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AIR TOUCH: Human Machine Interface Using Electromyography Signals

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Abstract. Novel interactions between futuristic devices and humans in the ever-expanding digital world is gaining momentum in the current era. In this paper, a system is proposed where electromyography (EMG) signals are used to control the cursor on a PC with the movement of the hand, making effortless interaction between user and the computer. The hand movements are detected using accelerometer and EMG signals acquired using electrodes are used to classify the hand gestures. Time domain features are extracted from the EMG signals and the gestures are classified using K-Nearest Neighbor (KNN) classifier. The operation to be performed on PC is determined from the gesture with help of a suitable interface. This system is implemented to perform the positioning of the cursor and two of the most common actions of a mouse, namely, single click and double click. The system showed an accuracy of 98% in classifying the gestures.

1. INTRODUCTION

We live in an era in which technological advancement and development happens at a rapid rate. Effortless and user-friendly interaction between humans and digital devices is the need of the hour. This is especially relevant in the case of people with disability or older generations who are not well versed with digital devices. Wearable devices which can assist humans to interact with digital world is becoming very popular. One of the ways to operate these devices is by making use of the biological signals and extract information from them. Various signal processing tools and machine learning algorithms have been developed to effectively understand these signals [1]. These can be effectively used in our daily life other than clinical purposes.

Gesture based control systems have always attracted researchers and they have gained popularity in a wide range of applications like robotics, automation, gaming and military applications [2]. The most commonly used biomedical signal in gesture-based control is the electromyography (EMG) signal. These are electrical signals that are generated from the muscles during its contraction and relaxation. Analyzing these signals helps to use them as a control signal in human-machine interface. A methodology to control a robotic arm using EMG signals from the upper arm is proposed in [3]. It uses a combination of position trackers and EMG signal to develop a model for 4 joint angles on the upper limb. The kinematic equation for these joints is deduced and used for training. Hand gesture based wireless mouse enabling an effortless interaction between the human and the computer was developed in [4]. A robot with a gesture controlled 3-axis accelerometer is presented in [5]. In both [4] and [5], a wireless transmitter/receiver module is used for purpose of gesture control.

The paper [6] discusses a mobile-phone based brain-muscle-computer interface where a person with advanced spinal muscle atrophy is able to control a television using EMG signals and a mobile phone.

The mobile phone is equipped with an IR blaster which is used to control the television. Electrodes placed at a position just above the ear acquires EMG signals. This signal is used by the phone which processes the signal and produces an output code to control the television.

One of the most important steps in using any biomedical signal for control purpose is to obtain a smooth signal from the raw EMG. [7] and [8] describes the various steps in this direction. There are different types of noise that affects strength of the EMG signal such as interference from power supply, noise from neighboring muscles, DC offset, dead cells in the skin, quality of electrodes and more [7].Different blocks in signal conditioning needed to acquire a clean EMG signal is discussed in [7] and [8]. Some of them being pre-amplifier for initial amplification, high pass and low pass filter to eliminate higher and lower frequency noise and rectifier to get a positive signal.

Feature extraction plays a crucial role in EMG signal analysis and classification, especially when used as a control signal, as it could improve or reduce the speed and effectiveness in identifying the gesture [9]. Features like Integrated EMG (IEMG), Variance, Mean Absolute Value (MAV), Zero crossing, Wilson Amplitude were used here. This paper also showed that the selected features can be used to effectively classify hand gestures from EMG signal. Selecting the right set of features to be extracted is crucial in the effective prediction of the data. There are two approaches in feature selection namely, time domain features and frequency domain features. Time domain features can be calculated directly from the raw data and does not require additional computing while the frequency domain features require complex computations [10]. After feature extraction, a suitable classifier has to be chosen to classify the data and make predictions. There are different classifiers such as Probabilistic Neural Networks (PNN), Support Vector Machine (SVM), K-Nearest Neighbor (KNN) algorithm, etc. The classification performance of all these classifiers is mostly similar [11] even though the complexity levels are different. [12] presents a single channel EMG model, which is used to classify various movements for dexterous prosthesis control. EMG signals for prosthetic control using frequency analysis was implemented in [13].

