to convert it for less than 30 seconds. With more than 16 characters (up to 160 characters), the next button will be activated after a single beep.

In Real-Time testing, the researchers got the average time rate of the stepper and servo motor movements in each pins and the average time was 1.2 seconds. The device has a uniform speed rate in each embossed pins for the reason of the precise steps and delays set in the program. Given the delay in the program, it was able to function well with uniformity.

Hence, the authors achieved the prerequisite goals of the device and have managed to do that for the blind people's ease and comfort. The researchers grasped the idea of helping all the blind people in the Philippines be literate in using braille with a device that can be for everyday use

Recommendations:

The researchers of the study would like to recommend the following:

1. Make messages more than 160 characters in length.
2. Able the users to delete messages of which they prefer.
3. Improve mobility of the device.
4. Improve battery life.
5. Making use of Grade 2 and Grade 3 of braille.
6. Improving memory capacity of the device.
7. Make standard size of braille cell.
8. Capacity of the user to read previous messages.

ACKNOWLEDGEMENT

The researchers would like to thank Dr. Roger D. Posadas and the staff of the Research and Innovation Center of LPU-Cavite for invaluable encouragement and editorial assistance.

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