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THESIS ON IMPULSE CONTROLLED PROSTHETIC

Priyan Kumar
Electrical and Electronics Department
Pranveer Singh Institute of Technology
Kanpur, India

Rahul Kumar
Electrical and Electronics Department
Pranveer Singh Institute of Technology
Kanpur, India

Abstract-

Recently, In the field of prosthetics has seen many researches especially with the integration of technological advancements. In this paper, we study about different arm (robotic, surgical, prosthetic and static) are analyzed in terms of usage, flexibility, cost, effectiveness and potential. Most of the techniques have some problems. They are very expensive, really tough to install and maintain and may require surgery. Therefore, we introduces the initial design of an impulse controlled smart prosthetic arm. The arm is controlled by our mind impulses, obtained from an electroencephalography (EEG, and equipped with a network of micro sensors and actuators that give the patient intelligent feedback about the surrounding environment and the object in contact or movement. This method provides the arm with normal hand functionality, smart reflexes and smooth movements. Different types of sensors are being used including temperature, pressure, ultrasonic proximity sensors, accelerometers, potentiometers, strain gauges and gyroscopes. The arm is fully 3D printed built from different lightweight and high strength materials that can handle rough impacts and elements as well. Our project requires the use of five servomotors installed at different places in the arm. Therefore, the static and dynamic modes of servos are analyzed. The total cost of the project is estimated to be very cheap compared to other previously built arms. Many scenarios are analyzed corresponding to the movements that the prosthetic arm or limb can perform, and an algorithm is created to match these scenarios. Experimental results show that the proposed EEG Mind-controlled Arm is a promising alternative for current solutions that require invasive and expensive procedures.

1:- Introduction-

In recent studies, the World Health Organization (WHO) reported that about 15% of the world's population suffers from a form of disability, many of them cannot afford health care . Due to various economic, scientific, and demographical reasons, the overall rates of amputees and limb dysfunction patients are increasing. There are over 10 million amputees worldwide and 30% are arm amputees. Although prosthetic limbs exist since decades, they are not very natural in terms of operation and interaction with the surrounding. They require undergoing an invasive surgical procedure. The main goal of such complex procedures is to reassign nerves and allow amputees to control their prosthetic devices by merely thinking about the action they want to perform. Prosthetic limbs need to be measured and fitted to the patient for his needs. To test prosthetics on a patient, intense medical observation and deep study for the patient are needed so that he can use the prosthetic comfortably. There are various techniques used as a means of controlling robotics arms, and the preferred three methods are highlighted hereafter. The first one is to use an electroencephalogram (EEG) device, which will record the person’s brain impulses when he is giving any commands or implementing a facial expression. These readings are then converted to commands for the movement of the arm. We observed that the mind regulates its activities by electric frequencies registered in the mind that emits electrochemical impulses having different frequencies, which can be taken by an electroencephalogram. For instance, beta frequencies are emitted when a person feels nervous or afraid with frequencies ranging somewhere between 13 to 60 Hertz. Alpha frequencies are emitted when a person feels relaxed mentally and physically with frequencies from 7 to 13 Hertz. On the other hand, delta frequencies are emitted when a person is in a state of unconsciousness. The advancement in technology made it possible to process these Electromyography frequencies and data directly in real time by the use of a microcontroller interface which is a combination of hardware and software. The second method is the surgical implantation. The arm is surgically connected to the person’s torso. Connections are also command to the nerves to take the reading of electrical signals so that these signals can then be filtered and converted to commands. The last method consists in using sensors, which will be connected to the robotic arm in order to take precise readings. Some of the most common sensors used in this case are EMG, gyroscope, and accelerometer sensors. This will allow the user to be aware of the position his arm can be in as well as expand and enclose it. All the types of arms used are summarized and compared with each other hereafter in terms of usage, flexibility, cost potential. The Electromyograph (EEG) method is not only cost effective, but it is also precise and gives the patient complete control of the arm. It also gives the user the benifit of taking it off when feeling discomfort. EEG is a preferred method of monitoring brain activity. Typically, it uses electrodes placed on the outside of the head, and measures voltage oscillations in the neurons of the brain caused by ionic current. It has been used in medical applications for a very long time. Emotiv EPOC instrument is an example of an EEG headset with fourteen sensors and having an internal sampling rate of 2048 Hz. After filtering the signals, it sends the data to the computer at approximately 128 Hz. The signals are transferred from the headset to the computer through wireless technology. This offers much more mobility, and instead of requiring a gel, the electrodes of the EPOC simply need to be dampened using a saline solution that in disinfectant and common. The project presented in this paper aims to develop a low-cost and general human-like prosthetic arm controllable via mind activity using EEG neuro-feedback method. The arm is fully attached with a network of smart sensors and actuators that provide the patient intelligent feedback about the
surrounding and the object in contact. It also allows

