

ParaCom: An IoT based Affordable Solution Enabling People with Limited Mobility to Interact with Machines

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Abstract—There are many people in this world who don't have the ability to communicate with others due to some unforeseen accident. Users who are paralyzed and/or suffering from different Motor Neuron Diseases (MND) like Amyotrophic Lateral Sclerosis (ALS), Primary Lateral Sclerosis etc, by making them more independent. Patients suffering from these diseases are not able to move their arms and legs, lose their body balance and the ability to speak. Here we propose an IoT based communication controller using the concept of Morse Code Technology which controls the smartphone of the user. This paper proposes a solution to give the user ability to communicate to other people using machine as an intermediary. The device will require minimal inputs from the user.

Keywords—Internet of Things (IoT); Motor Neuron Disease (MND); Amyotrophic Lateral Sclerosis (ALS); Arduino

I. INTRODUCTION

Communication is a crucial requirement in people's everyday life, but patients suffering from MND, communication can be a very challenging task. Daily conversation is an effortless task for general people with no disabilities. However, for a person with limited bodily movement and speaking disabilities, a simple task of communication becomes an immense challenge. Creating a practical and straightforward communication medium for a person with hearing and speech disabilities can be a challenging task as each person is in different stages of ALS and the body posture of each patient varies. Thereby many solutions have been proposed, which are general. These earlier proposed solutions are either difficult to implement or are expensive to be affordable by many patients suffering from MND [9].

In today's world, we see many modes and form of communication. Mobile Phones are the most used mode of communication as it removes the barrier of communication in long distances and different regions. In today's world mobile phones are upgraded to smartphones where it's like having a computer in your pocket. These smartphones connect one to all the latest happenings, discovering and situations across the globe. One of the good things of a smartphone is customization where we can customize the user interface based on our needs and desires.

Our society has people with special needs, especially those who have been immobilized due to paralysis as a result of diseases or unfortunate events [17]. Many people suffer from severe stages of paralysis, making them completely immobile and unable to communicate with other people in any way possible. According to a study conducted by the World Health Organization, 250,000 – 500,000 people around the world suffer from spinal cord injuries [27]. People suffering from these injuries tend to die two to five times prematurely than those who do not have these injuries. People who suffer from injuries due to the accidents or violence tend to find that their entire world has changed, making them unable to communicate freely, unable to do actions on their own, unable to move their body and many other things which lead to depression and is followed by suicide [16].

We built an IoT based Device which connects an ALS patient to the smartphone, thereby connecting him/her to the world digitally. Even though there are many proposed methods and devices available like Equalizer, which was used by Dr Stephen Hawking, who was diagnosed by MND immobilizing from the neck downwards [22], but unfortunately, not many people with low and middle-class income can afford such devices or methods. In a study done by the World Health Organization, only 5-15% of people in low- and middle-income countries have access to such assistive devices which they need [16].

Here we have made an Arduino based controller using sensors as activation switches which would be connected to a smartphone can be used for these patients to have a medium of communication. The concept of our controller is Morse Code Technology. Although the Morse Code [4] was primarily invented to transmit telegraphic messages, there are new applications of the code, intended mainly for persons with disabilities. The simplicity of the Morse code demands minimal resources from the end equipment, requiring only the ability to send and receive dots and dashes, unlike other systems that depend on keyboards with 100 or more keys. In every Smartphone, we see a Morse Code style keyboard with dots and dashes [20]. Morse Code is also compact and easy to understand, since it assigns shorter codes for more frequently used characters in the English language, thereby making the overall function of the controller easy to use. Here the controller emulates the use of the smartphone for the user, making him/her use their smartphone smoothly.

II. BACKGROUND

A. Amyotrophic Lateral Sclerosis (ALS)

Amyotrophic Lateral Sclerosis [4] is a spinal nervous disease. In this, the patient's motor movements gradually decrease and stop at some point in time. Necessary activities such as gripping, walking, speaking, swallowing, breathing etc. This is followed by slurred speech later leading to loss of voice and stiffening of the whole body to one posture. So, communication is very improbable for such patients [6] as they can't speak and are also incapable of using their hands for sign languages. It is also challenging to diagnose, as there is no independent test or tests to detect ALS. There are tests done to rule other conditions like blood tests, brain scan, spine scan, lumbar puncture etc. ALS or Amyotrophic Lateral Sclerosis is one of the most severe types of paralysis [21].