In [14] EMG signals for multiple hand gestures is classified using neural network approach. The system is implemented in MATLAB with EMG signals acquired using Arduino with the help of MyoWare™ Muscle Sensor. Features like Mean Absolute Value (MAV), Root Mean Square, Median, and Wavelength (WL) were used for classification. The overall system showed an accuracy of 80%.

In this paper, a gesture-based system for the human computer interaction is proposed where the need of a mouse is eliminated. An accelerometer sensor is used to measure the motion of the hand, in particular the acceleration in any direction and is used to position the cursor at the needed location on the screen. The electromyography signal from the user helps to identify the operation that the user wants to perform i.e., single click, double click or do nothing. Time domain features such as mean absolute value (MAV), root mean square (RMS) and simple square integral (SSI) are taken as the features to be extracted and to be used for classification. These features can be calculated in real time with much less computations compared to frequency analysis.

2. METHODOLOGY

2.1 Overview

The general block diagram of the proposed system is shown in Figure 1 which consists of two subsystems. The first one is the cursor system to mimic the mouse movements and the second is the EMG signal acquisition, conditioning and prediction system that mimics the mouse function which is, single and double click. The cursor system is designed using the accelerometer sensor. The EMG signal acquisition, conditioning and prediction system consists of surface electrodes and signal conditioning circuit. The Arduino board is interfaced both with the accelerometer sensor and the EMG signal acquisition and conditioning circuit, and acts as the central unit that provides the acceleration value and EMG value to the computer. The feature extraction and classification are carried out and the classifier output is used to drive the cursor. The acceleration data is used to identify the cursor positioning and the EMG data corresponding to a clenched fist or a relaxed hand is used to determine the operation to be performed.

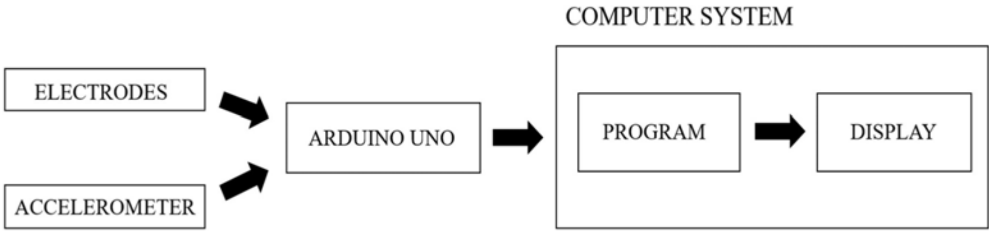

Figure 1. General block diagram

2.2 EMG Signal Conditioning

The raw EMG signals obtained from the electrodes is in the range of 1 to10 mV and at a frequency range of 10 Hz to 200 Hz with dominant frequency components in the range 50 to150 Hz. The raw EMG data acquired is not reliable to use directly as the signal will be a mixture of EMG data and noise. Figure 2 shows the block diagram of the signal conditioning circuit to obtain a smooth signal from the raw EMG. The signal is amplified and passed through a high pass filter thus eliminating the low frequency noise. The signal is then rectified and passed through a low pass filter that remove high variations in the signal. Thus, a smooth signal is obtained after the signal conditioning operations.