the arm to react and perform pre-programmed series of actions in critical cases. A first prototype has been created to test the prosthetic arm with the inbuilt electro-mechanical system. This prototype is controlled using flex sensors integrated within a glove. A microcontroller is attached to the system, thus commanding to perform programmed actions and tasks. The prostrate arm is created using a 3-D printer in order for it to be cost efficient. All parts are printed separately then all assembled together. This prototype focuses on the arm-environment interaction. Other prototype based on the EEG control has also been developed and still under test. Preliminary experimental results show that the EEG technique is a precise and good alternative to other existing techniques.

2:- Technical architecture-

The proposed system is divided into 4 major units as shown

in Figure 1:

1- Input Part– EEG sensors

2- Processing Part– Pattern recognition

3- Electro-Mechanical Part - The arm

4- Interface Part– Smart sensor

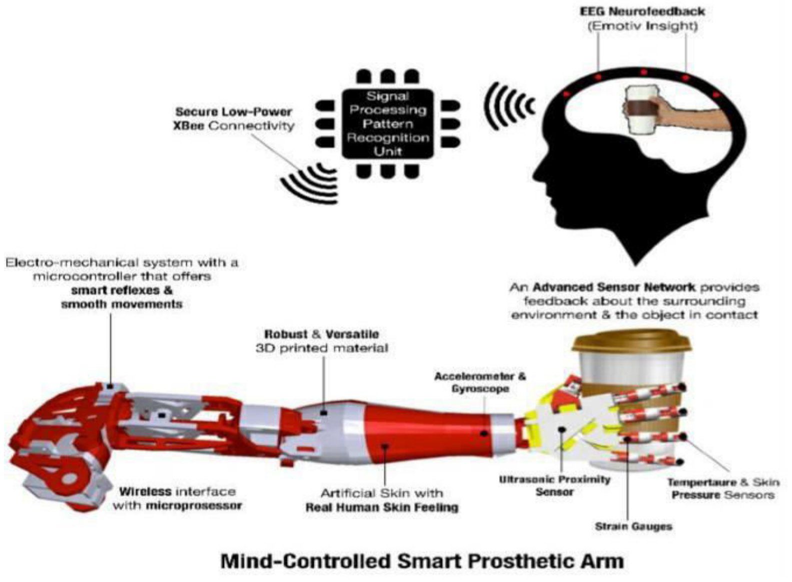

Figure - 1

2.1 Input Part- In this part, mind signals were received by an array of advanced EEG sensors communicating to Signal Processing Unit via low-power and secure connectivity using Bluetooth technology. This device has an internal sampling rate of 2048Hz and fourteen sensors arranged according to the international between 10-20 System as shown in Figure 2 in order to cover the most useful area over the

Emotiv EPOC instrument wireless recording headset bearing 14 channels (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8), referenced to the common mode sense.

2.2 Processing Part- The EEG signals provided by the input part were tested and processed on a lightweight wearable gloves – the Processing part This processing activity consists of two main parts: one is a pattern recognition part that identifies different mind behavior captured by the input part, and other one is a command part that generates a series of commands to be sent to the mechatronics system of the arm. This unit was programmed to distinguish between different state of the mind representing various levels of meditation and focus. Each state of mind was captured and encoded to represent a set of individual tasks to be performed by the arm. Due to the diversity and the complexity of mind wave activities among different humans, machine-learning techniques were required to train patients to specific arm movements according to a set of mind states.