The number of ALS patients was arguably much higher than any other MND cases. The average age of onset is between 45 and 55 years which has been found a decade earlier than the Western world. An increased risk of development of ALS has been observed in the rural population, possibly due to a link between exposure to chemicals such as pesticides and the event of neuronal injury. ALS is a devastating disease; 50% of the patients succumb within the first 30 months of symptom onset, while 20% continue suffering from the disease for 5–10 years from its beginning [18].

There is no cure for ALS to date; however, few treatments are available to reduce the impact of the symptoms. This includes physiotherapy, exercises, a special diet, few medicines to relieve muscle stiffness and saliva problems etc.

Most of the people who have ALS lose their ability to speak in its early stages [19].

ALS can be classified in three stages; they are early stage, middle stage, last stage. In the initial stage, the patient faces muscle weakness, tightness, cramping, or twitching. This stage is also associated with muscle loss or atrophy. In the middle stages, muscle weakness and atrophy spread in the body of the patient. Some muscles also become paralyzed while others lose its strength leading to contractures in joints. In the last stage of ALS, almost all the voluntary muscles of the patient's body become paralyzed [7]. These muscles include the ones used in speaking, eating, breathing, walking, etc. Breathing ventilators and feeding tubes are used to assist the patient to keep them alive. Most people with ALS die due to respiratory failure after 3-5 years since the appearance of the first stage [19].

B. Morse Code

We help people suffering from ALS to connect to the digital world using the morse code as an interactor between our hardware device and smartphone. The Morse Code alphabet uses "dots" and "dashes" to encode the characters in the English language. Each letter is represented by a unique sequence of dots and dashes, e.g. the letter "a" is encoded as "dot-dash" [8]. Codes are also included for numerical characters and special characters. Amateur radio operators use the system. In HAM radio sets, a dot makes a short sound and

is called a "dit" whereas a dash makes a longer sound and is referred to as "dash." The duration of a dash is three times the duration of a dot. Each dot or dash is followed by a short silence, equal to the dot duration. In Google Keyboards we can set the default keyboard to Morse keyboard making it very efficient to use and reducing the span of errors which used to cause in earlier Morse Code sequences [1][2].

When Samuel F.B Morse initially invented morse code, it consisted only to translate numbers in the beginning.

Alfred Vail expanded the morse code and included letters and few special characters such as punctuation marks. The Morse code has an assigned unique sequence of all the letters, numbers and special characters. The combination of signals was attached to each letter by conducting research on which letter is used the most by people and that letter has a shorter sequence than the characters that are used less frequently. The table below gives the morse code signal for all the letters, numbers and special characters [1] (Fig. 1).

C. Internet of Things

Internet of Things (IoT) is an integration of multiple devices connected through internet which shares or collects the data (Fig. 2). IoT is a platform where you collect the data through the sensors and even control the function of the devices. IoT technology transforms a simple device into smart computing peripherals that function to merge the digital and physical worlds of human beings. The equipment that is being controlled via the network transforms it into an IoT device. An example of using an IoT device is a simple light bulb which can be operated from anywhere using a controller as simple as a mobile phone. IoT device helps people in much more ways nowadays by reducing the error margin. It helps the user by giving them control, even being distant from the IoT device. For example, a User lives in a smart home which allows the user to turn off lights also if he is away.

MORSE CODE TABLE

A	· -	N	- ·	1	· - - - -	Ñ	- · - - -
B	- · · ·	O	- - -	2	· - - - -	Ö	- - - ·
C	- · - ·	P	· - - ·	3	· - · - -	Ü	· - - -
D	- · ·	Q	- · - -	4	· - · - ·	,	· - - - ·
E	·	R	· - ·	5	· - · - ·	.	· - - - - -
F	· - · ·	S	· · ·	6	- · - · -	?	· - - - · ·
G	- - ·	T	-	7	- - - · -	;	- - - - ·
H	· · · ·	U	· - -	8	- - - - ·	:	- - - - · ·
I	· ·	V	· - · -	9	- - - - ·	/	- · - · -
J	· - - -	W	· - -	0	- - - - -	+	· - - - ·
K	- · -	X	- · · -	Á	· - - - -	-	- · - · - -
L	· - · ·	Y	- - - -	Ä	· - - -	=	- · - · -
M	- -	Z	- · - ·	É	· - · - ·	()	- - - - ·

Fig 1. Morse Code Table.



