Wireless sEMG Monitoring System for General Fitness Training to Maintain Biceps Muscle Based on Muscle Fatigue

Wireless sEMG Monitoring System for General Fitness Training to Maintain Biceps Muscle Based on Muscle Fatigue

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Abstract

Muscle fatigue detection is one of the important applications of surface electromyography (sEMG) measurement during exercise and fitness. However, there are still few sEMG monitoring systems by using wireless technology. The implementation of wireless sEMG monitoring system offers more advance to support people including safer, smarter, and user-friendly application. The wireless sEMG system for monitoring and guiding people during exercise in maintaining biceps muscle based on muscle fatigue is proposed in this paper. The proposed application is developed to be running on android smartphone and Personal Computer (PC). The smartphone application for android platform is designed and developed by using Eclipse IDE. The system also has been successfully implemented by using Hypertext Transfer Protocol (HTTP) and Hypertext Preprocessor (PHP) that able to invoke the MatLab as PC application to monitor the sEMG signal. Furthermore, the sEMG signal is computed by using MatLab Software to calculate and analyze muscle fatigue. Based on the testing and implementation shows that the android smartphone can achieve to send the sEMG signal. Furthermore, it can receive the computes and analyzes result of sEMG signal from the PC. It is an important reference value to the wireless sEMG monitoring system. The system also can help to maintain biceps muscle until exercise complete. Detailed information about the design and implementation result is reported in this paper. The result of the testing and implementations has proven that the system is correct and feasible.

Keywords: sEMG, Muscle Fatigue, Wireless, Android, MatLab

1. INTRODUCTION

Surface electromyography (sEMG) is measured by electrodes attached to surface of a skin, above a muscle of interest[1)]. The applications based on sEMG have been widely used such as upper limb prosthesis control[2)], exercise and fitness monitoring[3), 4)]. However, the muscle fatigue detection by using the sEMG is very important to be concerned. Athletes or general people most often strive to get muscle fatigue for muscle growth. Therefore, getting muscle fatigue is an important point in building muscle[5)]. In contrast, athletes or general people do not have to get muscle fatigue to grow the muscle because they have sufficient muscle growth. The main purpose is for maintaining the muscle.

General physical strength training in fitness should have a specific objective, for example targeting the biceps muscle. Biceps muscle is the muscle of the upper arm between shoulders and elbows. In order to maintain biceps muscle, has many exercises, sets, and repetitions must be done under guidance and monitoring from a fitness trainer. In fact, fitness trainer is limited in guiding and monitoring all people at the same time. The sEMG monitoring system was not only required by fitness trainer or athletes, but also needed by general people. However, the sEMG monitoring systems by using wireless technology is very limited. In addition, the device required is very expensive and need a complicated design and development of hardware[6)]. For the purpose massive monitoring usage of the application and hardware which can be used by many people, the application and device should be designed and developed with minimum cost. Now days, the smartphone has been widely used, and the smartphone features has been advanced. Therefore, it is important to develop a wireless sEMG monitoring system by using the advantages of the combination of smartphone features and PC for guiding people to maintain biceps muscle based on muscle fatigue with more safer, smarter, and user-friendly application.

The design and implementation of a wireless sEMG to monitor and guide people in maintaining biceps muscle based on muscle fatigue are discussed in this paper. The general user (such as athletes or general people) use android smartphone to record and then send the sEMG signal to the PC using wireless technology via Hypertext Transfer Protocol (HTTP). Furthermore, a Hypertext Preprocessor (PHP) will invoke a software tool calculation based on MatLab software as Personal Computer's (PC) application.

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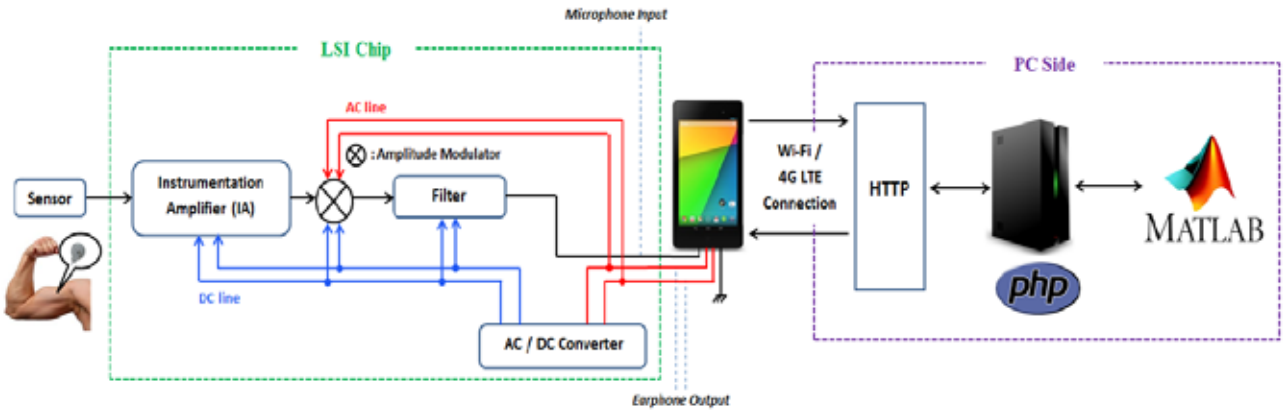

