DON BOSCO INSTITUTE OF TECHNOLOGY

Premier Automobiles Road, Kurla (W), Mumbai-70

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&

Affiliated to the University of Mumbai

B.E. PROJECT REPORT "I"

On

"Computer Assist for Paralyzed using EEG"

Department of Computer Engineering

University of Mumbai

2015-2016

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CERTIFICATE

*This is to certify that the following project members of final year class have satisfactorily completed the PROJECT- I report on_**"Computer Assist for Paralyzed using EEG"** in the partial fulfillment of the Computer Engineering course of Bachelor of Engineering of the Mumbai University during July to October 2016.*

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

ABSTRACT

Computers have made life easier for the general population, however a technology is not fulfilling its purpose unless it is accessible by everyone. Namely the paralytics (hemiplegia, quadriplegia) who have a hard time with technology because it is designed for an average person. This is why we decided to make a hardware interface for desktop computers which would allow these patients to use a computer with ease. Various combination of non-invasive Brain-Computer interface have been promising in helping such patients by giving interactive solutions. A combination of 3 electrode EEG and an Arduino Leonardo, on basis of P300 waves which play crucial role in decision making process in brain will be used to make this hardware interface. This hardware interface aims to mimic a mouse and keyboard in operation and also its speed of use as much as possible for the concerned patient.

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ABBREVIATIONS

EEG	ElectroEncephaloGram
AI	Artificial Intelligence
GUI	Graphical User Interface
IP	Image Processing

CHAPTER 1 : INTRODUCTION

The most convenient hardware interface for a computer would be one which directly detects brain signals or thoughts and converts them into appropriate input signals for the computer. This is possible, however this requires some training for the user and is complex to implement and requires a more sophisticated EEG with ~32 electrodes. These “sophisticated” EEG sensors tend to be 3 or more times more expensive than simpler ones. Since we wanted to make a conduit to make computers more accessible it would make more sense for the interface to be affordable and available to the masses.

A simple EEG on the other hand has relatively serious limitations making it useful for mainly binary(yes/no) actions. This meant that there was a requirement for another sensor to get the complete idea of what a user wanted to do. So it was decided that the hardware interface will implement only the mouse in hardware since the keyboard is too complicated to handle with 1 or 2 sensors without making too complicated to use just like a real keyboard. A simple EEG which could handle yes/no questions would be ideal to record mouse clicks and a second sensor, an accelerometer would through the tilt angle decide in which direction and how fast the mouse cursor would move. This 2 sensor configuration reduced the cost to a 3rd.

As far as ease of use is concerned this system has had its own set of difficulties in implementation. For which a plan of action and possible alternatives have been discussed in the following sections. If the proposed system can be made to be almost as accurate as a mouse and keyboard this could vastly improve the lives the people who have lost dexterity or complete use their hands and need constant supervision. Since through the interface the affected people could firstly communicate a lot more easily with the outside world and with further development in AI the very computer they use could work as their personal assistant.

1.2 AIMS AND OBJECTIVES

- We aim to make the operation of a computer completely hands free for the paralyzed patient
- Replacing the mouse with an EEG Headset mounted on the head of the patient and replacing the physical keyboard with a keyboard application
- Being able to manage the system easily with minimal effort and type using the keyboard application.

1.3 PROBLEM STATEMENT

- The digital revolution has brought us technologies like computers, mobile phones and tablets.
- It is very difficult for a paralyzed patient to operate any digital device such as computers and mobile phones
- There is always a dependence on a helper to do certain tasks.
- The current systems available are either too costly or the availability is limited

1.4 SCOPE

- Our system will offer a paralyzed patient basic control of a personal computer or a laptop
- It will provide hands free mouse navigation using natural movement of the head
- There will also be a typing interface based on 9 keyboard layout for easy typing and other common functions such as enter, cut, copy, paste, etc

