Four Gesture Recognization of a Robotic Hand using EMG

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Abstract: Electromyography (EMG) measures muscle response when nerves are stimulated. The objective of this research paper is to present a work on control of a robotic hand using Electromyography. CAD model was selected using various open sources. The structure is printed with poly laic acid (PLA) material with the help of a 3D printer. EMG signals were acquired by wearing the eight channel Myo Armband, placed on the forearm muscles of 10 subjects. Then, these signals were filtered to remove noise. Different features are applied on noise free acquired signal and KNN is used for classification. From the KNN classifier, we achieved 98.9% accuracy. Gestures exhibited were Victory, Thumbs Up, Open Hand and Grasp. The classified signals are used to control the robotic hand.

1 INTRODUCTION

A physical disability is a condition that affects a person's mobility or physical capacity. Therefore we uses prosthesis which is an artificial device, developed to replace the function of a lost limb. Prosthesis are classified as exoskeleton and endoskeleton. Exoskeleton prosthesis gain its structural strength from outer laminated strength whereas, endoskeleton prosthesis gain its structural integrity from the inner endoskeleton.
There are two major types of exoskeleton: Upper-extremity prostheses and Lower-extremity prostheses. Upper-extremity prostheses further have following types transradial amputation, trans-humeral amputation, wrist dis-articulation, elbow dis-articulation and shoulder dis-articulation. Whereas, lower-extremity prosthesis includes prostheses for transfemoral amputation, knee disarticulation, hip disarticulation, ankle disarticulation, transtibial amputation and partial foot amputation.

Depending on the use of external power they are divided into Active and Passive techniques (Windrich et al, 2016). An active prosthesis powered devices externally and consist of sensors in contact with the skin, which then pick up the signals from the arm and sequentially operate the actuators, which in order controls the movement(Windrich et al, 2016).

Different techniques are used to developed control for brain controlled interface (BCI) (Mattia, 2016) for example Surface Electromyography (Anil and Sreeletha, 2019), Electroencephalography (EEG), Functional Magnetic Resonance Imaging (FMRI), (Bright et al, 2016), Force myography (FMG) (Cho et al, 2016) and Targeted Muscle Reinnervation (TMR) (Cheesborough et al, 2015). From which sEMG, EEG, FMG and FMRI are non-invasive techniques whereas, TMR are invasive techniques.

Electromyography (EMG) measures muscle response when nerves are stimulated (Anis, 2019). Electromyography (EMG) is a symptomatic program used to survey the wellbeing of muscles and the nerve cells that control them. These nerve cells are called engine neurons (Shi, 2018). A brief description of the different EMG strategies signal separation and comparison of different strategies by analyzing the EMG signals, in relation to their execution was proposed (Raez, 2016).

EMG is performed by an instrument called an electromyograph, which recognizes electrical signals generated by muscles. Electromyography (EMG) can be assessed utilizing conductive parts or anodes on the outside of the skin, or it tends to be evaluated utilizing an obtrusive technique (coordinating the sensor into the muscle) (M. Ali, 2020). Surface EMG is the most common techniques (Del Vecchio et al, 2017).

EMG is a non-invasive method of indirect BCI which gradually grows in number of applications, such as EEG (Mattia, 2016) (Gandhi, 2010).

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Including biomedical, a prosthesis, a combination of a human machine. In any case, there is noise EMG symptoms are important barriers to overcoming them achieves the best performance of any based EMG application known as Human Machine Identifier (HMI)(Zimenko, 2013).

A robotic hand is an electro-mechanical system. It is composed of different parts. The main parts are the electrical components and mechanical structures that allow movement. In many such configurations, the kinematics of the robot are the same as those of a human hand, and the joints of each finger can be controlled independently (Naseer, 2018).

Virtual prototyping technology is used to create designs for 3D printed Myo robotic hands. CAD models were selected using a variety of open source. It can be easily accessed on the Internet. This hand uses a small motor to control the movement of the fingers of the hand. Use a 3D printer to print small parts of the hand, and finally assemble all the parts into a robot. The design is tightly based on the function of the tendon, which is how the hand works. By using servo motors to help open and close the clamps, threads are used to manipulate the structure. Print structures with polyacrylic material (PLA) using a 3D printer.