Fig. 1. An overview of the system

In addition, software tool based on MatLab will compute and analyze the sEMG signal then send the result back to android smartphone to be displayed. The system is characterized based on functional and non-functional requirements. Functional and non-functional requirements describe the function and attributes such as reliability, maintainability and security of the system. It is proved that the system is correct and feasible.

2. SYSTEM ARCHITECTURE

The system architecture that describe the structure and behavior of the wireless sEMG monitoring system for general fitness training to maintain biceps muscle based on muscle fatigue application is given in Figure 1. The system architecture is discussed as follows:

2.1. System design

The system is composed of three main parts; the first is a hardware part which is realized by large scale integration (LSI) chip; the second part is application programs running on the android smartphone; the last is PC computed and analyzed the sEMG signals. The earphone and microphone terminal is used for connecting between hardware and android smartphone. The sEMG signal has very low frequency and very small amplitude, therefore it is necessary to amplify the signals by instrumentation amplifier (IA). In addition, the earphone terminal has the band limitation between about 10 Hz to 20 kHz. Then, the signal is modulated to the frequency region by amplitude modulator. After that, the noise is cut through the filter and the sEMG signal is inputted to the android smartphone. Furthermore, the power supply to the hardware is generated by the AC/DC converter, which converts from sine wave produced by the smartphone to DC voltage source.

The android application is developed using the Java programming language within the Eclipse Integrated Development Environment (IDE), while running on the Asus Google Nexus 7. The application will guide user (athletes or general people) to maintain biceps muscle and record sEMG signal. The recorded sEMG signal is then sent to a PC through HTPP. On the PC side, the WAMPSERVER64 which open source server is used that allows the PHP can be programmed. The PHP programming allows android smartphone to connect to the PC so that the data can be transferred over Wi-Fi or 4G LTE connection. Furthermore, PHP will invoke the software tool based on the MatLab as PC's application. In addition, the software tool will compute and analyze the sEMG signal then send the result back to android smartphone to be displayed.

2.2. Signal processing aspect

The software tool based on MatLab is used to process the sEMG signal recordings that received by the PC from android smartphone. The data received by PC is sound format (*.wav*) file. Fast Fourier transform analysis is then performed to obtain the power spectrum of the sEMG signal. Furthermore, the sEMG power spectrum can be obtained median frequency.

Muscle fatigue is a reduction of the ability of a muscle to contract and exert force. Traditional muscle fatigue is detected from the median frequency of the sEMG signal[7]. Median frequency is a frequency value which dividing the spectrum in two regions with an equal power spectrum[8]. The median frequency can be obtained by using Eq.1 as follow.

$$\int_0^{MF} P(f)\,df = \int_{MF}^{\infty} P(f)\,df = \frac{1}{2}\int_0^{\infty} P(f)df \quad (1)$$

where P(f) is the power spectral density of sEMG signal (dB/Hz) and MF is the median frequency (Hz).

The median frequency will decrease when muscle exercises time increase as an index of muscle fatigue[9]. The software tool based on MatLab to complete all exercise for maintaining biceps muscle based on muscle fatigue is depicted in Figure 2. The

flowchart of MatLab depends on general fitness training to maintain biceps muscle, as shown in Table 1[10].

The final sEMG signal of the user is calculated on MatLab by taking a recorded sEMG signal of each set in exercise. The application will show the result using Graphical User Interface (GUI) MatLab. It has been developed to monitor the sEMG signal on the PC.

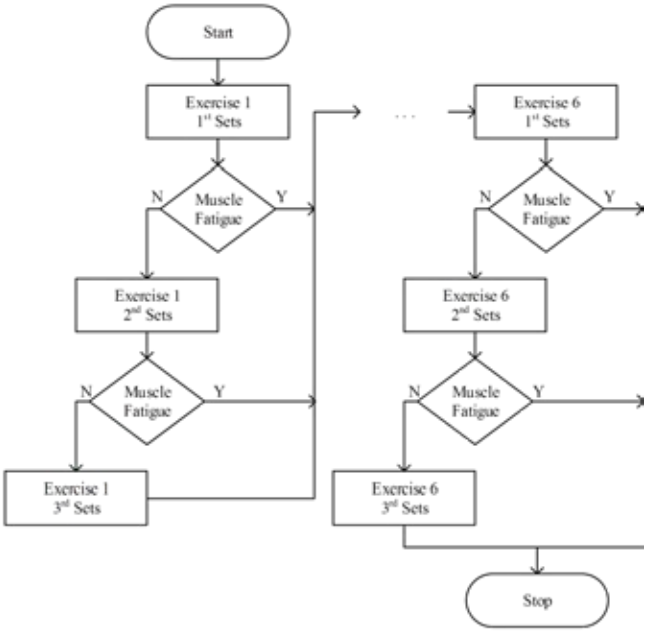

Fig. 2. The flowchart of MatLab.