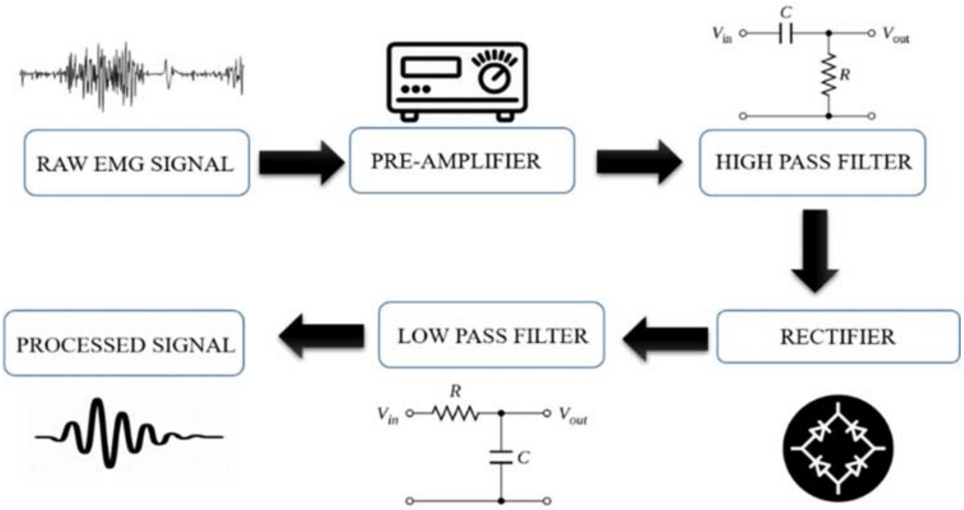

Figure 2. Signal Conditioning block diagram

2.3 EMG Classifier and Prediction

Classification is one of the most significant steps in determining unknown data from the known. For the EMG prediction system, features from the conditioned EMG data need to be calculated and then classified using a classifier. In this work, K Nearest Neighbor (KNN) classification algorithm is used as the classifier. The time domain features selected for classification are root mean square (RMS), mean absolute value (MAV) and sum integral square (SSI). These features can be calculated in real time with much less computations compared to frequency analysis.

The EMG signal data is divided into segments of 30 values each and the features are extracted for this segment. These values are used by the classifier to predict the action of the hand, i.e., relaxed or clenched hand. The relaxed hand is labelled 1 and the clenched fist is labelled 2 for prediction. The predicted action is used to find if the user wants a single click, double click or no action. Though, single click and double click are the actions that are considered, double click is the combination of two single clicks. Hence, the system is designed to perform only a click and when the user performs two clenched fists back to back, the action turns out to be a double click.

2.4 Cursor System

The cursor system consists of an accelerometer sensor (ADXL345) and the Arduino board as shown in Figure 3. The values from the accelerometer are used to find the roll and pitch, and this value is used to position the cursor on the screen. The cursor position is determined relative to the previous position of the cursor like a normal mouse. Since a 30 segment value is calculated for the EMG data, the cursor system also finds the average of 30 values obtained from the accelerometer. The ADXL345 sensor does not have a memory so the sensor needs to be calibrated each time it is powered ON. In this work, the values were manually found and the offset value is directly included in the setup function of the Arduino.

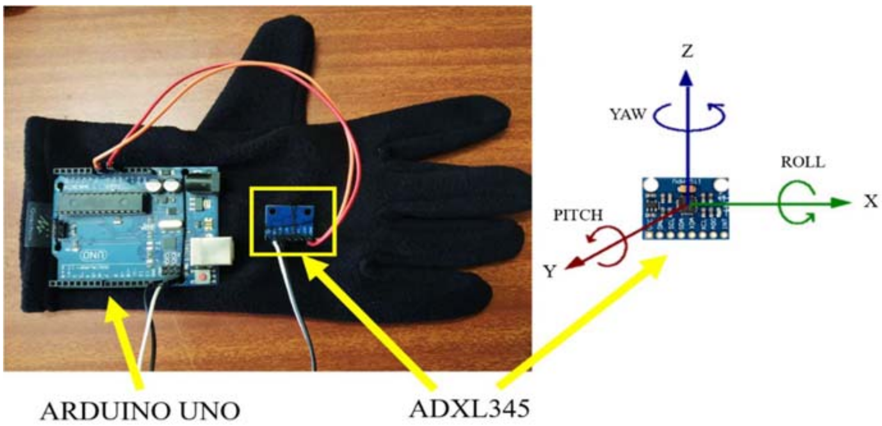

Figure 3. Cursor positioning system using Arduino and ADXL345 sensor

3. RESULTS AND ANALYSIS

3.1 Training and Simulation Data

In this paper, the publicly available data for EMG from the UCI Machine Learning Repository: "EMG data for gestures Data Set" is considered. This data set had raw EMG data of a series of static hand gestures performed by 36 subjects. A total of seven gestures were included in the dataset which are: hand at rest, hand clenched in a fist, wrist extension, radial deviations, wrist flexion, ulnar deviations and extended palm. The gestures we are interested in are the hand at rest and clenched in a fist, they are labeled 1 and 2 respectively for our analysis. A part of the same data is used for simulation and analysis. For the cursor dataset, the data from the cursor system designed earlier is used to log the data. A python program was used to log the data and convert it into a csv file.