Fig 2. IoT Devices.

Nowadays, the commonly known IoT devices are google home assistant, smart homes, smart shoes, Google Lens and many other accessories. IoT has become a commonplace which is used to integrate the digital world as well as the physical world of the humans to make the tasks more convenient.

III. RELATED WORK

A. Eye Tracking (Laser & Twitch)

A more straightforward approach to Eye-Tracking includes hardware like two sets of IR LED sensors and an Arduino board. The process is such that the user's eyes are detected using the IR sensors by sensing the amount of light reflected from the eye and sends this data in the Arduino [23]. The Arduino then compares the data received from the IR sensor and determines whether the eye is open or closed with a predefined value. The closed eye is read as a blink [10], and then the flash and its duration are recorded temporarily, and these readings are taken at a rate of 10 per second. If the blink pattern matches a previously set design, then the alphabet is printed, or that function/command corresponding to that pattern is executed on the system [5].

A famous eye-tracking system for ALS patients is the Eyegaze Edge, which provides users with the ability to control devices like stereos and television, surf the internet, send emails, read books, and hold conversations. Many people cannot afford the equipment due to their expenses. The eye tracking device is based on the patient's knowledge, understanding the language as well as experience with the computers. The patient should be familiar with the recent technology to use this device. The eye tracking device is costly for the people who are having a low-class income or lives in a country which has low- and middle-class economy which is why most of the people cannot afford this device economically [22] (Fig. 3).



Fig 3. Eye Tracking Device.

B. Voice Amplification

This approach is used if the patient is suffering from the initial stages of ALS. Often after sometimes, patients with ALS in its later stages find themselves no longer able to project their voices due to complications in their respiratory system. So, there are devices made to help amplify the projection of their views can help to reduce fatigue by reducing the effort needed to speak. Some of these devices are Chatter Vox Voice Amplifier which comes with a headset microphone and can boost one's volume up to 18 decibels. It can also be comfortably fastened and worn at the front of your waist [22].

Voice Amplifier is a great device, but there is a big flaw for communication for ALS patients (Fig. 4). It can only be used by the patients that have not lost their voice [14] and according to a study conducted that around 80%-90% of the patients who have ALS lose their voice in the early stages which makes them unable to communicate. The reason mentioned above is not the only one a dumb person who is suffering from a severe paralysis also will not be able to communicate with any other person.

C. Voice Banking

This is a method used by ALS patients before they experience a disability to speak. Users either record typical phrases like "How are you today?" and "Let's go out to eat." etc. but some users also record a list of sentences and the sounds generated during these recordings are used to synthesize speech. One example is Samsung's and Google's initiatives to record one's voice in their intelligence assistant software like Bixby and Google Assistant, and these recordings are then used by this software whenever they are used.



Fig 4. Voice Amplifier Device.

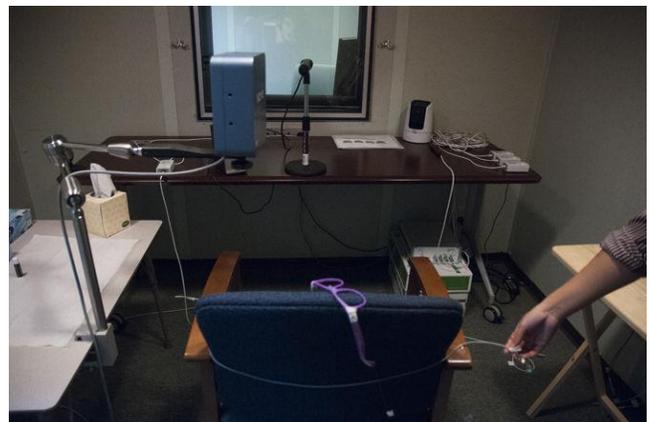


Fig 5. Voice Banking Device.