CHAPTER 2 : LITERATURE REVIEW

The initial idea for the system was to use solely EEG as the sensor for the input signal for the computer. However as pointed by [1] the EEG being a non-intrusive sensor is riddled by low signal-noise ratio and the signal quality depends on the quantity of electrodes and their proximity to the source of the signal, namely the brain. A typical EEG headset gives P300 signals i.e. alpha (attention levels), beta (meditation levels) waves taken from the brain and eye blinks. Since when using a computer, the user will hardly be in a meditative state. So the signals which could be used were attention and eye blinks. The study mentioned in [2] and [3] used attention levels as a way to decide the next action in a game. Both of the studies had problems with the usability of attention signal, since it tended to frequently fluctuate. [2] used a dynamic algorithm which adjusted the acceptable attention level threshold as per the average attention level in the recent past. It [2] also proposes a t9 keyboard (a 9 button layout in old mobile phones) as a simpler version of a conventional keyboard with over 200 keys. Another study established an estimate of the attention levels with noise over time for an average human along with the same for eye blinks and found that the fluctuations were too high for attention signals while being a lot more reliable for eye blinks. So eye blinks were a selected as the primary signal from EEG.

A similar interface system as the one proposed was discussed in [4] which used a combination of EEG and a gyroscope. The team initially considered other alternatives such as tongue-based mouse movement, which involved a magnet being attached to the tongue. Based on the movement of tongue there was a change in the magnetic field through which the desired mouse movement could be deciphered. This system was convenient and easy to use; however, it was a little too intrusive. So it was rejected in favor EEG-gyroscope system which was less intrusive but slightly more difficult to use because the user had to continuously move their head to keep the mouse moving which could be tiresome to do over a long period. This lead us to use accelerometer which could detect tilt and hence enable mouse movement through tilting the head and keeping it so till the cursor reaches destination which is less tiresome.

A new system design in [6] used HC-05 as Bluetooth device for interfacing Arduino and EEG. The system worked to move the wheelchair for the paraplegic using EEG. The authors of this papers cited HC-05 as a reliable and well supported device for Bluetooth interfacing with Arduino.

There are also discussions about the concepts and conventions of Morse code and how it could be adapted to be used with Arduino [9]. The Morse code is based on a binary search tree where the path taken to reach the required letter decides its respective Morse code as shown below [16].

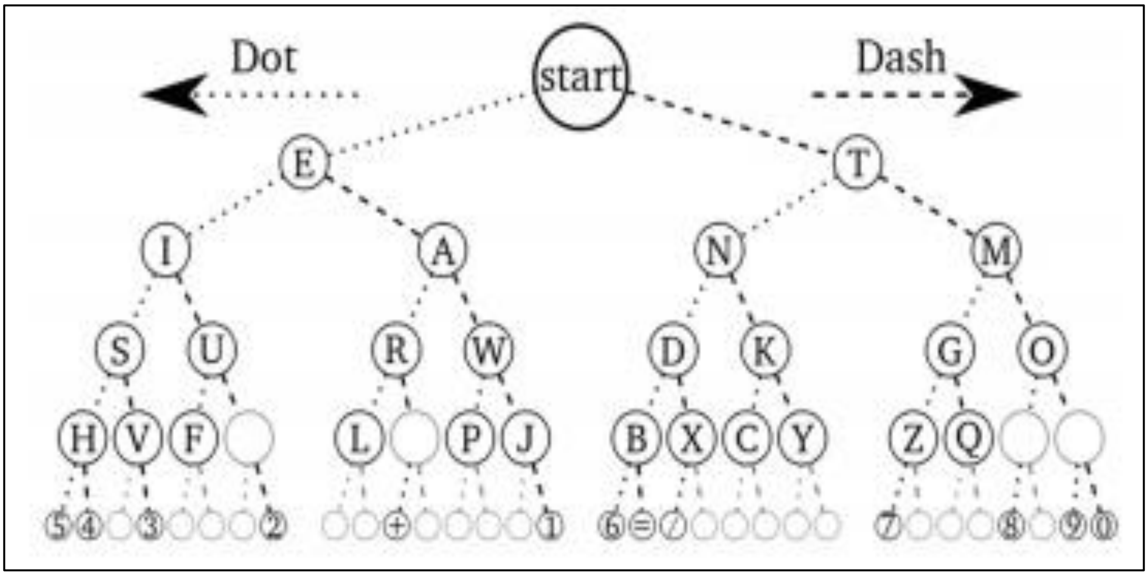

Fig. 2.1 *International Morse Code Letters and Numerals*

Dots and dashes could be decided on the basis of the duration for which the user blinks or keeps their eyes closed. According to study in [10] Morse code typing should produce about 6-7 words per minute and that voluntary eye blinks tend to be about 2 times longer than involuntary ones.