For simulation, a combination of cursor data i.e., accelerometer sensor data and EMG data had to be designed. In the proposed system, at any instance, the Arduino provides two values from the accelerometer sensor and one EMG value. The cursor log was created using the cursor system for a decided path on the screen. The EMG data for the wrist clenched position and relaxed position was added at the appropriate instances of the cursor log to create the final simulation data.

3.2 EMG Training and Prediction
For training the classifier, data from one of the 36 subjects was used. Before the EMG data can be used for training, signal conditioning is carried out. Each signal is multiplied with a gain of 100, fed through a high pass filter with a cutoff frequency of 50 Hz, rectified, again passed through a low pass filter with a cutoff 150Hz and finally multiplied by a gain of 10. The conditioned data is divided into segments and the time domain features i.e., RMS, MAV, and SSI are calculated.

3.2.1 Root Mean Square (RMS)
The root mean square is a popular feature used in EMG signal analysis. It is defined as the root of mean of the square of EMG values.

$$RMS = \sqrt{\frac{1}{N}\sum_{i=1}^{N} k_i^2} \tag{1}$$

3.2.2 Mean Absolute Value (MAV)
The mean absolute value is the mean of the sum of absolute values of the EMG signal.

$$MAV = \frac{1}{N}\sum_{i=1}^{N}|k_i| \tag{2}$$

3.2.3 Simple Square Integral (SSI)
The simple square integral is the summation of the square of values of EMG signal

$$SSI = \sum_{i=1}^{N} k_i^2 \tag{3}$$

After feature extraction, the data is passed to the KNN classifier and is used for training the classifier. This trained classifier is used for prediction of label.

3.3 Results

3.3.1 Classifier
The results and accuracy of the classifier is shown in Figure 4 and Table. 1. Figure 4 shows the confusion matrix of the classifier. The values from the confusion matrix is used to determine the precision and recall mentioned in Table.1. Label 1 is hand at rest and label 2 is clenched fist. In the case of label 1, the precision is 0.99 indicating that from the total predicted values 99% of them are correct. The recall for label 1 indicates that among the true values the classifier predicted correctly 97% of the true values. Similar comments are true for label 2 also. The F1 score indicates the overall performance of the classifier for a particular label. The F1 score for both the labels are 0.98 indicating a reliable classification of both the labels. The accuracy is the overall performance of the classifier and is 0.98. The support value indicates the total true data points that were used for classification. So there were 104 data points with label 1 and 103 data points with label 2. Thus the total data set turns out to be 207 points.

Table 1. The metrics for the classifier

Label	Precision	Recall	F1 Score	Support
1	0.99	0.97	0.98	104
2	0.97	0.99	0.98	103
Accuracy		0.98		207

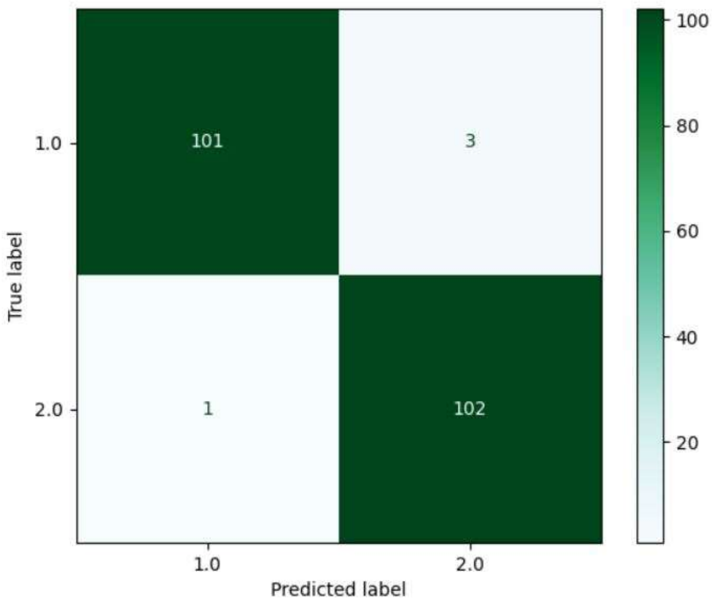

Figure 4. Confusion matrix using data of subject 3 for prediction and of subject 10 for training