Our robot-based manipulator is controlled by the movement of the hand. Its working principle is EMG sensor based. Sensor record hand movements and then transmit the information to the encoder, which prepares the encoder for receiver-side transmission. This information is received via Bluetooth and then transmitted to the Arduino. The micro-controller makes various decisions based on the information received. These decisions are passed to the motor driver, which triggers the motor in different configurations, causing the robotic hand to move the Myo Robotic Hand to a certain direction. Depending on the application, the robotic hand can be designed to perform all required tasks such as welding, gripping, rotating, etc.

The task has numerous utilizations in the territories of wellbeing, apply autonomy and bio-robots, just as an individual deadened with a couple of hands. This structure can be utilized to distinguish high radiation objects. This plan can be utilized for prostheses with a high number of degrees of opportunity. With some modifications, it can be used in heavy industry to collect and position various objects with real-time signals. The objects that can be treated can be, for example, toxic chemicals, radioactive materials. It can also be used on assembly lines in the automotive industry

This research has several applications in different field such as Robotics and Bio-medical Industry. Such as, to help people with wrist disarticulation so that they become independent and return to normal life.

2 METHODOLOGY

A methodology was evolved in which research is divided into different part or stages.

Fig .1 shows the experimental setup of this research. CAD model was selected using various open sources. Then the structure is printed with poly

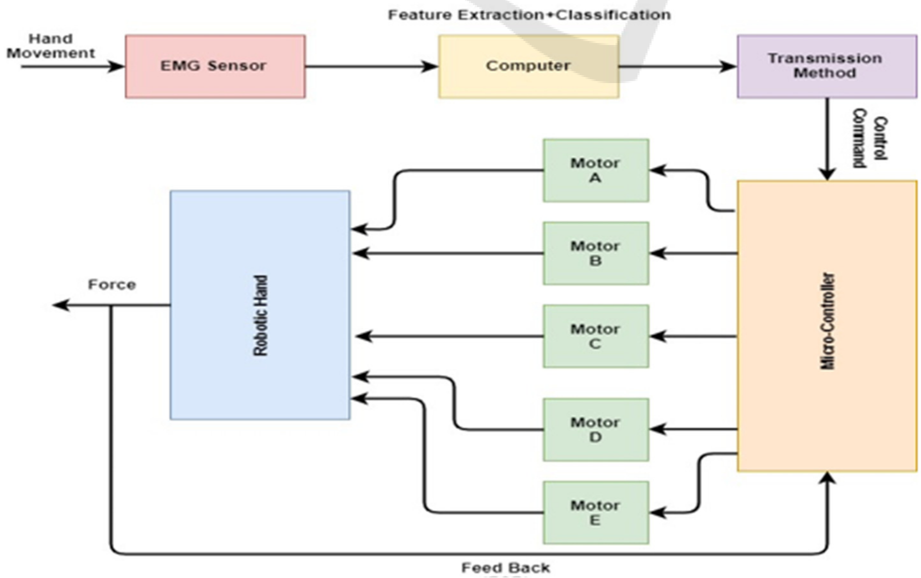

Figure 1: Experimental setup.

laic acid (PLA) material with the help of a 3D printer. EMG signals were acquired by wearing the eight channel Myo Armband, placed on the forearm muscles of 10 subjects. Different features are applied on noise free acquired signal and KNN is used for classification. From the KNN classifier, we achieved 98.9% accuracy.

2.1 3D Printing of Robotic Hand

Rather than structuring a CAD model which isn't our project goal. We looked through CAD models of hand on different open sources. After all the examination and study we finished a streamlined plan which comprise of four moveable fingers, a moveable and contradicting thumb, improved gripping design, simple and reliable.

The following point must be considered while choosing the cad model:

- A cover over all the electrical components to protect them from environment.
- Close resemblance with natural human hand.
- Entire weigh of hand including electronics not more than 600g
- Fingers actuation using threads attached through motors.

Fig. 2 shows the 3d print/design of the robotic hand.