Table 1. General fitness training menu to maintain biceps muscle.

Step	Sets	Repetition	Times		
			Sets	Rest Time	Total Times
Warm-Up	-	-	-	-	10 Minutes
Exercise 1: Preacher Curl	3	12	3 x 2 Minutes	3 x 1 Minutes	9 Minutes
Exercise 2: Bicep Curl	3	12	3 x 2 Minutes	3 x 1 Minutes	9 Minutes
Exercise 3: Contraction Curl	3	12	3 x 2 Minutes	3 x 1 Minutes	9 Minutes
Exercise 4: Reserve Curl	3	12	3 x 2 Minutes	3 x 1 Minutes	9 Minutes
Exercise 5: Incline Curl	3	12	3 x 2 Minutes	3 x 1 Minutes	9 Minutes
Exercise 6: Hammer Curl	3	12	3 x 2 Minutes	3 x 1 Minutes	9 Minutes
Cool-Down	-	-	-	-	10 Minutes
Total Times for Maintain Biceps Muscle :					74 Minutes

3. SYSTEM REQUIREMENTS

A system can be characterized according to functional and nonfunctional requirements. Functional requirements describe the function of a system while non-functional describe attributes like reliability, maintainability and security, etc.

The system's functional requirements are as follows.

- The android smartphone records sEMG signal using microphone input (almost all of the smartphone are available) and stores the result on the SD card of the smartphone.
- The system allows the secure sending of the required sEMG signal via Wi-Fi/4G LTE the PC using HTTP requests.
- The MatLab code accurately processes the sEMG signal.
- A user-friendly Graphical User Interface (GUI) is used to monitor the sEMG signal.
- The result is sent back and displayed on android smartphone.

A non-functional requirement in this system is not time-critical. Therefore, it does not require the results to be provided to the user in real-time. Hence, data is processed on the PC side rather than on the smartphone. Furthermore, the MatLab processing to the smartphone side will no doubt consume battery energy, and require more time, given the slower processor on the smartphone. In addition, the reliability and maintenance of the system become less of a hassle if the processing is done on the PC side as algorithms can be easily updated. Therefore, non-functional requirements for the system dictate that the system is reliable, portable, accurate, maintainable, secure, and easy to use.

4. SYSTEM TESTING AND IMPLEMENTATION RESULTS

Fig. 3. The main layout view of application.

In order to complete the design and implementation of the proposed system, the system was successfully tested by following the performance and design requirements as mentioned in section 3.

Fig. 4. The recording of sEMG signal is started.

The user starts by placing the one chip sensor on his/her upper arm (the location of biceps muscle) and start the application. The main layout view of the application is shown in Figure 3. The application will guide user to maintain biceps muscle. Then, the sEMG signal will be recorded by pressing "Start" button in each set as shown in Figure 4. After set in each exercise complete, the recording will be stopped by pressing "Stop" button as shown in Figure 5. In addition, the recorded data is sent to the PC (by pressing "Send" button).

The application was tested and the functionality was verified by implementation. The sEMG signal in each exercise is recorded using android smartphone as shown in Figure 6. Furthermore, all sEMG signal entries are stored and uploaded (as a *.wav* file) to the PC using HTTP requests and PHP, as depicted in Figure 7. The processing time is approximately 2 seconds including Wi-Fi/4G LTE connection.

PHP will invoke the MatLab as PC's application after sEMG signal is stored and uploaded to the PC. Figure 8 shows the verification of the result on PC by GUI MatLab to monitor a condition of user. The treatment computation is automatically completed that consist as follows.

- The display sEMG signal on power spectrum.
- The value of median frequency.
- The condition of user that refer to the normal or muscle fatigue conditions.
- The treatment for maintaining biceps muscle.

Fig. 5. The recording of sEMG signal is successfully recorded.

Fig. 6. The recording of sEMG signal is successfully uploaded.

Fig. 7. The recording of sEMG signal is successfully stored and uploaded to PHP server (as *.wav* file).