3.3.2 Simulation

Figure 5 shows the beginning of the program where the cursor is positioned at the center of the screen and the terminal shows the status of the system. The cursor is indicated using a yellow circle. The X and Y values are the coordinates which are calculated based on the values from the sensor. The X and Y values are relative coordinates i.e., these are relative to the previous position of the cursor. So initially the coordinates are 0 and 0.The KNN classifier result is what is shown as PREDICTED and ACTUAL values. The predicted value is what the KNN predicts and the actual values is the known value that was passed to the KNN classifier. So initially the hand is at rest, thus the label is 1.

Figure 5. The initial cursor position and the EMG label predicted

Figure 6 shows the change in X coordinate and the corresponding change in the cursor in the direction of the X axis from the initial position. The predicted value shows 1 indicating that the user has a relaxed hand.

Figure 6. The movement of cursor with the change in value of X coordinate

Figure 7. The movement of cursor with the change in value of X and Y coordinates

Figure 7 shows the movement of the cursor in both X and Y directions with the corresponding coordinate change. The X and Y values represent relative change in cursor movement. The predicted value shows 1 indicating that the user has a relaxed hand. Figure 8 shows the cursor on the folder which needs to be opened and is in the process of performing a double click. The predicted value shows 2 indicating that the user has a clenched fist.

Figure 8. The double click action performed when the EMG label is predicted as 2 back to back

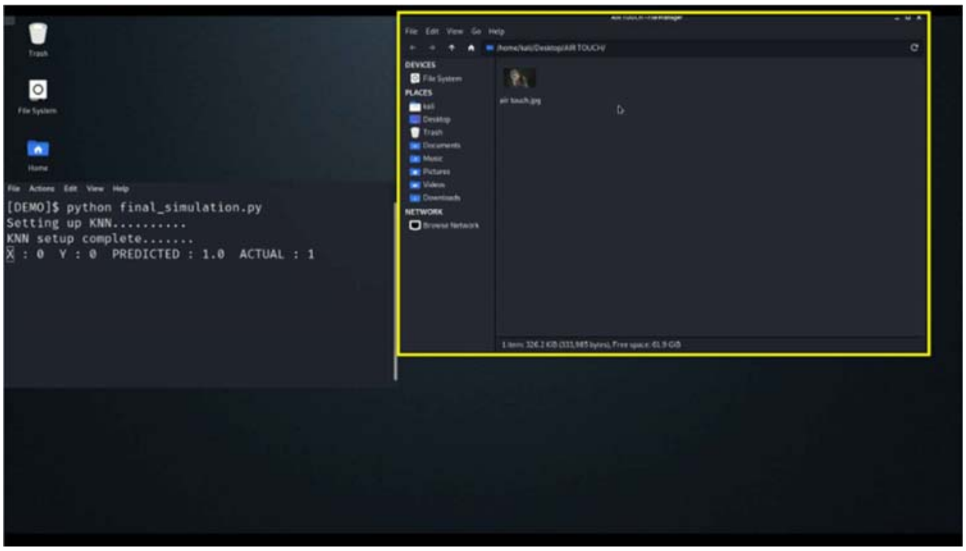

Figure 9. The folder is opened

Figure 9 shows the result after the double click. The folder is opened as intended. The predicted value shows 1 indicating that the user has now relaxed his hand.

4. CONCLUSION AND FUTURE SCOPE

In this work, a gesture-based system for human computer interaction was designed and implemented. This is a technological advancement that could happen in the near future. We were able to show the role of electromyography not only in a biomedical aspect but also as a technology that could influence our day-to-day activities. The system designed has shown satisfactory results and improvements on the present system can bring out the best potential in the proposed concept.

