EMG-based IoT System using Hand Gestures for Remote Control Applications

Minh Nguyen [1], Tuan Nguyen Gia[1], Tomi Westerlund[1]
[1]Department of Computing, University of Turku, Turku, Finland
Email: minh.nguyen@tuni.fi, tunggi@utu.fi, tovewe@utu.fi

***Abstract*—Electromyography (EMG) has been widely used for detecting a person's hand poses and remote control applications. However, the traditional EMG-based control systems have limitations such as short controlling range, and supporting the limited number of devices. There is a need for a more advanced system that can deal with the limitations while maintaining a high quality of services such as high accuracy level and controlling complex devices. Hence, we present a real-time and remote control Internet-of-Things system using EMG signals together with motion-related signals such as acceleration and angular velocity. A user wearing the Myo-band at his/her arm can remotely control devices via 8 different hand gestures. The entire system was implemented and tested via two use cases of home assistant and robot arm control. The results show that the presented system could achieve a high level of accuracy e.g., 100% accuracy for simple control and 90% accuracy for complex cases. This system can be a potential approach for smart home controlling and assisting disabled people.**

***Index Terms*—Electromyography, EMG, IMU, Internet-of-Things, Home Assistant, remote control**

I. Introduction

Electromyography (EMG) collected from a human arm has been widely used for control applications such as controlling electrical devices via Bluetooth or controlling robot arm [1], [2]. However, these applications have some limitations such as short-range (e.g., less than 100 meters), a limited number of supported devices, or low quality of service. Internet-of-Things (IoT) can be a suitable candidate for overcoming the limitations [3]. For example, IoT applications using EMG can be used for remotely controlling many devices in smart homes anytime and anywhere. Nonetheless, the applications can still be enhanced due to the limited number of functions e.g., five classes of hand gestures including pinch, fist, open, wave in, and wave out [4]. Hence, 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. It is noted that this paper is a summary of a thesis made by M. Nguyen [5].

II. System Design

The proposed IoT system architecture shown in Fig. 1 consists of 4 main parts including sensing devices, gateways, cloud servers, and smart devices. 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 connecting with sensing devices (e.g., EMG bands) are two different devices that can be located in different geographical locations.

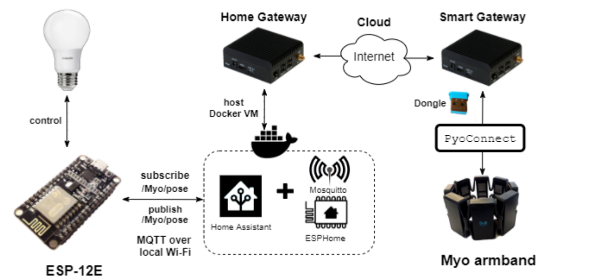


Fig. 1: The presented EMG-based IoT system architecture

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 Fig. 2 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 made by D. Zhu [6].

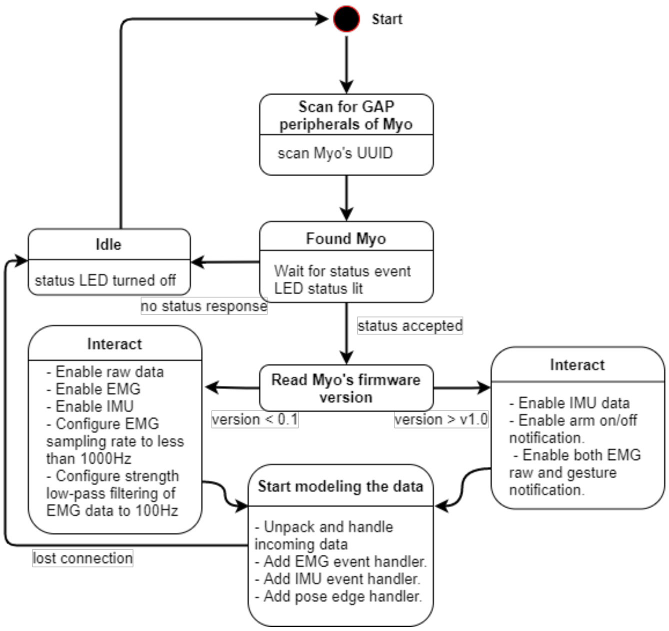


Fig. 2: Bluetooth communication flow state diagram

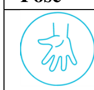
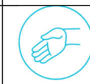
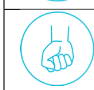
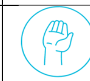
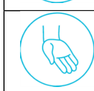
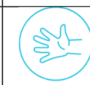
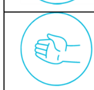
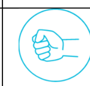
III. System Implementation and Results

We have implemented the entire system and validated the system via two use cases, including home assistant application and robot arm control application. Myo band developed by Thalmic Labs was used for collecting EMG, acceleration and angular velocity from a user arm [7]. The smart gateway and the home gateway were implemented by utilizing the Intel UPS-GWS01 gateways equipped with Intel® Atom™ x5-Z8350 processor, 4GB RAM, and Ubuntu. ESP8266 (e.g., ESP-12E), a 32-bit micro-controller with an integrated TCP/IP protocol stack [8], was used as a micro-controller for controlling electrical devices and connecting to the home gateway via Wi-Fi. In the home assistant use case, the 220V light bulb was connected with the micro-controller via a connection circuit using a relay. A user wearing the EMG band can turn on/off the light bulb in real-time even though the user is not at the same geographical location as the light bulb. Similar techniques can be applied for different electrical devices such as a fan or electrical heater. In such cases, the accuracy of the system is 100%. Particularly, a user can apply a double-tap motion that is two continuous touching times between a middle finger and a thumb to control the light bulb. If the current status of the light bulb is off, the device will be on and vice versa. The status of the light bulb is monitored by the micro-controller and synchronized with cloud servers. A user can monitor the device status by using a web browser.

The robot arm control use case is more complex than the home assistant use case as it requires different types of gesture input to control several robot arm's servos simultaneously. We applied 8 different gestures shown in Table 1 to control a robot arm using 4 servos. The system could achieve 90% accuracy for completing a mission such as using the robot arm to pick up an item and drop the item in the desired location.

In our system, the Message Queue Telemetry Transport (MQTT) protocol, a standard messaging protocol for the Internet of Things (IoT), was used for publishing/subscribing message transported between smart devices and cloud servers.

TABLE I: Pose-to-command protocol

Pose	Servo action	Pose	Servo action
	Open clamping hand, top servo move CCW		Rotate arm to the right, base servo move CW
	Close clamping hand, top servo moves CW		Raise arm, left servo moves CW
	Lower arm, left servo move CCW		Stretch arm reach, right servo moves CCW
	Rotate arm to the left, base servo moves CCW		Shorten arm reach, right servo moves CW

IV. Discussion and Conclusions

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 transradial 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-scoops-up-myo-armband-tech-from-north/.

[8] "Esp-12e wifi module datasheets." Updated: Jan. 2020, Accessed: Jan. 2020, https://docs.ai-thinker.com/_media/esp8266/docs/esp12e_datasheet.pdf.