Real-time Implementation of Electromyography for Hand Gesture Detection Using Micro Accelerometer

Subhendu Roy, Sraboni Ghosh, Aratrika Barat, Madhurima Chattopadhyay and Debjyoti Chowdhury

Abstract This paper focuses on the development of a novel approach for identification of various hand movements of a person that involves actions like fist opening, closing, and arm roll. The system consists of an electromyogram (EMG) sensor coupled with a digital MEMS accelerometer (full scale range of ±2 g, ±4 g, ±8 g, and ±16 g) for detection of hand gestures; this system is mounted over a strip strapped on the limb of its user. Based on the analysis of the EMG signals that are coupled with the MEMS accelerometer data from the limb, innumerous hand gestures are identified. Six-point-based calibration of the accelerometer data is done to eliminate mounting errors. The hand movements involving roll are better identified using this sensor topology, which is based on EMG sensor coupled with MEMS accelerometer than a system which just uses an EMG sensor to find out hand gestures because the accelerometer data gives precise information about the orientation of the limb in three-dimensional spaces.

Keywords Electromyography · Hand gesture recognition · MEMS accelerometer · Hand gesture · Six-point calibration

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S.S. Dash et al. (eds.), *Artificial Intelligence and Evolutionary Computations in Engineering Systems*, Advances in Intelligent Systems and Computing 394,
DOI 10.1007/978-81-322-2656-7_32

1 Introduction

The electromyography is the measure of electrical activity produced by the muscles which is usually represented as a function of time. This electromyography can be used in abundant applications including identifying neuromuscular diseases and control signal for prosthetic devices, controlling machines, robots. Hand gesture identification has numerous applications hence it has become an active research theme because of its use in human–machine interface (HMI) and it has got a focus in the sense that it will help the disabled people or aged people. The gesture recognition is to create a system that recognizes the gestures and use them for controlling the device. There is a significant body of research describing the use of pattern recognition of myoelectric signals to control prosthetic devices.

The surface electromyogram has the advantage of easy recording and noninvasive procedure. The hand gestures are captured by sensors through EMG signals [1]. When compared with the other biosignals, EMG is a noisy signal and it contains complicated types of noises that are caused by environment, electromagnetic induction, motion artifacts, interaction of different tissues, and sometimes it is difficult to get the useful information from the muscles that is left over by any disabled person. This paper presents an approach to detect, analyze, and classify EMG signals generated by the limb.

Accelerometers can measure acceleration from vibrations and the gravity [2–4]. Since both accelerometers and EMG sensors have their own advantages in capturing hand gestures, the combination of both the sensing approaches may improve the performance of hand gesture recognition. In this paper, a wearable gesture-based real-time interaction prototype using the fusion of accelerometer and EMG signals are presented.

The combination of EMG and accelerometers has previously been used by Roy et al. [5] for monitoring patients with stroke and by Li et al. [6] for sign language detection and game control. To the best of our knowledge, the combination of EMG and accelerometers has not been used in conjunction with prosthesis control. This study is an example of a general trend toward including more sensor types to maximize the environmental and intent information provided to the control system.

2 System Architecture

This gesture-based interaction prototype enables operating a mobile phone without touching it. It consists of a custom-wearable gesture-capturing device and an interaction application program running on a smartphone, worn on an user's forearm. The gesture-capturing device records EMG and accelerometer signals, and

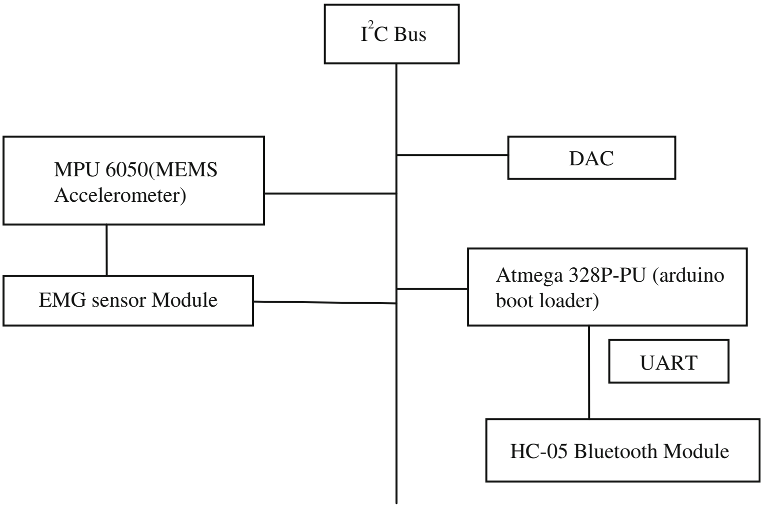


Fig. 1 Gesture capturing device (proposed)

sends them to the phone through a wireless connection. The interaction application program processes these signals, translates each gesture into instructions, and then provides feedback [7].

