EMG-Based IoT System Using Hand Gestures for Remote Control Applications

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Abstract- Smart technologies are increasingly being utilized in all areas to improve our lives. The Internet of Things (IoT) is revolutionizing the way we live and work. A large number of impairments and disabilities in human body is increasing day by day. So to improve the quality of life of disabled people researchers think on the necessity of simple and natural human-machine control interface. This paper presents an IoT-based hand gesture control system utilizing a combination of EMG and motion-related signals from an inertial measurement unit (IMU). By using the system, a user can use eight different hand gestures to remote control electrical devices of a smart home in real-time. The entire system from sensing devices to an end-user application was implemented. Two use cases including light bulb control and robot arm control were used for testing and validating the system. This present an embedded solution for real-time EMG based hand gesture recognition. It involves acquisition of EMG signal, hand gesture recognition and controlling.

Indexed Terms- Internet of Things (IoT), EMG (Electromyography), Sensing devices, Human machine interface, Hand Gesture Recognition, Real-Time.

I. INTRODUCTION

The EMG signal is the superposition of the action potentials of the muscle tissue cells occurring during a voluntary contraction. The resulting electrical activity can be acquired by using surface electrodes and appropriate signal conditioning circuitry. Sometime surface EMG signals are affected by several sources of interference, like as the power line noise or the high signal variability caused by the contact impedance of the sensors, the skin perspiration and by the crosstalk between different muscular fibres. The muscular activity recognition is based on simple threshold detection. The measuring of EMG signals can be acquired either directly from within the muscle (termed as invasive as sEMG) or from surface of the skin above a muscle (termed surface EMG or sEMG). Electromyogram (EMG) signals are generated by muscles when activated by the nervous system, which generates electric potential. The more force applied to the muscle the larger electric potential generated from the muscle cells. Typically, EMG signal varies from 10 Hz to 500 Hz in terms of spectrum. The raw EMG signal ranges no more than 5 mV before amplification. It may seem small in nature, but after amplification, the signal can produce very valuable data to researchers. These signals then cause contraction of the muscle which results in body movement. These EMG signals can be read through the use of surface EMG electrodes to assess the muscle to read the signals from the skin above the desired muscle.

These EMG signals can be read through the use of surface EMG electrodes to assess the muscle to read the signals from the skin above the desired muscle. EMG signals can be useful for developing systems that can help the disable. This assistance can be performed through the development of prosthetics. The medical field has benefited from intensive research in EMG signal analysis in the past couple decades, which has improved the quality of life for those with psychomotor skill disabilities.

This study aims to design and develop a wearable EMG based human machine interface system for in home assistance. Specifically, the system shall read EMG signals from the user; The system shall be calibrated to provide four control commands left, right, forward, and stop based on EMG patterns from different movements; The system shall send out commands wirelessly to control a service robot; The system shall generate PWM signals for motor control; and the system shall provide live video for the purpose of monitoring.

II. PROPOSED SYSTEM

The proposed IoT system architecture shown in below figure, consists of 4 main parts including sensing devices, gateways, cloud servers, and smart devices.

Fig: The presented EMG-based IoT system architecture

The sensing device is responsible for collecting EMG signals and motion-related signals (e.g., acceleration and angular velocity) from a user's arm and transmitting the collected signals to a smart gateway via Bluetooth. The smart gateway receives the data transmitted from sensing devices, processes the data (e.g., filtering noises and extracting information from the data), and then forwards the processed data to cloud servers which can store big data and perform complex algorithms for providing a high quality of services. A smart gateway can serve several sensing devices simultaneously. It consists of four main parts including an electrical device, a connection circuit, a micro-controller, and a wireless communication module. An electrical device such as a 230V light bulb is connected with a 5V micro-controller via a connection circuit built from direct-current (DC) components. The micro-controller is responsible for monitoring the status of the electrical device and controlling the device.

In details, it communicates with a home gateway via Wi-Fi. It is noted that the home gateway connecting with smart devices and the smart gateway mentioned above EMG-based IoT System using Hand Gestures for Remote Control Applications Dept of ISE 2021-22 7 connecting with sensing devices (e.g., EMG bands) are two different devices that can be located in different geographical locations. In the presented system, band wearing at a user's arm for collecting EMG signals and motion-related data is one of the most important components as it plays a large impact on the quality of the system including accuracy and gesture recognition. Therefore, the Bluetooth communication between the band and the smart gateway must be carefully considered. We have applied a mechanism shown in below figure, to establish the connection between the band and the smart gateway and to collect data including EMG and motion-related signals. The mechanism was built by customizing the communication flow used in the python library.