The output of GUI MatLab is stored in the PHP (as a *.jpg* file). The output is sent back to the user android smartphone application for guiding user to complete all exercise based on muscle fatigue. The result performed by the MatLab GUI can be retrieved and viewed on the android smartphone is shown in Figure 9 by pressing "Show Result" button. Furthermore, a dialog box will appear for guiding until exercise complete is shown in Figure 10.

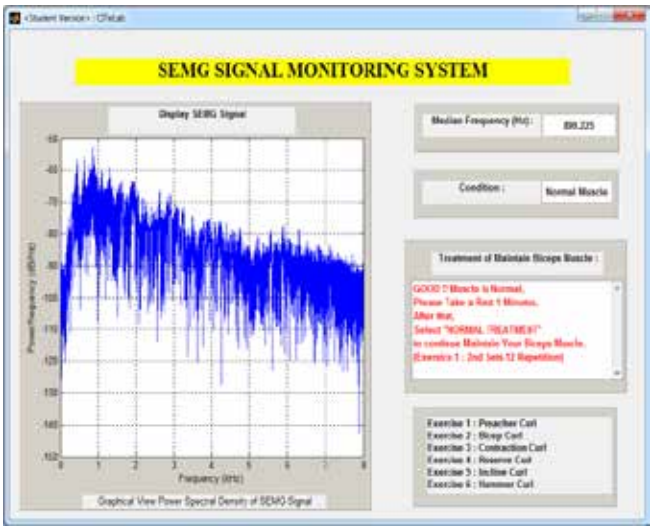

Fig. 8. The main layout view of GUI MatLab.

5. CONCLUSIONS

A wireless sEMG monitoring system for general fitness training to maintain biceps muscle based on muscle fatigue has been designed and developed. Through the testing and implementation result show that android smartphone can accomplish to send the sEMG signal. Furthermore, it can receive analyzes and computes result of sEMG signal from the PC. It is an important reference value to the wireless sEMG monitoring system. The system also can help to maintain biceps muscle until the exercise complete.

The future work will focus on optimization of this system as follows. First, develop a wireless sEMG monitoring system in real-time, so the system can give early warnings to the user before muscle fatigue. Second, the standard muscle fatigue index such as the subject characteristic, regression coefficient, and slope of median frequency for loading exercises must be examined.

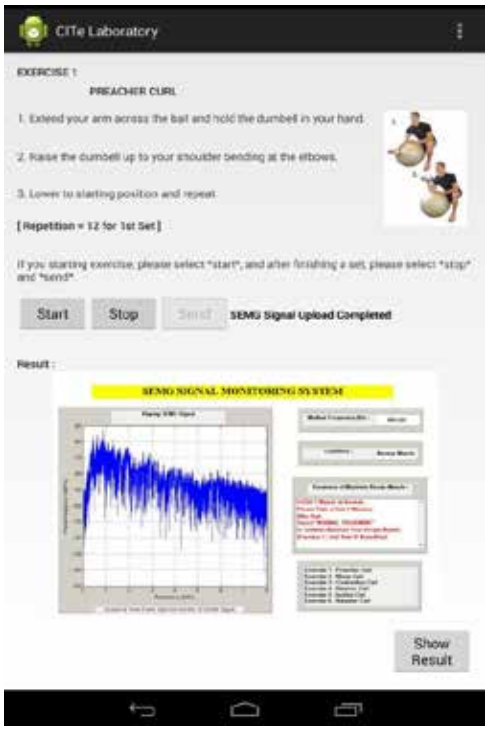

Fig. 9. The display result figure on android application.

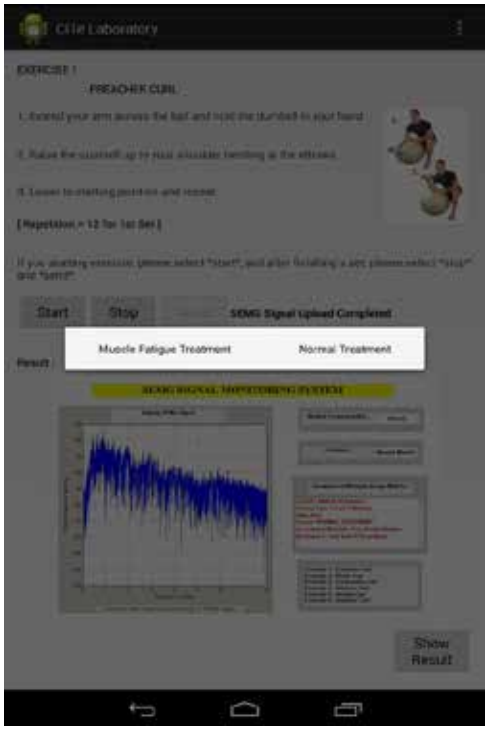

Fig. 10. The display result of dialog box of treatment.

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