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Brain Controlled Prosthetic Leg

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Abstract— the brain controlled prosthetic leg involves the technique of using the brain waves to control the motion of a prosthetic leg. The brain waves are obtained using a device called Mind wave. This device captures the complex brainwaves through the analysis of electroencephalogram power spectrum. The brain signals are then further processed using an Arduino microcontroller which then drives the motors to control the motion of the prosthetic leg. Through this approach the natural motion of human leg can be regained using prosthetics at a very low cost.

Keywords— Mind wave, Electroencephalogram, Arduino, Prosthetics, Brainwaves.

I. INTRODUCTION

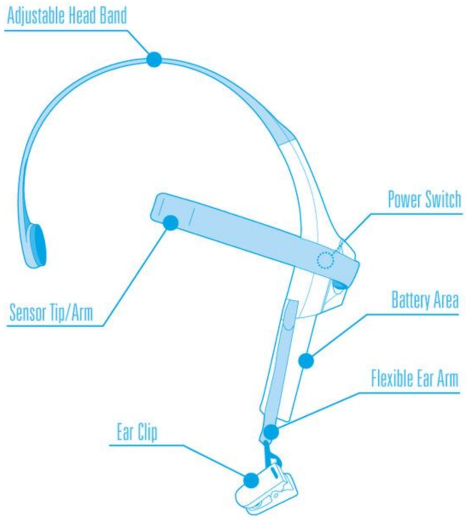
Every year a lot of people around the world lose their legs due to cardiovascular diseases, infections, tumours, diabetics, nerve injuries during accidents, congenital anomalies etc. Most of the victims depend highly on prosthetics for their daily routines. Simple artificial prosthetic legs works on the principle of gravity that is the user learns to walk using it through practice by swinging them in the required positions and balancing it with the other leg. These kinds of prosthetics make use of mechanical parts for the motion. Another recent development of prosthetics is through the use of myoelectric electrodes. They involve the use of muscular impulses in the residual limb and using these signals the motors are controlled. The main drawback of this technique is that it involves major surgery to implant these electrodes into the human body which may prove fatal and is very expensive. Moreover this technique is not applicable for the ones who suffers from nerve damages or paralysis. The proposed method involves the use of signals directly from the brain to control the motion of the prosthetic leg. Here the EEG signals are extracted from the brain using mindwave. Further the required brain waves are processed using an Arduino microcontroller and the required motion is obtained. The use of Mindwave to extract the brain signals simplifies the large wiring and complexity of EEG extracting methodologies. Moreover the communication between the Mindwave and prosthetic leg arrangement is done wirelessly using Bluetooth technology.

II. HARDWARE DESCRIPTION.

A. NeuroSky Mindwave Mobile

The core hardware behind the working of the proposed prosthetics is the Mindwave headset. The Mindwave Mobile safely measures and provides the output in the form of EEG power spectrum. The EEG power spectrum consists of parameters such as alpha, beta, theta, delta, gamma waves from the brain. The Mindwave Mobile also provides certain NeuroSky trademark parameters such as eSense attention and eSense meditation and eye blinks. On the hardware side the

Mindwave mobile consists of a sensor arm and ear clip. The sensor arm acts as the EEG electrode and the ear clip acts as the headset's reference as well as ground electrode. The sensor arm is designed so that it rests on the forehead above the eyes. The output from the Mindwave mobile is in the form of preconfigured packets of data which is transmitted wirelessly using Bluetooth communication. The headset is powered using a AAA size 1.5V battery which provides backup of more than eight hours of continuous use.



B. HC-05 Bluetooth Module

The system is controlled through Bluetooth communication technology. For that purpose a HC-05 module is used. It is an easy to use Bluetooth Serial Port Protocol module which is configure for transparent wireless serial communication setup. It is basically a class-2 Bluetooth module which can be configured either as a Master or as a Slave. HC-05 uses Gaussian Frequency Shift Keying as its modulation technique working in the 2.4GHz ISM band. It is powered using a +5VDC 50mA supply. One of main advantages of using HC-05 is that it is cheap, easily available and is having lower power consumption when compared to the products of same category

C. Arduino UNO

Arduino is an open-source electronics platform which is widely used for building variety of electronics projects. Arduino consists of both programmable circuit boards which are referred to as a microcontroller and software platform which is an Integrated Development Platform which runs on the computer through which the user develops and upload the code to the microcontroller board. The Arduino platform has become so popular because of the fact that it does not need an extra programmer in-order to load the code to it and it is open source as well as cheap. The Arduino is powered using a +5V DC supply. It consists of six analog pins, seven digital pins, analog reference pins and eight pulse width modulation pins which can act as normal digital pins. It also consists of several light indications for power, transmit and receive. The proposed system is designed using an Arduino Uno even though it can configured using any members of Arduino family because of its cheap cost and ease to use.