Methods	Electronic Eye Gaze	Laser Twitch	Morse	Voice Amplification
Cost	Very High (~ \$ 10000)	High (~ \$ 8000)	Low (~ \$ 100)	Moderate (~ \$ 5000)
Requirements	Dot Projecting Specs	Laser Guided Muscle Scanners	Switches	Step up Transformer
User Interface	Easy to Use	Moderate	Moderate	Easy
Maintenance	Moderate	Low	Moderate	Low

Fig 6. Market Survey.

Voice banking is a great communication device, but it has many flaws, some of which are sometimes it may not be able to express the correct thoughts of the user, it is costly, and it only helps if a person is communicating with another person right in front of him (Fig. 5). It is hard to use by patients who have their whole body paralyzed. It also does not help the patient to communicate with someone through the digital world [22].

Our experiment was inspired by an ongoing google experiments campaign wherein they are working on providing ALS ridden people with the ability to effectively communicate with others through the medium of Android device and a coupled morse input switches (Fig. 6). The user punches in the input as morse signals and there are further processed to be taken as keyboard input or device navigation gestures.

IV. LIST OF COMPONENTS

A. Arduino Leonardo

Arduino Leonardo is a microcontroller board based on the ATmega32u4 (Fig. 7). There are 20 digital I/O pins out of which seven can be used as PWM (Pulse Width Modulation) outputs and has 12 pins as analogue inputs. It also contains a 16 MHz crystal oscillator, a micro USB connection, power jack, ICSP header and a reset button.



Fig 7. Arduino Leonardo.

The Leonardo board differs from all preceding boards in that the ATmega32u4 has built-in USB communication, which eliminates the need for a secondary processor. This allows Leonardo to appear to a connected computer as a mouse and a keyboard, in addition to a virtual (CDC) serial / COM port. The Arduino IDE software allows one to write the program on a digital device and helps them upload to your board. It is an open-source software which allows any user to code and upload the application to the board quickly. The environment of Arduino IDE is written in Java and is based on processing and another open-source software. The Arduino IDE can be used with any Arduino board. The Arduino IDE supports the languages like C and C++ using special rules of code structuring [24].

B. NodeMCU

NodeMCU is one of the most popular open-source IoT platforms. It provides access to GPIO (General Purpose Input Output) Pins and includes all the necessary firmware and hardware. Firmware is being run on an ESP8266 Wi-Fi SoC which consists of an ESP12 module. It contains 13 GPIO (General Purpose Input/Output) In all the 13 GPIO pin, only the GPIO 16 can be used for reading as well write operation. It does not support 1-wire, open drain, Interrupt or PWM [25] (Fig. 8).

C. Potentiometer

A potentiometer is 3 terminal variable resistors in which the resistance is manually varied to control the flow of the electric current. A potentiometer acts as an adjustable voltage divider.

It is a passive electronic component which works by varying the position of the sliding contact across a uniform resistance. The entire input voltage is applied on the whole length of the resistor, and the output voltage is applied across the entire range of the resistor [26] (Fig. 9).

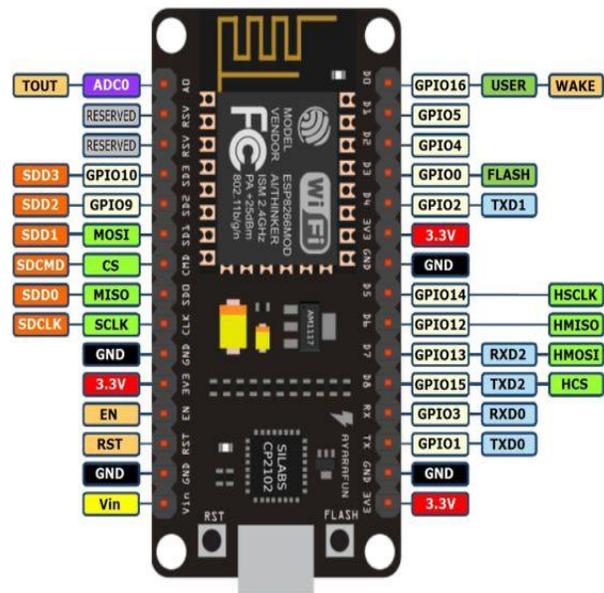


Fig 8. Schematic of NodeMCU.