Now there are alternatives to EEG for detecting eye blinks, mainly through image processing. We can perform image processing using an Arduino and openCV library. Using image processing could allow us to detect winks which are almost always voluntary and could greatly improve the speed of typing if used in Morse code, where left and right blinks are used to traverse the BST instead of dots and dashes based on blink duration. This would also enable easy implementation of left and right click.

Though this might seem like a better solution than an EEG but from the system mentioned in [7] we numerous limitations crop up. Such as the fact that room should be welllit. The angle of the face is very important and so at oblique angles the system could stop working altogether. having to maintain a constant posture for a system work is difficult for the user and also IP tends to take a lot more processing power than using an EEG. The combination of lacking reliability and requiring more processing power meant that we had to stick with the EEG for eye blinks.

To ensure the registering of deliberate blinks we needed the reliable attention values from the user, the kind of values which would help differentiate voluntary blinks from involuntary ones.[14] and [15] explore the possibility of using artificial neural networks to enable learning and dynamically adjust the threshold value for attention. This nearly eliminates all errors after a certain period of time. However the network has to adapt for each user separately so the reliable usage might take some time.

2.2 EXISTING SYSTEM

Another product manages to work with a computer using a single input. So potentially only an EEG could be used to run a computer. The name of this product is Tilvus [4]. It works by constantly shifting over selectable options, and once the desired option is highlighted the user has to trigger the input, say by eye blink which could be detected by an EEG.

But for the system to be usable the highlighting of options had to be fairly slow which in turn made the overall operations slow and rather tedious and hence this idea was rejected as being too slow.

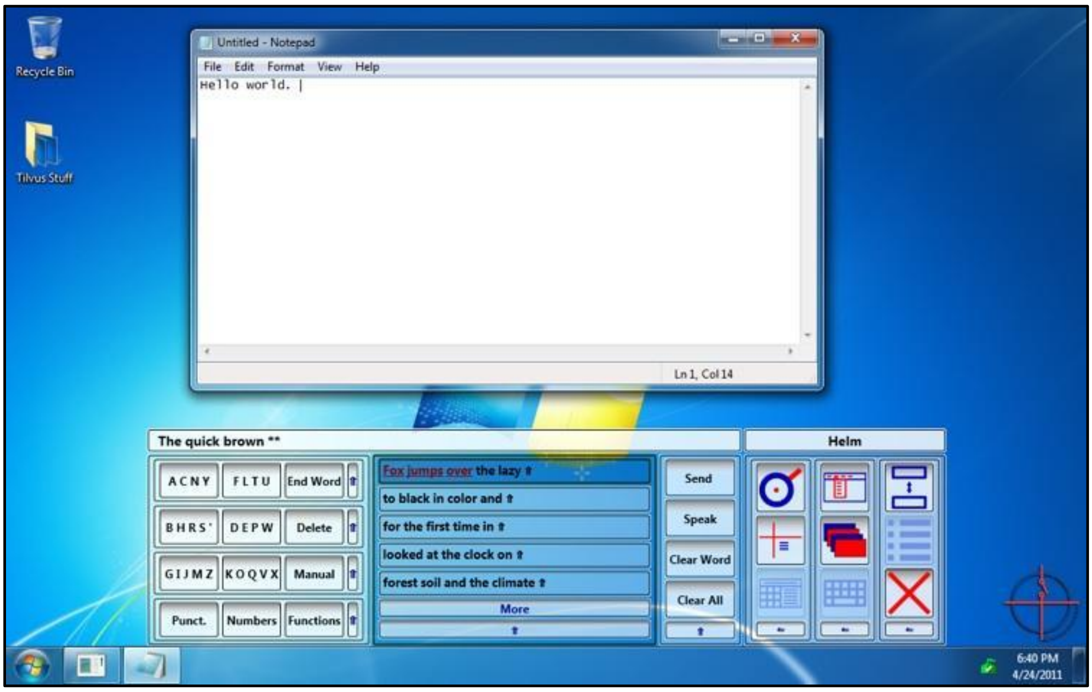

Fig. 2.2 *Tilvus Program*

CHAPTER 3 : ANALYSIS AND DESIGN

3.1 PROPOSED SYSTEM

The proposed system will implement only mouse functions in hardware because mouse as a pointing device unlike a physical keyboard is versatile and simple. So not only will it be easier to use but also simpler to implement. The keyboard function will be accomplished using on-screen application based keyboard and a quick access bar for opening applications from anywhere.