D. Servo Motors

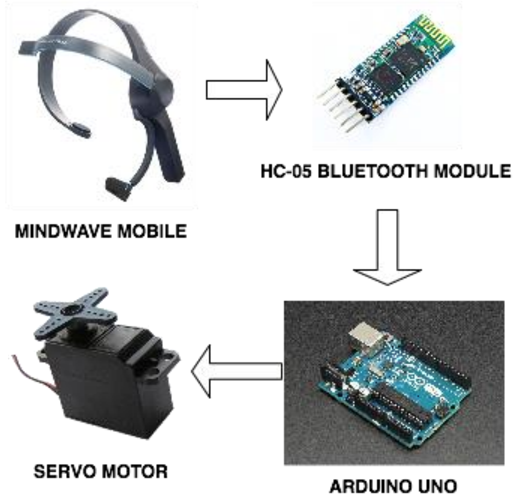
The servo motors play a significant role in the proposed system. The Arduino drives the servo motors on the basis of the signals from the EEG spectrum. Servo motors are preferred over the stepper motors because they provide high torque, fast response and accurate rotation with limited angle. They are commonly used for robotic arms/legs or rudder control and therefore more suited for the purpose.

E. Battery

The micro-controller and associated circuitry including the servo motors are powered using a 5v lipo battery 4000mah.The battery is having a life of 500 charge cycles and is having a small size of 26mm*50mm*80mm. Thus it is quite easy to mount the battery inside the prosthetic leg module.

III. SYSTEM DESIGN

Electroencephalography is considered as a medical imaging methodology which is used to read the brain mental activity directly from the brain scalp. The resultant activity when picked up using electrodes is called electroencephalogram. The brain activity changes in a consistent and recognisable way when the status of the humans changes from the state of relaxation to alertness. The mental state of the humans change from one state to another during different activities. This can use for different brain computer interfacing systems where the communication and action is done through human brain activity.



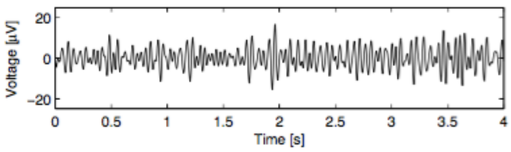


Fig. 3: High powered beta waves

Through a detailed experimental study about the brain waves and its response during different human activities, it is observed that beta waves of a particular range are responsible for the motion of human legs. Experiments were done on several persons of different age groups and observations were made. It was then concluded that beta waves in the frequency range of 13 to 40Hz are responsible for simulation of motor nerves in the human body.

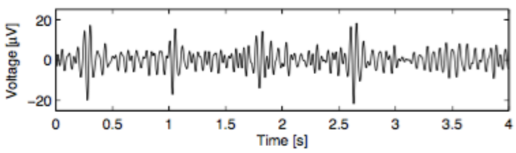


Fig. 4: Low powered beta waves

The difference between fig 3 and fig 4 is that, the former one is having larger number of high peaks when compared to the later which is having only three high peaks and so less power. Thus there is a core relation between the wave amplitudes and the associated activities.

The Bluetooth module is initially paired with the Mindwave Mobile using AT command set. Through this method particular headset gets paired with particular Bluetooth module only. Here the pairing is done in such a manner such that the Bluetooth module act as the master and Mindwave act as the slave. After getting paired the EEG values from the Mindwave is fed to the microcontroller via Bluetooth module at a baud rate of 57600.

The single dry sensor and reference, pickup the potential differences on the skin at the forehead and the ear. The two voltages are then subtracted through a common mode rejection to serve as a single EEG channel and then it is amplified 2000x to enhance the faint EEG signals. The signals are then passed through a combination of analog and digital low and high pass filters to retain the signals in the range of 1-50Hz. After correcting for possible aliasing these signals are ultimately sampled at 128Hz or 512Hz. The output format from the Mindwave is in the form of data packets. The data packet consists mainly of

- Packet Header
- Packet Payload
- Payload Checksum

[LENGTH] gives the number of bytes of data from 0 to 169. [PAYLOAD] consists of various data which obtained by the Mindwave mobile.[CHECKSUM] is used to find the integrity of the data packets payload. The power of the EEG signal can be obtained from a 32 bit big endian 3 byte unsigned integer value. [SYNC] represents two synchronisation bytes (0xAA 0xAA).

```
[SYNC] [SYNC] [PLENGTH]  [PAYLOAD...]    [CHKSUM]

_______________________  _____________  ____________
^^^^^^^^(Header)^^^^^^^^  ^^   ^^^^^ (Payload)^^  ^(Checksum)^
```