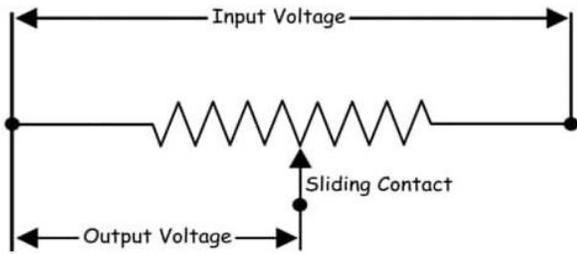


Fig 9. Circuit Diagram of Potentiometer [26].



Fig 10. Rotary Potentiometer.

Here we have used a Rotary type potentiometer in our device. It is used to obtain an adjustable supply voltage to a part of electronic and electrical circuits. It includes a rotary knob of the potentiometer which controls the supply to the amplifier (Fig. 10). This type of potentiometer has two uniform resistance terminal contacts places in semi-circular patterns. It also has a middle terminal through which the sliding contact on the semi-circular resistance is connected. When we rotate the knob, we move the sliding contact on the semi-circular resistance. It is used in substation battery chargers which adjust charging voltage of a battery.

V. IMPLEMENTATION

ParaCom helps to give a mode of communication to those people who do not have any pre-existing modes to communicate using the digital world as a medium, especially for the people who suffer from ALS. It helps the patient to use his/her digital device and give complete control of the device to them Morse code.



Fig 11. Relay Module (4 Channel).



Fig 12. NodeMCU.

Our devices brain can be considered as the Arduino Leonardo itself as it is the device which has the keyboard interfacing capabilities, which in turn are an integral and essential part of our product (Fig. 11).

The Arduino Leonardo, in turn, acts as an i/o device as it accepts input from the users and feeds them as an output to the corresponding device. This is done by the fact that the inputs are individually recorded as '.' and '-' and these, in turn, are interpreted as Morse code by the corresponding Morse keyboard. These inputs are taken by the switches which are assigned to either a '.' or a '-'. These purpose matched switches are correctly programmed for such an ideal operation wherein the user input may or may not be of the highest accuracy. Also, our setup includes a third switch as this is also an integral part to invoke the functioning of the system of the whole system [2] (Fig. 12).

This switch is the mode change switch, and it works by, as the name suggests changing the mode between the typing mode and the User Interface (UI) navigation mode. In the typing mode, the switches are used as '.' & '-' whereas in the UI navigation mode these are used as arrow keys for either going left or right throughout the menu [21].

The scanning of the screen is done entity wise from the top left of the screen to the bottom right of the screen. This intern ensures that none of the features is missing and we encompass every individual, and it is accounted for in the resulting film real estate (Fig. 13).

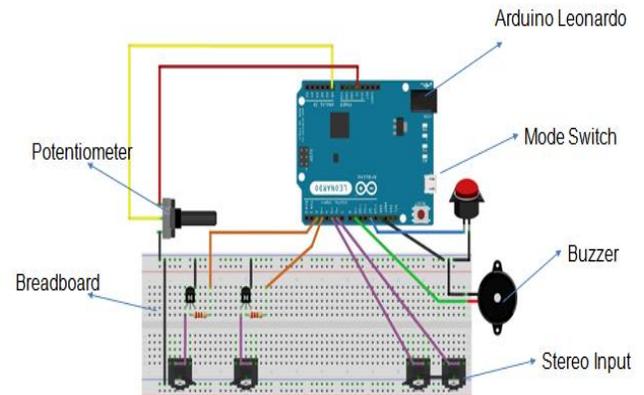


Fig 13. Connection of the Circuit.