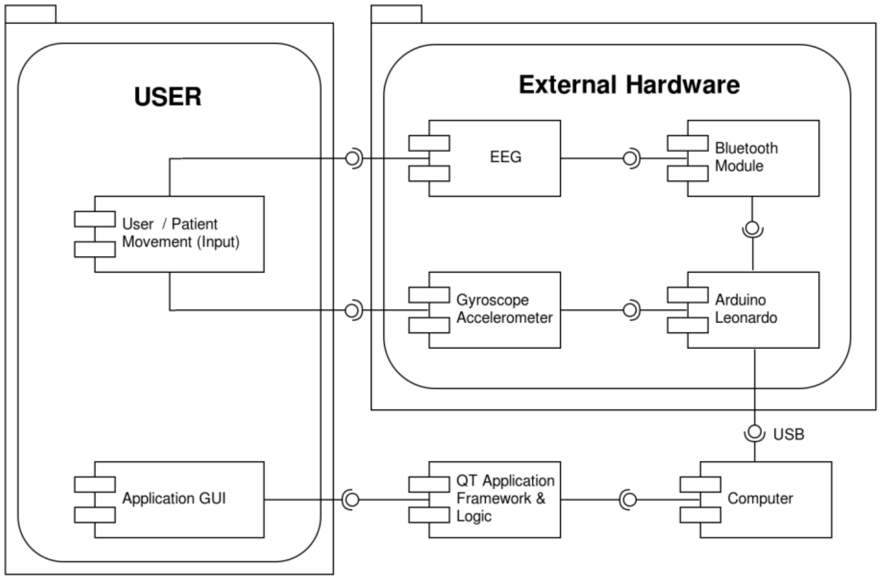

Fig. 3.1 *System Architecture*

The system is divided into three major modules:

Module 1: Mouse pointer movement

The mouse pointer movement is done using combination of Arduino Leonardo and Accelerometer. Supposing the unit is attached to the patient's head, the movement of the head will make the acceleration in X and Y axis change. If the change is detected the mouse pointer on the computer screen is moved according to the head movement in sync. Thus using the accelerometer 2D values in X and Y axis we move the mouse pointer on the screen

Module 2: Mouse click function using EEG

The mouse click function is done using EEG headset, Bluetooth HC-05 module and Arduino Leonardo. Whenever there is a voluntary hard blink from the user or patient there is a change in the blink strength which is calculated from the raw value from the brain waves. If the change detected is above minimum threshold it triggers the mouse click function on the Arduino Leonardo which does a mouse left click on the computer screen wherever the mouse pointer is currently focused on.

Module 3: Keyboard Application

The keyboard application is developed using Qt and consists of text area and a 9 key based keyboard layout for numbers and letters. This helps the user in typing better as the keyboard is very compact than the traditional keyboard and does not require the user to move the mouse pointer to reach every letter. Also contained in the application are common function key combinations used by the average user such as cut, copy, paste, enter, delete, clear text area. The application will also have a list of shortcuts of applications installed on the computer and helps the user in quickly opening the application he/she wishes to.

3.2 FEASIBILITY OF PROPOSED SYSTEM

Operational Feasibility

The System shall be free to be calibrated for every user. The usage of application is fairly easy even for the patients. The easy access panel makes it even easier. The hardware installation needs about 5-10 minutes for system settings and shall be free for use from there on.

Technical Feasibility

The current systems available in market work on EEG / or have high end sensor technologies which might not be accessible to masses. The technology that we plan to use is fairly easily available. Neurosky Mindwave technology is in commercial production of EEG’s and hence can be ordered for ready use of technology, same applies to most other hardware components. The application too shall be open source and hence freely available for use by people.

Economic Feasibility

The current market research provides details about some similar product that shall cost in approximate range of Rs.4.0 lakhs-10 lakhs while our system shall cost only Rs. 50K. Apart from this The framework for application development is open source and hence reducing the software cost.