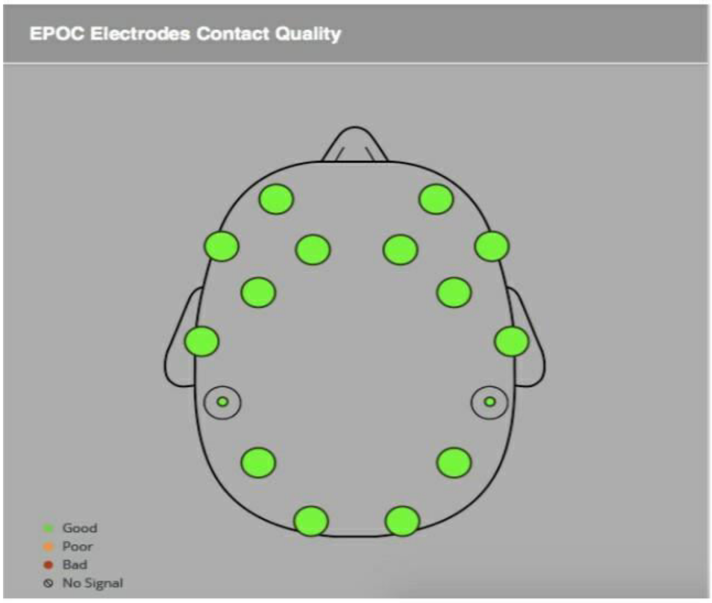

Figure 2. EEG 14-sensor arrangement

2.3 Electro-mechanical Part- This part was designed and built from various lightweight high-strength materials that can handle high impacts and integrated servo motors capable of handling 800 oz.- in. of stall torque. These servos were strategically settled to minimize hardware and facilitate complex moves. A microcontroller was also integrated accordingly to provide the interface between the Mechanical and the Processing part. It can also be programmed to act a series of movements, allowing the arm to have realistic real hand behavior.

2.4 Interface Part- This part is composed of a network of smart sensors, including temperature, skin pressure and ultrasonic proximity sensors, accelerometers, potentiometers, strain gauges and gyroscopes. The main functions of this part to allow the arm to interact with and adapt to the surrounding. Moreover, a bi-directional communication was required to give task to the prosthetic arm and provides feedback to the patient. This integrated network of sensors and actuators required custom communication protocols and networking techniques that allow interaction and control between the arm and patient. By default, controlling arm was handled by the mind (patient); however, it can be transferred to the arm to proactively manage itself against damage. Due to its uniqueness, the proposed Brain-controlled Smart Prosthetic Arm should be able to make improvements to the quality of life for millions of patients and their families around the world. Its lowcost design makes it accessible for a wide range of beneficiaries, especially those persons who have limited or no access to advanced health care.

3:-Technical Components and their overview-

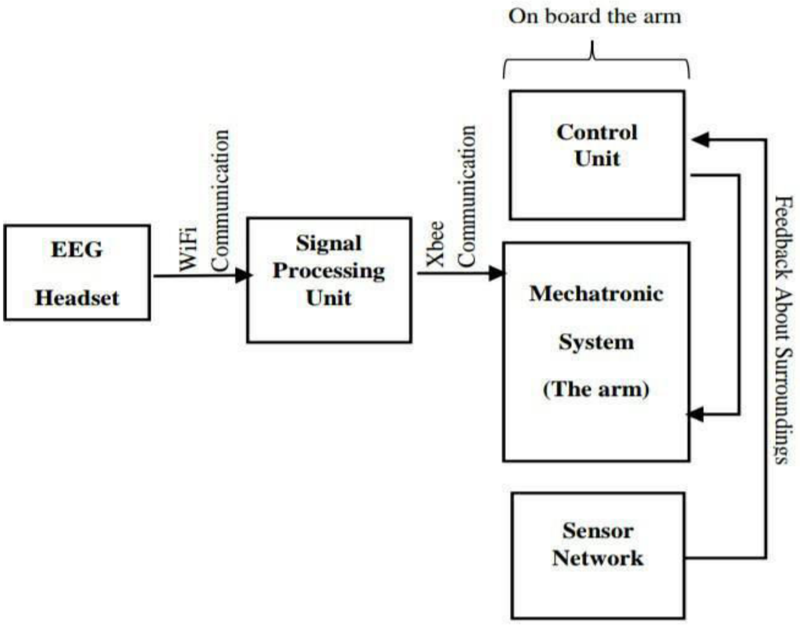

Figure 3. System overview – block diagram

Electromyograph (EEG) Headset-Electroencephalography (EEG) is a monitoring method to record the electrical activity of the brain. Wearable EEG headsets position noninvasive electrodes along the scalp. The clinical definition of EEG is the recording of brain activity over a period of time. EEG electrodes pick up on and record the electrical activity in your brain. The collected signals are amplified and digitized then sent to a computer or mobile device for storage and data processing