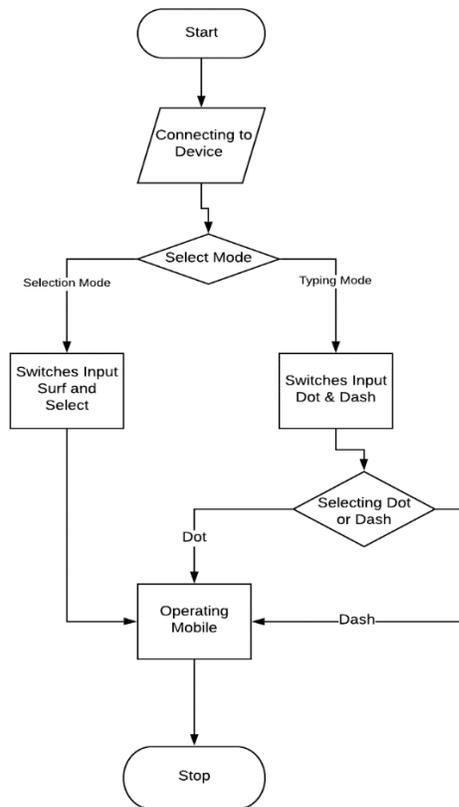


Fig 14. Flowchart of the Operations.

The other major component that helps less able people in using this whole system is the variable potentiometer. Since the patients have limited motor neuron skills, it only helps for them to have the system configured to their way of typing. In turn, this is the most any system can wish for, i.e. a system which adapts to the user itself as no system shall ideally present the user with any discomfort (Fig. 14).

This potentiometer works by reducing or increasing the input speed the input by lowering or raising the voltage resistance across the switches. This helps for higher accuracy as the rate at which the system gets an input signal can be made constant by adjusting such variables. For this to happen, the user at no time needs to adapt to the system, and the system takes care of this itself, which is what we strive for [26].

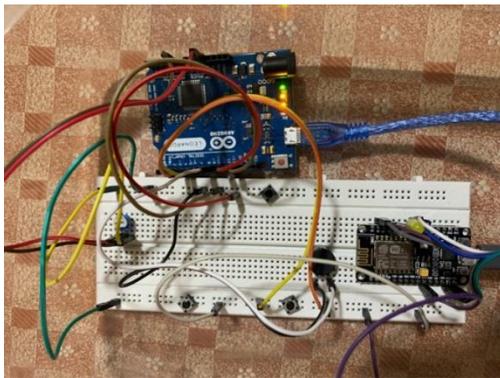


Fig 15. Architecture of the Device.

The next major component is the smart home automation environment of our device. This is done using a NodeMCU (ESP8266) and firebase protocol [25] (Fig. 15). The NodeMCU is hooked up to a relay which in turn can work as a switch to control several connected appliances of any magnitude.

All of this is made possible through a companion android application which helps us control the individual relays through virtual buttons remotely. The phone need not be on the same network and needs to just reconnect through the internet to the same firebase database virtual server as our NodeMCU.

The NodeMCU is connected through a preconfigured wireless network which is already defined in its Arduino programming code. The signals are sent from the phone to the server, and then these signals are in turn picked up by the NodeMCU as it keeps scanning for changes in its connected server and these changes are reflected in its output pins and turn to the relays (Fig. 16).

A module has been added in our device, i.e. the module of home automation. The patient can control the electrical devices in their homes, i.e. using our IoT device through their smartphones, they can remotely monitor their electrical appliances, i.e. other IoT devices like television, fans, led lights, geysers etc. This module will provide more independence to the patient using our devices by making them in charge of their home appliances [11].

The user interacts with the device by virtue of the buttons placed in the headrest of the wheelchair ridden user. These buttons would help the user control the whole device mounted in front of them in the way mentioned above and will hence allow them to control the corresponding smart home services too.

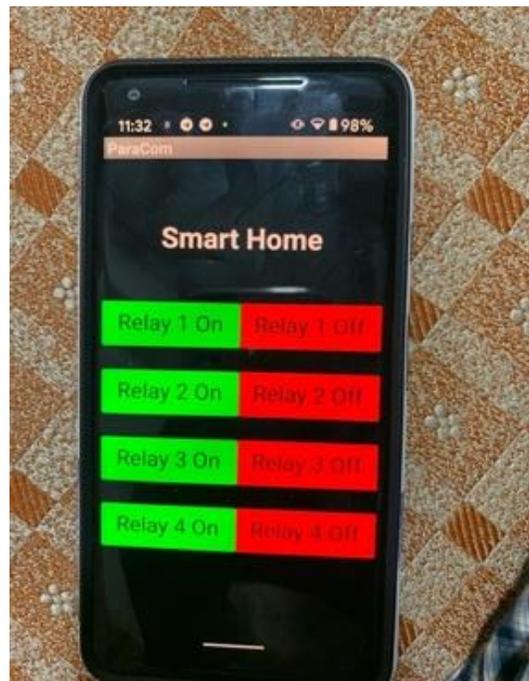


Fig 16. User Interface of Android App.