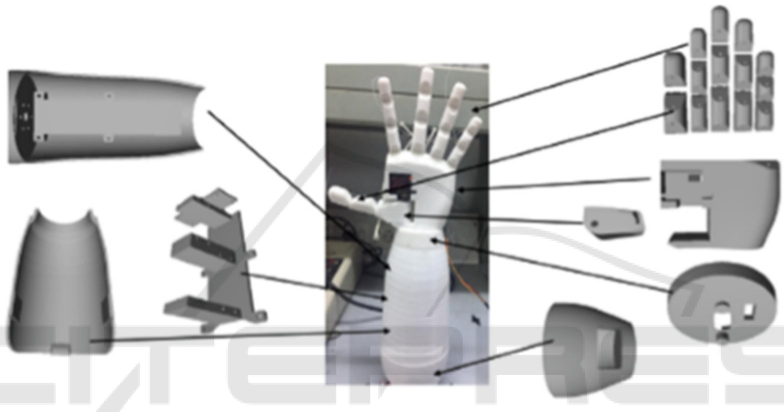

Figure 2: 3D hand design

For 3D printing we used Poly Lactic Acid which is a thermoplastic and is derived from sugar. It is carbon free material. PLA when heated above 180° C become mold-able and upon cooling hard. It is used with 3D Printer because it is reusable, light, has strength than produces products with high quality.

Another material that can be used is Acrylonitrile-Butadiene-Styrene (ABS). It is made from monomers Acrylonitrile, 1,3-Butadiene and Styrene. It is strong and durable but it need a hot printing bed above 200C. It also produces poisonous gases.

After receiving 3d printed robotic hand, it was assembled. Electronic circuits, controller and motors are placed inside the

3D Printed Myoelectric Hand. 5 Servo Motors and fishing line are used to actuate the fingers. Device is attached to the patients disabled with upper limb. As our project is robotic hand therefore no need for exact dimension.

The components/hardware used for regulating the robotic hand are as follow: Actuator, battery, microcontroller and wires. Actuator is a device due to which a machine or any other device can operate. They are characterize on the basis of their rotation and the power they use. The actuator we are using in our project is servo motors. Servo Motor is DC engine with a mechanism known as feed-back mechanism.

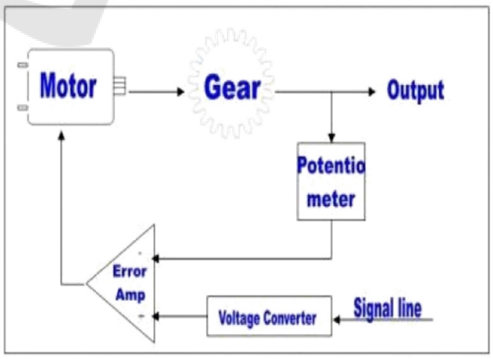

Figure 3: Servo Motor Flow Diagram

This motor run on electricity with the help of a battery and spin at high RPM. Servo Motor (MG995). Fig.3 shows Servo Motor Flow Diagram.The reason for selecting MG995 is that they are providing us the required Torque as well as they are small in size and inexpensive in comparison to other DC Motor available in the market.

RPM stands for rotation per minute but put out very low torque (a rotational effect used to work). Servo motors have different types.

Their main feature is to control the position of shaft which is inside it. Servo DC Motor are of small size, relatively low in price and provide torque from 9.4kg/cm to about 11kg/cm. They are widely used in robotic applications. Servo Motor attract current relative to the mechanical burden applied and has capacity to turn to explicit precise position, which depend on the model utilized. Fig.4 shows servo motor.

Figure 4: Servo motor

In this project 4 buck converters (LM2596) are used. One with each servo motor. The LM2596 is a series of buck converter basically regulator which provide us with the functions of a step down (buck) controller. They are able to drive 3A load easily that is enough for the project. Some other specification of this regulator is given below:

Input Voltage (min-max): 4.5V-40V

Input Voltage (min-max): 3.3V-37V

Arduino is an open-source and open-authorized programming (IDE) which make it easy to form the code and to move it on to the Arduino Board. Utilizing Arduino MATLAB library, Arduino board goes about as the fundamental correspondence load up between the constant development of client's finger and the mechanical hand giving every actuator the ideal PWM. An Arduino as a microcontroller was utilized to process the information gained from the sensor of Myo Armband. Arduino sheets depend on equipment and programming. Arduino Uno is used.