Figure 4 EEG headset

Surface Electrodes: Surface electrodes are the electrodes which applied to the skin of the subject. Major applications include electrocardiography (ECG), electromyography (EMG), or electroencephalography (EEG), which are techniques for recording and evaluating the electrical activities of the heart, skeletal muscles and neurons of the brain, respectively, from the surface of the skin. Other types of electrodes are used to measure the conductance of body parts. Examples are measurements of skin conductance or transthoracic impedance. Some electrodes are simple metal plates connected with a lead wire. Electrodes can be made in the form of a suction cup attached with a bulb, facilitating easy to fit and relocation. Commonly used for measurements of EEG are cup-shaped gold electrodes with an open apex, from which electrolyte gel is being added to improve connection. Dry electrodes a do not use electrolyte. They are basically made of silicone elastomer added with graphite. One of the most important goals for desirable surface electrodes is to obtain a lower contact impedance, which is crucial to attain high signal-to-noise ratio.

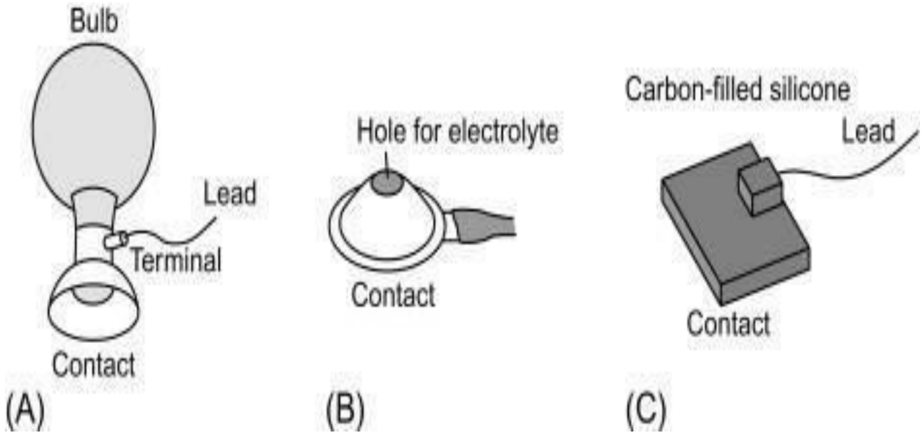

Figure 5 Electrodes

Microcontroller Unit: Here we have used Arduino Uno - The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc. The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 Digital pins, 6 Analog pins, and programmable with the Arduino IDE (Integrated Development Environment) via a type B USB cable. It can be powered by the USB cable or by an external 9-volt battery, though it accepts voltages between 7 and 12 volts.

Li-Ion Battery: A lithium-ion battery or Li-ion battery (abbreviated as LIB) is a type of rechargeable battery. Lithium-ion batteries are commonly used for portable electronics and electric vehicles and are growing in popularity for military and aerospace applications. In the batteries, lithium ions move from the negative electrode through an electrolyte to the positive electrode during discharge, and back when charging. Li-ion batteries use an intercalated lithium compound as the material at the positive electrode and typically graphite at the negative electrode.

Servo Motors: A servo motor is an electrical device which can push or rotate an object with great precision. If you want to rotate and object at some specific angles or distance, then you use servo motor. It is just made up of simple motor which run through servo mechanism. If motor is used is DC powered then it is called DC servo motor, and if it is AC powered motor then it is called AC servo motor. We can get a very high torque servo motor in a small and light weight packages. Due to these features they are being used in many applications like toy car, RC helicopters and planes, Robotics, Machine etc.

4:- Working of the model-

The prosthetic hand is created using a material called Eco PLA, which is PLA mixed with some chemicals to provide a sense for heat recognition. This material can change its color when exposed to heat. The attached sensors provide visual aid to the user of the arm so that the user can measure the heat of the held item. Eco PLA is taken as a clean material, mainly extruded from starch, corn, and sugar cane, which makes it environmental friendly. For the mechanical moving parts like motors that need better endurance and will be exposed to more pressure, PLA is also used because of its strength, flexibility, and heat resistance, which makes it more reliable; therefore, it is the best material to execute the job with no flaws. It is also easily sanded and machined. For the forearm, shoulder, and elbow, PLA is used to complete the build. It is a printing material that is easily machined under Neutral conditions, on the other hand other materials needs special heating bed during the printing. PLA is also an environment friendly plastic which can be made using a mixtures of different plant substances, such as potatoes and corn, yet, it does not easily bio-degrade. It is also considered strong and rigid material, yet it has a lower melting temperature which makes it unreliable under pressure.