VI. RESULTS

As mentioned earlier our device will act as a medium for any ALS or severe conditioned patient who is unable to speak and unable to use his hands for gestures. We will use a sensor-based headrest acting as the communication medium for a device to the user. Based on the user's head movements (which can be calibrated to any movement) the user will be able to use the smartphone.

Since there are three buttons in our system as we are using the concept of Morse code which includes a dot(.), a dash (-), and a third button which changes the mode of operation on the device i.e. either typing or operating the phone. Using the head movements, the user will choose dot(.) or dash (-) and the mode button would be operated remotely where each sensor is connected to the respective button.

So, for example when the user turns his head left corresponding bit that goes to the controller board is a dot (.) and when the user turns his head to the right a dash (-) will be the bit that is sent to the controller. These two bits can be used by the patients to communicate with other people for sending a message in any social device. This will help the patient to convey his or her own thoughts to other people. The third bit helps the patient to change the mode of the digital device when the user nods, the device will send the third corresponding bit to the controller switch that is to change the mode of the device it helps the patient to switch between apps by himself/herself.

The user will also be able to control compatible devices in the house when the user switches to the software application that we made. For example, the user wants to turn on the light in the house, he/she will simply turn the head left sending the dot bit to the controller and it will turn on the light whereas turning the head right will turn off the light [15]. It will help the user to control home making the patient more independent. It will also be convenient for the user to control the device using a simple dot(.) and dash (-).

The control of these devices is finally handled by corresponding relays that are physically connected to each of the devices' line of communication. The relays act as a remote switch which can be operated by electrical signals and need not be accessed physically by a person [13]. We take advantage of this basic concept allowing the patient to control the corresponding relay-controlled devices remotely by the virtue of their smartphone [12] (Fig. 17).

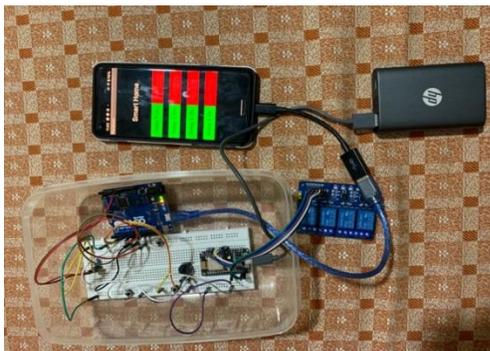


Fig 17. Complete ParaCom Setup.

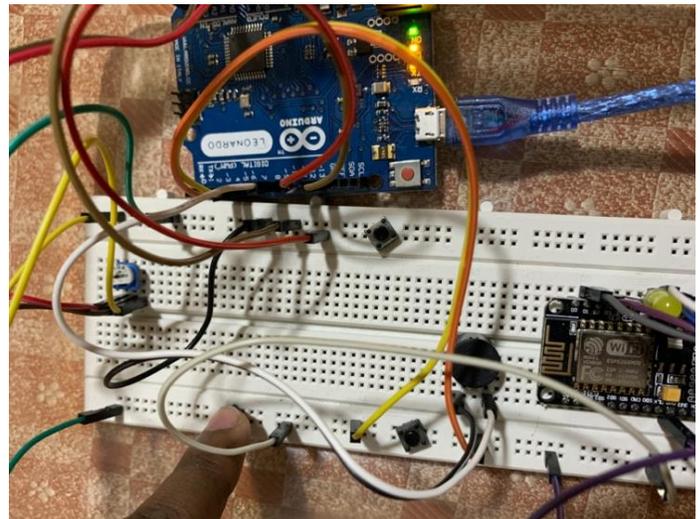


Fig 18. Using Dash (-) button of ParaCom.