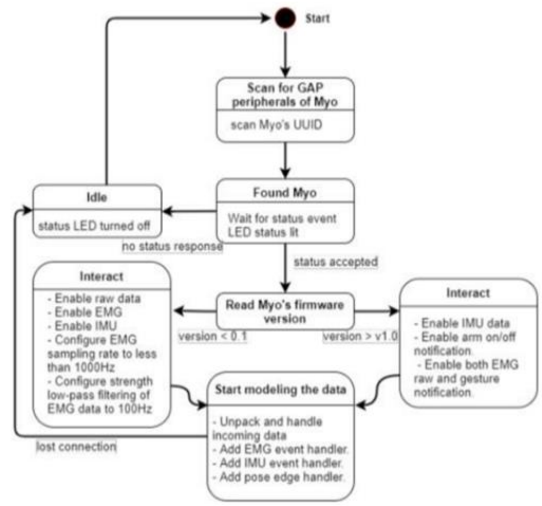

Fig: Bluetooth communication flow state diagram

III. METHODOLOGY

The EMG acquisition and hand gesture recognition is an electronic platform for hand gesture recognition which recognizes the hand gestures & controls the device. The block diagram of EMG acquisition and hand gesture recognition is shown in Fig.

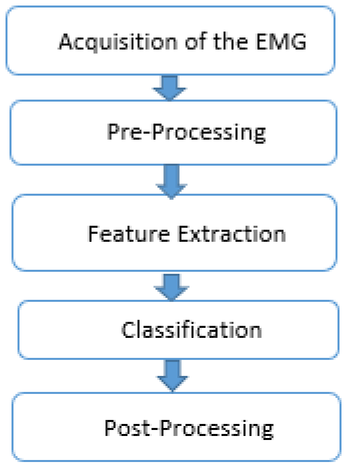

Fig: Block Diagram

In above, the muscle movement is capture by electrodes and that capture signal is given to signal conditioning circuit to amplify and remove noise from signal. After that from signal the hand gesture is recognized and from that signal device is controlled. EMG hand gesture recognition and controlling are having less cost, easy to build, less complex.

A. Acquisition of the EMG signals

There are two types of EMGs: surface and intramuscular. In surface EMG, non-invasive surface sensors are placed on the skin to record the electrical activity of the muscles under it [8], [10].In intramuscular EMG, a needle is introduced in the muscle. In this project, we will use surface EMG. Sensors used to acquire the EMG can be homemade and commercial, such as the Myo armband [21]. Additional some projects use EMG sensors with other types of sensors such as inertial magnetic units (IMUs). In this project, we will use the Myo armband sensor. We chose this sensor because of the following reasons: low cost, small size and weight, software development kit (SDK) and because the Myo is a small and open source sensor that is easy to wear. The Myo armband has eight EMG surface dry sensors, and an inertial measurement unit (IMU). The eight surface sensors measure 200 samples per second of the electrical activity of the muscles. The IMU has 9 degrees of freedom (accelerometer, gyroscope, and orientation in the X, Y, and Z-axes). The Myo armband uses Bluetooth technology for transmitting the data to the computer. Finally, the Myo armband has incorporated a proprietary system capable of recognizing five gestures of the hand: pinch, fist, open, wave in, and wave out.

B. Pre-processing

The pre-processing stage is necessary to obtain only the information of EMG signals without noise. EMG signals are shown without reprocessing. We will use two types of pre-processing:

- Rectification.
- Filtering

The rectification is used because the EMG signals have negative and positive values for the repolarization and depolarization of the fiber. It is necessary to filter the EMG signals to extract the essential information (e.g., discarding noise). Prior to the filtering, we will make an exhaustive analysis of the frequency components of the EMG signal, in order not to lose valuable information in the filtering process. We will test the following type of filters: infinite impulse response and finite impulse. EMG signals without preprocessing of Myo armband response.

C. Feature Extraction

In this stage, we will apply different techniques in time, frequency, and time-frequency domains to obtain meaningful information for each class to be recognized. In the time domain, we will test features like the mean absolute value, nth-order autoregressive coefficients, zero crossing, length of the signal, sign of slope changes, modified mean absolute value, simple square integral, root-mean-square value, sample mean and variance, log detector, average amplitude change, maximum fractal length, EMG integral, Willison amplitude, histogram, cepstral coefficients, and sample entropy. In the frequency domain, we will test features like the power spectrum, mean and median frequencies, frequency histogram, mean power, and spectral moments. In the time-frequency domain, we will test features like the wavelet transform. We will analyze the classifiers to develop a classification model.