Fig. 5: Data packet format

The beta waves are extracted from the data packets along with the Attention eSense values and are used to control the electric motor arrangement. The processing of data is done by the atmel microcontroller. Before preceding to the data processing it is ensured that the signal quality from the Mindwave mobile is greater than 90 otherwise a low signal quality is indicated through a LED indicator. The data values are then processed by dividing them into a group of 2000 each. Through random experiments it was observed that beta data values in the range of 30000 to 60000 from Mindwave are more prominent during the motion of the leg. The sampled values are then mapped to the range of 1 to 10 out of which 2-8 range causes the motion of the motor arrangement in addition only if the attention eSense value is greater than 70. The servo motors provide motion in the range of 0^0 to 90^0 depending upon the control signals from the atmel microcontroller based on the brain waves. The servo motors are attached to the piston joint arrangement in the prosthetic leg. The Fig.6 and Fig, 7 demonstrate the 3d design of the prosthetic part to which the motor and other electronic circuitry are attached. The prosthetic leg was designed using a 3D modelling software and prototyped using 3D printer which moulded the design using high quality plastic. The final circuit associated with the prosthetic leg control system is shown in the Fig.8.

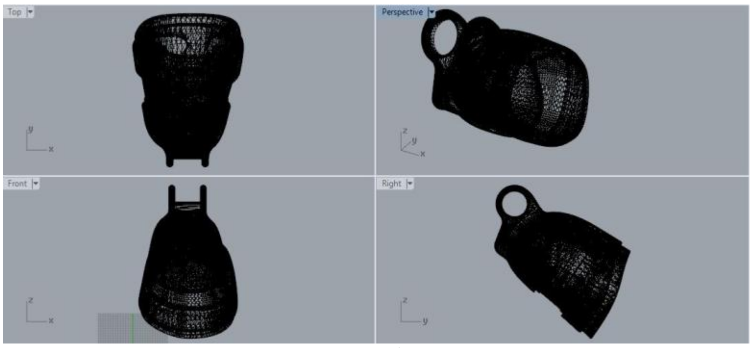


Fig. 6: 3D design of prosthetic leg

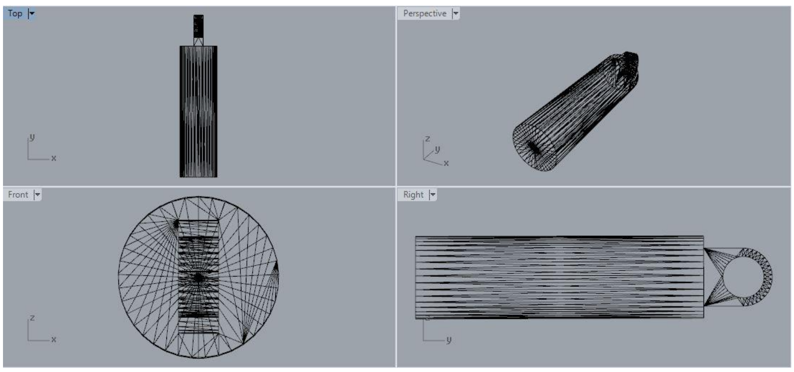
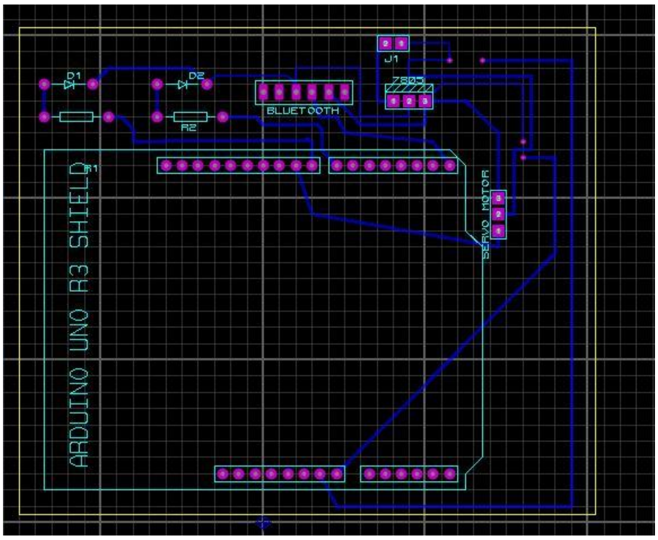


Fig. 7: 3D design of prosthetic leg



IV. CONCLUSIONS

This low cost approach will be a boon for the common man who still dreams about the expensive prosthetics. This prototype will reach the common man much easily when compared to the complex and expensive prosthetics even though the accuracy of motion is compromised to an extent. The electronic circuitry can be further simplified through the design of purpose specific integrated circuits. While coming to the practical scenario the user needs proper training to control the prosthetic leg motions similar to a child who gets training to walk. This technology when developed to the large extend can be helpful for the development of an exoskeleton for the paralyzed ones. Many additional features such capacitive toes and more improved signal processing technologies can be incorporated for improving the performance of the system.

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