After considering all the requirements, Lithium-ion polymer battery (LiPO) Battery 5000 mAh is used. Table 1 shows the battery calculation, on the basis of which, battery is selected.

Table 1: Battery calculation

Index	**Battery Calculation**					
	Component	***Quantity***	***Current***	***Voltage***	***Power***	***Total Power***
1	Servo Mg995	4	0.45A*	6V	2.7W	2.7x4=10.8 W
2	Micro Controller	1	0.05A	7V	0.35W	0.35x1=0.35 W
3	PSU Circuitry	1	1A	10V	10W	10x1=10W
4	Miscellaneous	1	0.5A	5V	2.5W	2.5x1=2.5W
5	Servo Sg90	1	0.36A*	5V	1.8W	1.8x1=1.8W

Total Power = 10.8+0.35+10+2.5+1.8

= 31.65 W (Power)

Assuming operation for 1hr = 31.65Wh (Energy)

Battery Capacity = 2851.35mAh (Wh x1000/V)

Battery Voltage = 11.1 V

Advantages of using lipo battery is as follow

- High Discharge Current
- Light Weight
- More Charge Cycle
- 11.1 V
- 5000mAh

Step by step procedure to assemble the hand:

Step1: All fingers except thumb are assembled from fingertip, joint and knuckle. String are used to joint these parts. Thumb is assembled from thumb joint, thumb tip and joint.

Step 2: Four Servo motors are placed in the Forearm region and tightened with a screw provided with the servo motor. Threads are connected to the servo on the horns. The infant finger and the ring finger are connected to a similar servo, as they provide the same functionality.

Step 3: Cut ten 20 inches fishing line. Two fishing line per finger are used. Crimp them by feeding the fishing line from one side. Feed the fishing line from the finger tips till the fishing line exists from the palm.

Step 4: Now the fishing line are attached to the corresponding servo motor. The fishing line should be tensioned. To check the fishing line is tension's move. The motor counter clockwise with hand and the finger will move inward. By rotating it clockwise the finger should open.

Step 5: Now wear Myo Armband and then connect Arduino with motors and place the forearm cover on forearm body.

EMG sensor is placed on the forearm muscle using Myo Armband. EMG is powered by a separate battery providing 18V. Robotic hand was also tested by using arduino.

As we are done with the assembling of Myo Robotic hand, after that we integrated Myo Armband with the arduino and perform the following four gestures of victory, thumbsup, open and close using IDE (open licensed software). Figure 5 shows the gestures performed by a robotic hand.

Figure 5: Gestures performed by robotic hand

2.2 Data Acquisition

For signal acquisition Myo Armband was utilized. It is a light weighted armband with a heap of just 93g and expandable between 7.5–13inches. It contains 8 Medical Grade Stainless Steel EMG sensors, fundamentally delicate, 9 turn Internal Measurement Unit (IMU), and there is whirligig, accelerometer and magnetometer all of 3-center point. It involves ARM Cortex M4 Processor.

It interacts with computer by methods of Bluetooth Smart Wireless Technology. Fig.6 shows Myo Armband sensor.

Figure 6: Myo Armband

A subject wore it on the forearm that continuously read the muscle data and sent it via the in-built Bluetooth to the laptop present right next to the subject in form of a vector. Figure 7 shows the position of sensor.

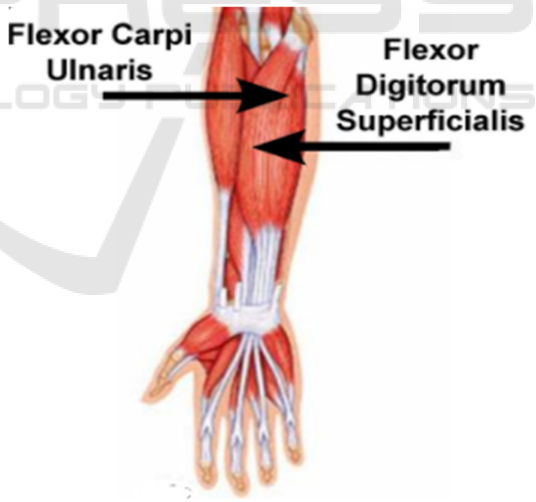

Figure 7: Location of electrodes on muscles (frontal view.)

The laptop's Bluetooth received the incoming data and passed it to the MATLAB.