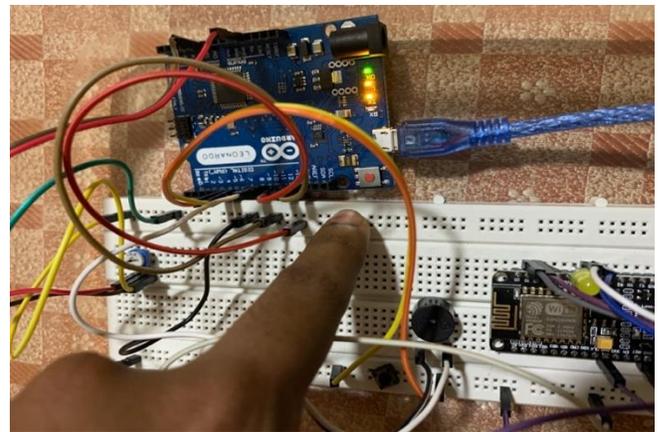


Fig 19. Using Mode Switch Button in ParaCom.

The pressing of an “ON” or “OFF” switch on the preinstalled application, in turn, sends a signal to the corresponding relay. This is achieved by using Google’s Firebase as a backend database and the NodeMCU (ESP8266) reads data from firebase and sends the appropriate signals to the relays thereby enacting the user’s desired command. This whole setup can also be controlled through voice activated control through Google assistant.

Here are some implementation images although they are using direct pressure buttons instead of sensor-based headrest but the implementation overall is the same (Fig. 18 and 19).

VII. CHALLENGES

The ParaCom device is a capable connectivity device built for paralyzed and ALS patients that is still in its initial phases. There is much room for further improvement and enhancement of the device. Below we have listed a few limitations of ParaCom.

- A. Device Dependent: One of the significant limitations of ParaCom is that it needs a smartphone or tablet device to work. It was mentioned earlier it acts as a medium for the patient and the Smartphone [3].

B. Slow Usage Speed: Using the smartphone through ParaCom decreases their speed of usage of the phone by ALS patients compared to the average rate of smartphone usage by ordinary people as they can directly use the touchscreen of the phone whereas when using through ParaCom it is like using a cursor in the smartphone to operate it [3].

C. Pre-setup and Calibration: ParaCom being a hardware device it needs to be placed near the patient's wheelchair or bed and near the smartphone to which it will connect to either using a USB cable or using Wi-Fi Direct. The Input rate of the sensors also needs to be adjusted according to patient's comfort of using his/her ability to use the sensors smoothly. Also, the sensors need to be calibrated according to the movement of the patient and also be placed in an effective position [3].

VIII. FUTURE SCOPE

As of the future scope of our device, we can implement many add on functionalities to it. One of them is the implementation of patient monitoring where we can measure the temperature, blood pressure, heart rate, breathing rate etc. of the patient using the device. All these recorded details of the patient are sent to their doctors and family members as a daily health status report. In case of any unusual or unpredictable readings being measured, an SOS can be sent to their doctors and family members regarding the health status and immediate measures can be taken accordingly.

A new companion application could be added to our project setup which would in turn allow the patient to navigate the device with ease and hence mitigate the frustration of going through complex menus while having limited accessibility to the device user interface. This application would encompass functionalities such as medication reminder, remote physician database updating, accessibility features to aid in device usage and much more.

IX. CONCLUSION

People who have severe paralysis or ALS feel separated from society as they would be unable to communicate and interact with other people. ParaCom is a solution for all those paralyzed individuals to perform on-screen tasks, especially those people who want to do something valuable with their own lives and contribute something to the world. ParaCom has several functions, especially for paralyzed people like.

A. Operating Gadgets: It helps the paralyzed person to control their digital device, giving them a sense of independence to manage their digital device.

B. Entertainment: paralyzed people can even play games or watch movies on their digital device. It can also help them to communicate to text with other person become more active on social media.

C. Information Seeking: Helps the paralyzed person to be up to date with the current world affairs. It helps them to get the information that they seek, to study and learn about various things where their interest lies.

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