3.3 METHODOLOGY

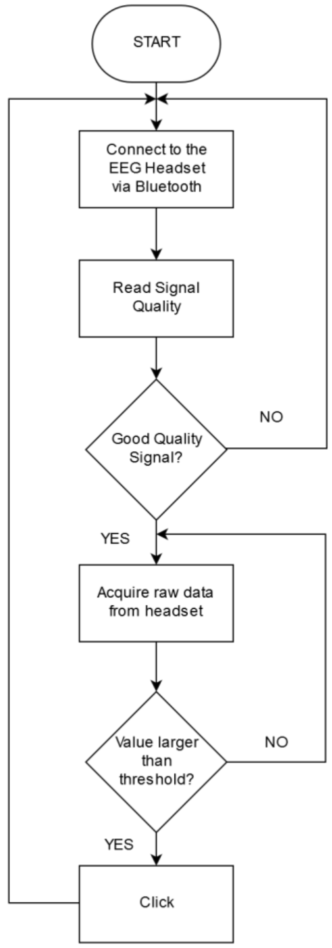

Fig. 3.2 *Flowchart for Mouse Click*

The mouse click program works on the following steps:

- Connects to the EEG headset using HC-05 Bluetooth module
- After the connection is established the EEG headset gets the brain wave signals and sends it to the Bluetooth module
- The Arduino connected to the Bluetooth module receives the data and parses the payload data
- If the checksum of the packet and the generated checksum matches this means that the signal is unaltered and of good quality
- The raw data is obtained from the payload and the blink strength is calculated

- If the blink strength crosses a set minimum threshold it can be registered when the user does a hard blink on purpose voluntarily
- This is passed as a mouse click activity to the computer and also to indicate the led on the pin 13 of the Arduino glows.

3.4 ANALYSIS

The first phase of the analysis was studying the alternate means of getting data from the user to replace the mouse and keyboard functionality. Eye movement and eye blink detection using image processing was an equally good option but was inefficient at times due to the lighting conditions and distinguishing between natural and voluntary blinks.

The second phase of analysis was studying the brain waves and the output of the EEG Headset on a graph showing the high and low values of the alpha, beta and gamma brain waves collected by the EEG electrodes when the headset is mounted on the head.

The third phase was the selection and buying of proper components which will be suitable for our system and emulation of mouse pointer movements with the help of accelerator sensor. Also the basic GUI of the keyboard application was designed using QtCreator and the program was tested on different systems for compatibility.

The fourth phase was the set up and connection of the Bluetooth module to the EEG headset and signal acquisition to detect the attention, meditation and blink strength. This was then analyzed and blink strength was selected as the signal of choice for the mouse click functions since it had a better peak of the P300 signal.

3.5 DETAILS OF HARDWARE AND SOFTWARE

Hardware:

- **EEG Headset**: The EEG headset allows us to capture brain activity and put it to meaningful use. The headset can recognize and remember the state of activity in the brain during certain thoughts via electrode sensors. Thus it can determine the levels of attention, meditation and blink strength of a user, and when these values cross a certain threshold, it can be used to trigger the mouse click. We are using a **Neurosky Mindwave** EEG headset.
- **Bluetooth Module**: The **HC-05** Bluetooth module is the most economical and easiest way to go wireless. Easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It has the footprint as small as 12.7mmx27mm.
- **Accelerometer Module:** ADXL335 is a small, thin, low power, complete **3-axis accelerometer** with signal conditioned voltage outputs. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. ADXL335 is 3v3 compatible device, it's powered by a 3.3v source and also generates 3.3v peak outputs. It has three outputs for each axis i.e. X, Y & Z.
- **Arduino Leonardo:** The Leonardo is Arduino's first development board to use one microcontroller with built-in USB. Using the ATmega32U4 as its sole microcontroller allows it to be cheaper and simpler. Also, because the 32U4 is handling the USB directly, code libraries are available which allow the board to emulate a computer keyboard, mouse, and more using the USB-HID protocol.