The system that is demonstrated here has a lot of scope for improvement. The accelerometer sensor can be replaced with a gyroscope to improve the degree of freedom of the system. KNN classifier was used taking into consideration the simplicity in implementation and expandability. Addition of a new class of gesture is easy using KNN and the new function added to the system can be easily incorporated in the software. But still the KNN algorithm can result in overhead for the system and so alternatives like fuzzy logic and Support Vector Machine (SVM) can be implemented.

5. REFERENCES

[1] Abdulhamit S Practical Guide for Biomedical Signals Analysis Using Machine Learning Techniques.1st edn. Masucci Stacy, United Kingdom (2019).
[2] Dakshit C, Jeevanigi J, Tamanneeta G and Sailaja V Gesture Controlled Bomb Diffusing Mobile Robot *2nd International Conference on Intelligent Computing and Control Systems*, ICICCS 2018, Institute of Electrical and Electronics Engineers Inc., p.1027-1031 (2019)
[3] Panagiotis K A and Kostas J K An EMG-Based Robot Control Scheme Robust to Time-Varying EMG Signal Features *IEEE Transactions on Information Technology in Biomedicine Vol. 14 No. 3*, May 2010

[4] Sohel A, Mohammed A Z and Irshad B S Accelerometer based Wireless Air Mouse using Arduino Micro-controller Board *Global Conference on Communication Technologies (GCCT 2015)*
[5] Rashmi V, Akshit S, Shantanu M, Saurabh D and Aman B Gesture Control Robot Using Accelerometer *4th IEEE International Conference on Signal Processing, Computing and Control (ISPCC 2k17), Solan, India, 2017*.
[6] Scott V and Sanjay S J, Brain–Muscle–Computer Interface: Mobile-PhonePrototype Development and Testing. *IEEE Transactions on Information Technology in Biomedicine, Vol. 15, No. 4, July 2011*
[7] Sharmila K, Sarath T V and K I Ramachandran EMG Controlled Low Cost Prosthetic Arm *IEEE International Conference on Distributed Computing, VLSI, Electrical Circuits and Robotics, DISCOVER 2016 - Proceedings, Institute of Electrical and Electronics Engineers Inc., p.169-172 (2017)*
[8] Ismail S, Nur Husna Bais, Bun Seng C, Mohd Zuhir H and N Bolong Electromyogram (EMG) Signal Processing Analysis for Clinical Rehabilitation Application *Third International Conference on Artificial Intelligence, Modelling and Simulation (2015).*
[9] Rim B, Sameh F, Houda D, Olfa K, Evaluation of EMG Signal Time Domain Features for Hand Gesture Distinction *16th International Multi-Conference on Systems, Signals & Devices (SSD'19), (2019).*
[10] Chitra P, Kumaran B V, Pranav M V and Dr. Sreeja, K Classification of sEMG Signals for Controlling of a Prosthetic foot using SVM and KNN *IEEE International Conference on Intelligent Computing and Control Systems (ICCS), May 2019, Madurai, India.*
[11] Anish C T and Balakrishna G, Feature Analysis for Classification of Physical Actions Using Surface EMG Data *IEEE sensors journal, vol. 19, no. 24, (2019): 12196-12205*
[12] Yogesh P, Vibha G and Ram A J, Comparative Analysis between SVM & KNN Classifier for EMG Signal Classification on Elementary Time Domain Features *4th IEEE International Conference on Signal Processing, Computing and Control (ISPCC 2k17), Solan, India (2017).*
[13] Supriya Mary S, K I Ramachandran, Myoelectric Control System based on Wavelet Features *2018 4th International Conference on Biosignals, Images and Instrumentation (ICBSII), Chennai, 22-24 March 2018.*
[14] Mohd Azlan Abu, Syazwani Rosleesham, Mohd Zubir Suboh, Mohd Syazwan Md Yid.,Zainudin Kornain and Nurul Fauzani Jamaluddin Classification of EMG signal for multiple hand gestures based on neural network *Indonesian Journal of Electrical Engineering and Computer Science, Vol. 17, No. 1, January 2020, pp. 256~263.*