D. Classification

The classification stage determines to which class (gesture) a feature vector extracted from the EMG signals belongs to. We will use two types of classifiers: parametric and nonparametric. The complexity of parametric classifiers is constant with the change in the number of training examples. We will test the parametric classifiers, including the logistic regression, linear discriminant analysis, naive Bayes, perceptron, artificial neural networks, and support vector machine. The characteristics of the parametric classifiers are simple to understand, fast to learn from data and can work well even if the fit to the data is not perfect. The nonparametric classifiers have a potentially infinite number of parameters. We will test the nonparametric classifiers, including k-nearest neighbors, and decision trees. The nonparametric classifiers can fit several functional forms and not assume the underlying function. The most common classifiers used in the hand gesture recognition with EMG are support vector machines, and neural networks.

E. Post-processing

In the post-processing stage, we will adapt the result of the classification stage for different applications of the proposed model. Therefore, in this stage, we will refine the output of the classifiers to obtain high recognition accuracy. For example, in Figure 5 a person makes a gesture in a time interval and a classifier performs four classifications during the time interval. The hand gesture recognition model must deliver a single result. Therefore, the model executes a post-processing technique (e.g., mode) to obtain a single result.

CONCLUSION

The EMG hand gesture recognition system works on the concept of electromyography signal. It is used in variety of application. A large number of impairments and disabilities in human body are increasing day by day. To improve the quality of life of the disabled or aged people researchers think on the necessity of simple and natural human-machine control interface. So, the EMG based hand gesture can help to develop good machine interface that increases the quality of life of the disabled or aged people. Thus, depending upon the application the electrodes, data acquisition system and the data processing unit can differ. Communication through gestures has been used since early ages not only by physically challenged persons but nowadays for many other applications such as human computer interactions, robotics, sign language recognition, etc.

FUTURE WORK

The presented system proved that the concept using EMG, acceleration, and angular velocity together with IoT could be applied for different remote-control applications such as room heaters, air-conditioners, and ventilators. Regarding applications requiring a high level of accuracy and complex control such as controlling robot arm supporting elderly people or disabled people, the presented system needs to be more enhanced. Particularly, the data processing part at the smart gateway needs to be more advanced and smarter to deal with different noises. In addition, EMG signals from various users are different. Therefore, it is required that more complex and smart algorithms at cloud servers need to be implemented to deal with these cases. For example, machine learning and deep learning approaches, such as 1-D Convolution neural network could be applied for improving the accuracy of the system while maintaining low latency.

REFERENCES

[1] F. Gaetani et al., “Design of an Arduino-based platform interfaced by Bluetooth low energy with myo armband for controlling an under-actuated trans radial prosthesis,” in 2018 International Conference on IC Design & Technology (ICICDT), pp. 185–188, IEEE, 2018.

[2] Y. Fan et al., “Improved teleoperation of an industrial robot arm system using leap motion and myo armband,” in 2019 IEEE International Conference on Robotics and Biomimetics (ROBIO), pp. 1670–1675, IEEE, 2019.

[3] T. N. Gia et al., “Fault tolerant and scalable iot-based architecture for health monitoring,” in 2015 IEEE Sensors Applications Symposium (SAS), pp. 1–6, IEEE, 2015.

[4] A. Jaramillo et al., “Real-time hand gesture recognition with emg using machine learning,” in 2017 IEEE Second Ecuador Technical Chapters Meeting (ETCM), pp. 1–5, IEEE, 2017.

[5] M. Nguyen, “Internet-of-things applications with hand motion for remote control: a case study on Home Automation and Robotic arm. Available:

https://www.theseus.fi/bitstream/handle/10024/339220/Nguyen Minh.pdf?sequence=2.

[6] D. zhu, “Myo-band Python library.” Available: https://github.com/dzhu/myo-raw.

[7] L. Matney, “CTRL-labs scoops up Myo armband tech from North.” Available: https://techcrunch.com/2019/06/27/ctrl-labs-scoopsup- myo-armband-tech-from-north/.

[8] “Esp-12e wifi module datasheets.” Updated: Jan. 2020, Accessed: Jan. 2020, https://docs.aithinker. com/ media/esp8266/docs/esp12e datasheet.pdf