Software:

- **Qt:** It is a cross-platform application framework that is widely used for developing application software that can be run on various software and hardware platforms with little or no change in the underlying codebase, while still being a native application with native capabilities and speed. We are using Qt version 5.7.0 for Linux 64-bit architecture.
- **Arduino IDE:** The open-source Arduino Software (IDE) makes it easy to write code and upload it to the Arduino Leonardo board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software.

System Requirements:

- Linux 64-bit (Ubuntu, Fedora, Arch)
- Intel i3 or better CPU
- 4GB RAM or more
- 320 GB HDD

3.6 DESIGN DETAILS

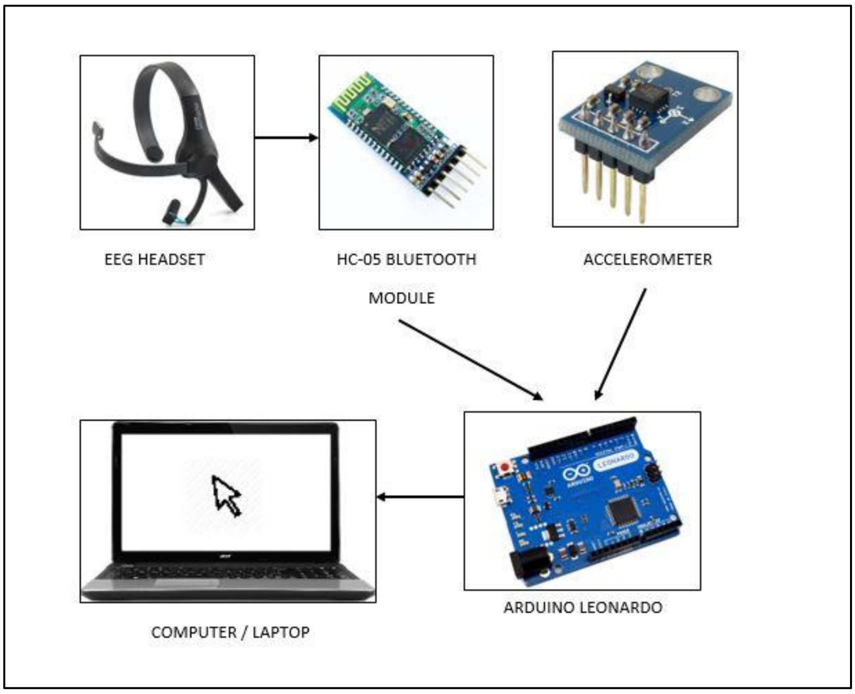

Fig. 3.3 *Proposed System Design*

The overall system design is as follows. The EEG headset is connected to the Bluetooth module and sends data to it which is then transferred to the Arduino Leonardo to which it is connected to. The Accelerometer is connected directly to the Arduino and takes the sensor values on the analog pins of the Arduino.

The accelerometer is responsible for the mouse pointer movements while the EEG headset is responsible for the mouse clicks. The Arduino Leonardo is directly connected to the computer or laptop using micro-b USB cable. The Arduino Leonardo is used for the mouse emulation and it works on the inputs by accelerometer and the EEG headset. Thus it can directly send commands to the computer for the mouse cursor and click functions.

The image below shows an illustration of how the Bluetooth is connected to the Arduino. The VCC and GND pins are used to power on the device. Since HC-05 works on 5V we connect it to the 5V VCC pin. The RX and TX connection is used to obtain the signals from the EEG headset.