Figure 6 Prosthetic arm made of PLA

4.1 Dynamic modelling of prosthetic Arm- In time domain, the mechanical model of the Prosthetic Arm can be represented as a second order differential equation form

$$f(t) = m\frac{d^2x}{dt^2} + C_1\frac{dx}{dt} + K_1.x(t).$$

for the translation motions.

where: f(t) represents here the applied tension forces in the two sides of the tendons to create displacement between fingers at different configurations, m is the mass of the movable part, x(t) is the displacement between fingers at different time, C1 is friction damping coefficient for translation motion , K1 is the spring constant . the same model can be restated for the torque T(t) at the elbow and shoulder joints as

$$T(t) = J\frac{d^2\theta}{dt^2} + C_2\frac{d\theta}{dt} + K_2.\theta(t).$$

shown in equation

where: J is indicating mass polar moment of inertia (kg.m2) of the rotated part, T(t) is indicating angular displacement of finger (rad.), C2 is the friction damping coefficient for the rotational motion , K2 is trotational spring constant .From the multibody dynamic model of the different parts of the Prosthetic Arm, we can get the required toque for each of the 5 motors at all movement configurations, the selection design value for the motors specifications was based on the maximum calculated required torque & Power.

***4.2* Control techniques-** The prosthetic arm is based on both fully autonomous and semi-autonomous control. A bi-directional communication channel was implemented between smart sensor network and embedded microcontrollerin such a way to autonomously control the electro-mechanical unit and give feedback to the user by displaying it on an display mounted on the arm. This setup offered the arm the ability to have smart and good reflexes when it counters delicate, dangerous and sudden situations such as protecting the arm from very hot surface contact or over squeezing objects. This integrated network of sensors and actuators requires custom communication protocols and control mechanisms techniques that allow seamless interaction and control arm over between the arm and the user. By default, the mind signals control the arm movements semi-autonomously via a wireless connection. The EEG headset has a proprietary wireless USB dongle that can be connected to the processing unit via a Bluetooth module. It reads the neuro-electrical signals and interprets them as a set of predefined outputs that reflect expressions of face mood and conscious intentions. These predefined outputs are received by the processing unit, compared with user-dependent predefined library of pattern and then converted into

functions. These functions are then labeled using variables and sent to the Arduino microcontroller through via UART channel. Based

on some of these variables, a movement of the arm occurs as the mapping that is done between the variables and the readings.

5:- Conclusion

The prosthetic arm hosts state-of-the art technological advancement, communication protocols, control systems, and interfacing. This gives it high potential in many applications related to the health care field as well as other fields. As long as health care is considered, this idea could be expanded to other body parts as well as to patients having other dysfunctions as nerve damage. On the other hand, many industrial companies and commercial companies can utilize many features and functions of the proposed arm. Within the health care department, there exists a class of patients who need extra help with their daily lives. This includes elder people, and people with limited mobility, etc. The proposed arm can be interfaced to a robotic-structure and function as a helper or caregiver to this group of people. It can be programmed to do various functions according to specific patient needs. This may vary from cooking to assistance with bathing or dressing. Another example in the medical field is needed high precision surgical procedures, where surgeons can undergo operations remotely with the help of the robotic arm. Many industries employ Robotic arm in the manufacturing process, many of which can make use of a modified version of the proposed arm. Based on a specific application, this smart prosthetic arm can be programmed to execute a series of predefined actions, and customized with dedicated sensors, actuators and customized algorithms (such as image processing, signal processing, gesture and voice and face recognition etc…). In addition, connecting the arm with the Internet, and making it part of an Internet of Things network (IOT) will increase the performance and productivity of many industry applications. The first prototype is designed, built and is under test. The testing required long training sessions in order first to build a user-dependent library of brain activity patterns, and second to make the user more familiar and comfortable using this hand.

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