The experimental setup decided for this project is as follows:

- Number of classes (actions) = 4
- Number of subjects = 10(4 male and 6 female)
- Number of male subjects = 4

- Number of female subjects = 6
- Age group = 20-25 years
- Number of activities per subject per trial= 10
- Total time for each trial = 40s
- All subjects are healthy.

2.3 Methods of Detecting Waves

Myo Armband is an advance band that read the electrical activity of muscles and movement of arm and signals are filtered by the Myo Armband on sampling frequency of 200Hz, in order to detect wave two methods are as follow:

- Detecting wave by Peak.
  Detecting wave by Peak is one of those best solution in which the required patch of the signal can be separated from the whole signal and can be utilize in the work. This method used the data of the indices of peaks by separating then-point to the left of each index and same n-point to the right of each index.

- Detecting wave by Slope.
  Wave detection can also be found by a method in which the required signal can be separated through the whole signal. In this technique the separation of the point begins when slope starts to increase till the time when it start decreasing.

2.3.1 Features Extraction

Signal provided by using Myo Armband is a filtered signal, Savitzky Golay filter was applied to smoothen the signal (Christov, 2018).

The features were extracted from filtered EMG signal. This features extraction help to reduce the data in beneficial way.

In order to get higher end result of classification, features vector must be cautiously selected. We extracted 4 features for each electrodes making a total of 32 features (4 features * 8 electrodes). The best results were found to be Standard Deviation (STD), Waveform Length (WL), Root Mean Square (RMS) and Mean Absolute Value (MAV) (Hong, Khan and Hong, 2018). Fig.8 shows unfiltered EMG signal whereas Fig.9 shows filter EMG signal.

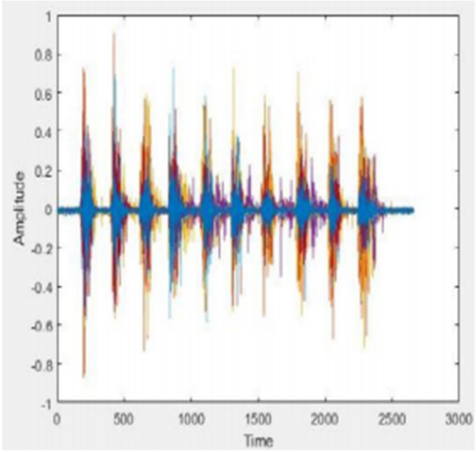

Figure 8: Un-filtered EMG Signal

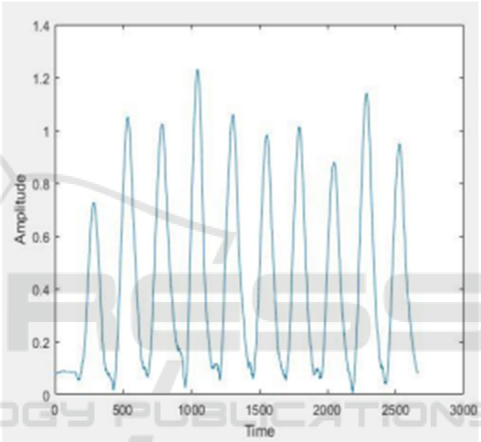

Figure 9: Filtered EMG Signal

2.4 Classification

Classification is the main part of the project and it is used to classify the signal as it is known as pattern-recognition in simple language.

We skilled three classifiers on extracted features, the classifiers have been Linear Discriminant Analysis (LDA), K-Nearest Neighbors (KNN), Support Vector Machine (SVM). The classifiers such as LDA, SVM and KNN were trained separately on each of the above feature. Maximum accuracy was achieved using Root Mean Square as a feature on KNN.

2.5 Interfacing

Next step of this project is to build the interface. At first Myo-Armband and laptop was interface, followed by laptop to robotic hand. Myo Armband can be also interfaced with any other devices through

Myo-script. To write a script for Myo-armband and to control any device, myo-script was used. Myo-scripts coding language is lua, which is commonly used for coding a lot of games or software. Notepad ++ for lua is used because Notepad++ supports different programming languages. It is also a source code for free.