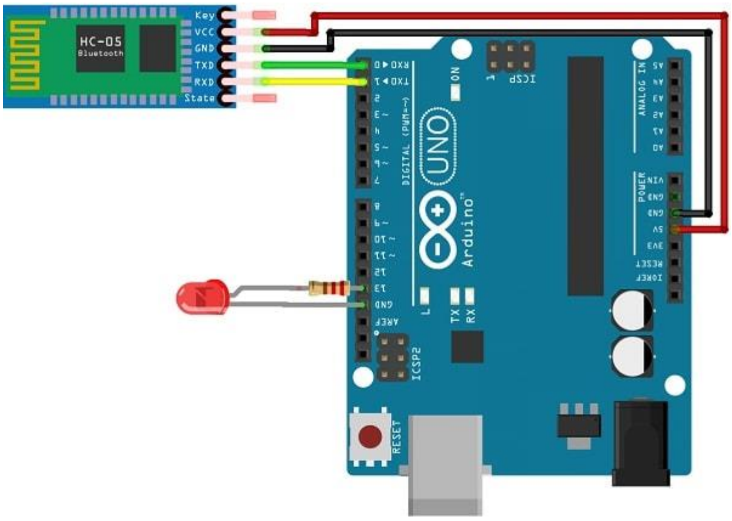

Fig. 3.2 *Connection of HC-05 to the Arduino*

As per the modules mentioned in the proposed system this is the output of program for obtaining Attention, Meditation values from the EEG Headset. PoorQuality is the opposite of Quality and ranges from 200 – 0. Thus a value 0 means that the signal is of good quality and there is either no noise interfering with the system or that the connections of the electrodes of the EEG headset is perfect.

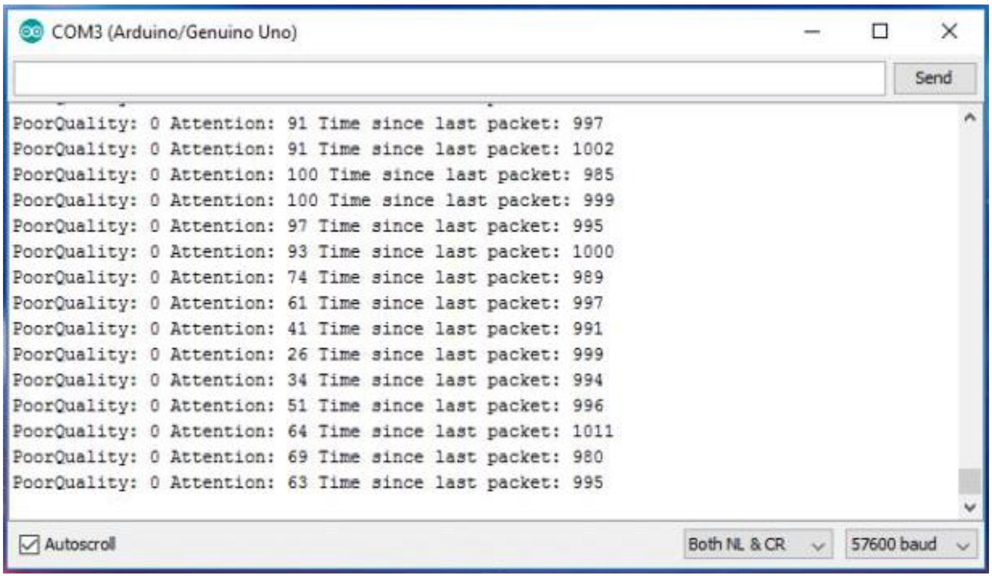

Fig 3.3 *EEG Output on Serial Monitor*

The user will utilize the hardware component to click on the required on the on-screen keyboard developed using Qt framework which supports OSX, windows RT and Linux. This means that the framework will build a platform dependent application based off a single source code, greatly reducing our workload and at the same time increasing the accessibility of our system.

The onscreen keyboard will be developed using QT API which compiles applications for Linux and Windows and Mac PCs. The API can be availed for free as long as the application which is built on it remains open-source. The mouse implementation is nearly complete which means remaining system can be built within the given deadline. If the keyboard is implemented within the time limit. Text prediction capabilities which use machine learning could be worked upon, this would bring up the typing speed of the users.

As it has been made clear that the mouse emulation will be the primary feature of the system. It is only natural that mouse functions be implemented first. So we needed a central device which could read sensor values from both an EEG and an accelerometer and give a USB HID compliant mouse signals. Accelerometer being a simpler sensor in terms of working and signal output was interfaced first with Arduino Leonardo and later mapped for mouse movement. After this was interfacing the Neurosky EEG with Arduino Leonardo which required Bluetooth capabilities which was made possible with HC-05 chip. With EEG interfacing done eye blinks could be easily detected which are being used to send mouse click signals to the PC to which the system is connected.

However, Arduino Leonardo having fundamentally different architecture to an Arduino UNO is presenting a few challenges which is why the EEG is connected to Arduino Leonardo through Arduino UNO. This difference in architecture will be adjusted next, removing the need for and Arduino UNO. During the transit time of the Bluetooth module for Arduino no mouse related work could be done, which is why basics of the Qt framework were learned by the team. It is primarily based on C++ and comes with its own IDE called as QtCreator. The IDE allows for easy UI design allowing more time for the functional backend. The tentative keyboard layout is as shown below in Fig 3.6.