2.1 Gesture-Capturing Device

The proposed device comes as a wrist mountable belt, with the triaxial accelerometer MPU6050 mounted at the center of the band. An onboard processor, Atmega 328 reads the accelerometer data and sends it over to the bluetooth module after calibrating with the six-point algorithm as shown in Fig. 1. It consists of three dry EMG sensors connected via a main board embedded with an accelerometer. These three EMG sensors are attached to the main board in order to share the battery and the controller. The main board consists of a 1000 mAh lithium battery, a charging circuit, and a power circuit. After acquiring the signal by each EMG sensor, it passes through a band-pass filter.

2.2 EMG Sensor Design

In Fig. 2, the EMG sensor along with the associated circuitry is described. The signals from instrumentation amplifiers are used. The output of this amplifier passes through first-order low-pass filter (500 Hz) and high-pass filter (50 Hz), and finally

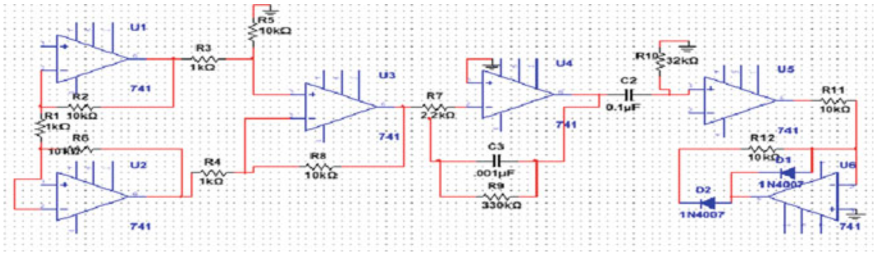


Fig. 2 EMG sensor design in MultiSIM

the filtered value is passed through the precision rectifier. Input of the instrumentation amplifier is connected with the electrode which is placed in the forearm of the user. The output of the precision rectifier is connected to the cathode ray oscilloscope (CRO) for observing the corresponding waveform.

2.3 Six-Point Calibration of Digital Accelerometer

Measurement accuracy of the accelerometer's can be improved by calibrating the sensor's output, the two deciding parameters in the sensor calibration are:

1. ZeroG: This number tells which voltage reading corresponds to zeroG's on an axis
2. Sensitivity: This tells by how much the voltage changes per G in an axis

The MEMS accelerometer calibration arrangement using six-point analogy for *Z*-axis, is (a) Not inverted (+1G) and (b) Inverted (−1G). Table 1 represents data read from the sensor [8].

The sensor read out for 0 g corresponds to digital 512; the zeroG and sensitivity values for *Z*-axis is shown here

$$m_z = (618 + 413)/2 = 515.2 \tag{1}$$

$$\delta_z = (618 - 413)/2 = 102.5 \tag{2}$$

Table 1 Values for six-point calibration of accelerometer (MPU-6050)

(a)				(b)			
Sample no.	*X*-axis	*Y*-axis	*Z*-axis	Sample no.	*X*-axis	*Y*-axis	*Z*-axis
1	512	513	619	1	511	514	413
2	511	512	617	2	513	512	412
3	512	511	618	3	512	513	411

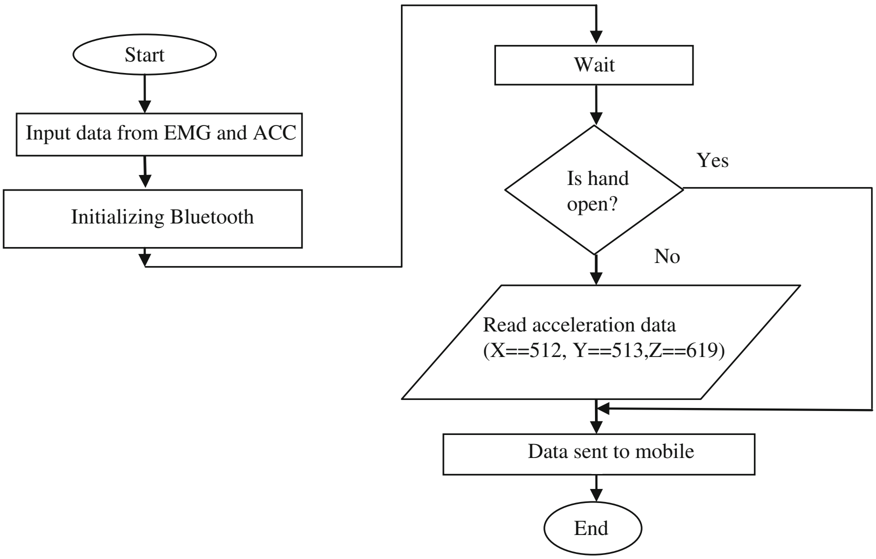


Fig. 3 Proposed algorithm flow sequence

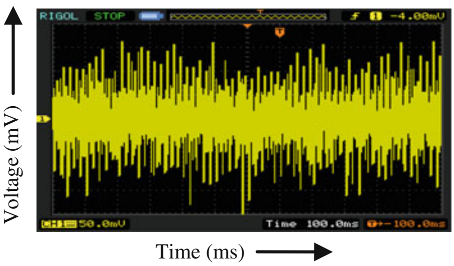
3 Algorithm of the Design

3.1 Results and Discussion

Figure 3 shows the raw EMG signal after passing through an instrumentation amplifier. The raw EMG signal passes through filters to remove the noise as shown in Fig. 4. Finally, the filtered EMG signal is fed to the precision rectifier as shown in Fig. 5 for high-precision signal processing. When an electrode is connected to the user's limb, the waveforms of Figs. 6 and 7 are obtained with palm in opening and closing positions, respectively [9].