Myo Armband was interfaced with the laptop, next step was to again interface the laptop with the robotic hand (L. F. Sanchez, 2017)

3 EXPERIMENTATION

Using the essential examination approaches for grouping we utilized three classifier which are as follow:

- Linear Discriminant Analysis (LDA)
- K-Nearest Neighbors (KNN)
- Support Vector Machine (SVM)

One of the non-parametric method of classification is K-Nearest Neighbors (KNN) works by using the fact of 'feature similarity'. The data will be assigned in that category whose feature are more likely similar with the incoming data points (Altın and Er, 2016). 98.9% accuracy was achieved by using KNN.

Another technique for arrangement Support Vector Machine (SVM) which is a watch over machine calculation by placing every information thing in a form of a points in n-dimensional space, n is known as numbers of features you have. After that a hyperplane was form between the data which actually separates the classes and the new data is divided into classes on the basis of side gap (Alkan and Günay, 2012). With the each feature value being the value of a particular coordinate, giving us the exactness of 94.7 Percent the element of Mean Absolute value (MAV). Fig 9 presents the Percentage accuracy versus features on three different classifiers.

The basic research technique is LDA. It works or identify different classes by calculating the probability using the Bayes Theorem (Alam and Arefin, 2018). 94.5% accuracy was achieved by using LDA from the feature of Mean Absolute value (MAV).

4 CONCLUSIONS

The hardware including the mechanical and electrical parts was completed within the designated timeline. Final application of LDA, SVM and KNN algorithms with maximum accuracy are completed.

A classifier model of LDA, SVM and KNN was trained using 400 movements (100 for each class). As the resulting data points after feature extraction was already well separated, the accuracy achieved was (accuracy of all classifier)

Although final accuracy will be calculated by taking account some more observation. The classifier was trained using 4 feature of data

- RMS (accuracy)
- WL (accuracy)
- STD (accuracy)
- Mav (accuracy)

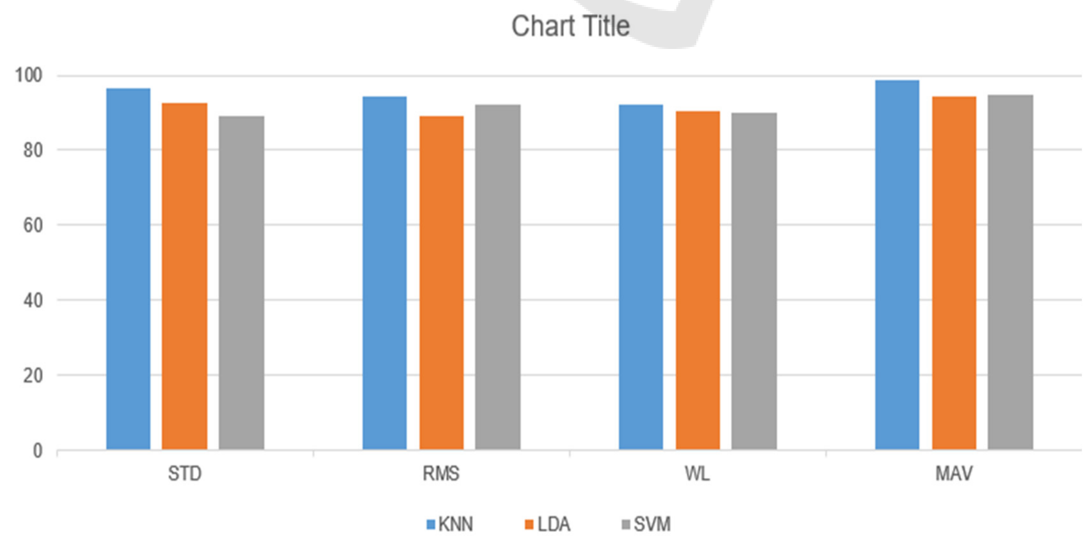

Figure 10: Percentage accuracy versus features on three different classifiers

Real time classification was checked by performing the gesture on real time and seeing if the predicted response is same as the performing one. Testing of the entire system was done step by step.

This project was started with an aim help the deprived and disabled people with upper limb disability. We applied our engineering knowledge and developed a Myo-robotic hand for this noble cause. The work done so far in Pakistan for the rehabilitation cause is not such as should have been. This motivated us to work on Myo-robotic hand.

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