Fig. 3.6 *Keyboard Application GUI*

Even though mouse functions have been achieved successfully they still need some fine tuning to maximize its ease of use, especially with respect to the precision of the mouse movement and also to reliably register blinks for left/right clicks. Following which we'll proceed with the implementation of the on-screen keyboard with quick access bar. Based on the typing speed the keyboard layout may be adjusted based on the most used keys and other related data.

CHAPTER 4 : IMPLEMENTATION PLAN

4.1 IMPLEMENTATION PLAN

This chapter includes the implementation plan:

- July to August: Research and implementation of module 1
- September to October: Literature Survey for IEEE paper and presentation
- October to November: Implementation of module 2 and documentation
- November to December: Research and development of Qt application for keyboard implementation
- January to February: Implementation of complete circuit as single unit and Alpha testing
- March: Final testing and implementation

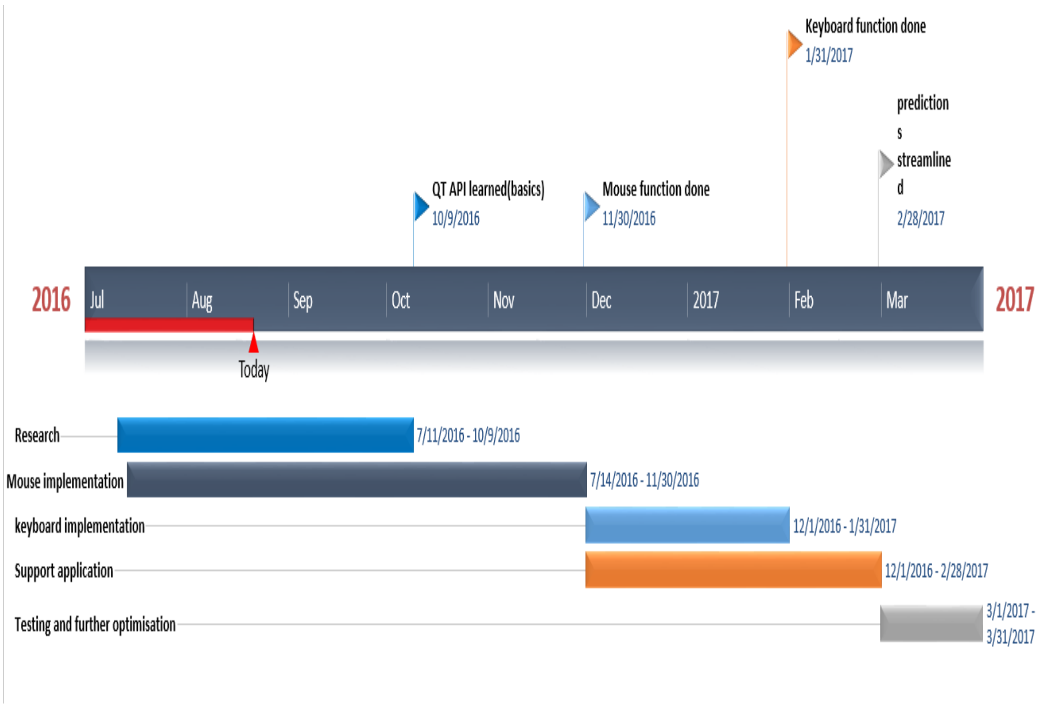

Fig. 4.1 *Implementation Plan Chart*

Thus we have currently implemented the major two modules related to hardware implementation of mouse movement successfully. The module remaining now is the keyboard application based on Qt.

CONCLUSION

This system helps the paralyzed patients use the computer with ease. The System proposed to be developed is feasible as a solution to current problems related to the system namely cost and ease of usage. It can be further enhanced by using a much better EEG headset to detect brain activity more accurately with the help of more number of electrodes. This can be also used to control more number of devices such as mobile phones, tablets or even home appliances connected to the network of Internet of Things (IOT). The bottlenecks mentioned above need to worked for possible solutions and its effectiveness.

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