Figure 8 shows the output waveform of the EMG circuit designed in MultiSIM using two out of phase sine wave, sampled at 60 Hz [10].

Fig. 4 Raw EMG signal



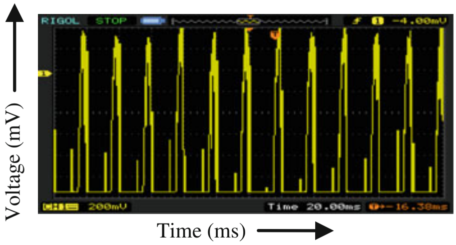


Fig. 5 Filtered EMG signal

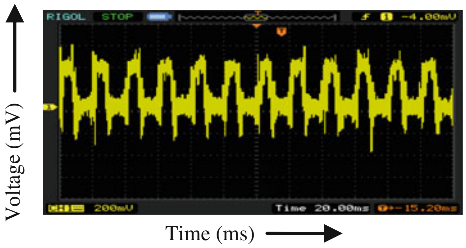


Fig. 6 Rectified EMG output with electrodes

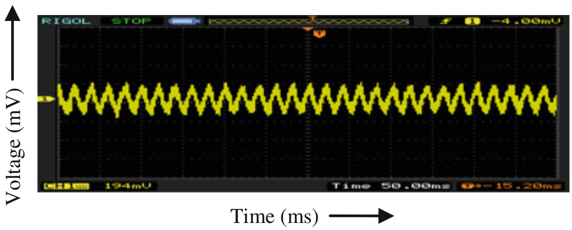


Fig. 7 EMG signal (while palm is open)

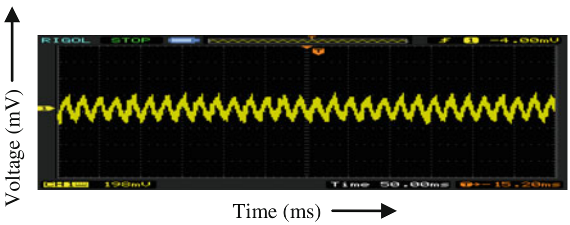


Fig. 8 EMG signal (while palm is close)

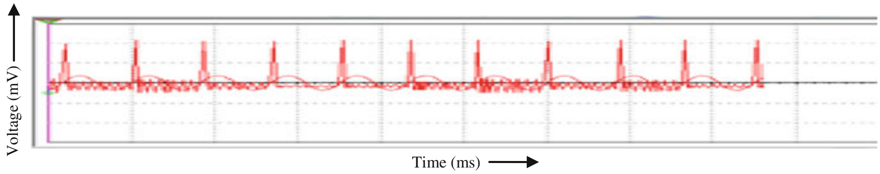


Fig. 9 EMG signal result in MultiSIM

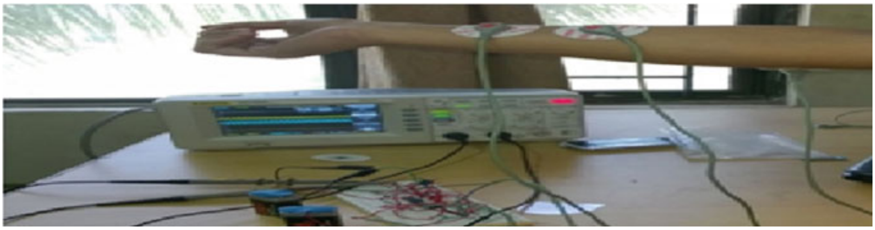


Fig. 10 Real-time implementation of acquiring EMG signal

4 Conclusion

In this paper, an accelerometer coupled electromyogram-based gesture recognition method is presented. The real-time implementation of hardware is shown in Fig. 9 [11]. Different from the popular sensor-based gesture recognition approaches found in the literature that uses only accelerometer to identify user hand movements cannot distinctly classify palm close and open movements. The proposed technique uses electromyogram signal coupled with accelerometer data to better identify hand gestures. The developed gesture recognition algorithm effectively reduces the need for extensive hardware to process the sensor data, so making it extremely efficient for mobile applications. To tackle the issue of sensor bias and installation error at gesture feature extraction, the six-point calibration is applied on the sensor data (Fig. 10).

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