Implementation of a Low-cost Wireless Multi-channel Surface EMG Acquisition System

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Abstract—**Electromyogram (EMG) signals have attracted much attention and have been applied widely. EMG signals have been used to evaluate the functional status of skeletal muscles. The commercial EMG acquisition systems are costly, so many researchers have provided low-cost solutions. Although the wireless acquisition systems are realized, the transmission speed is not sufficient for high-sampling and multi-channel measurement. The purpose of this work is to implement a low-cost and wireless surface EMG acquisition system supporting high-sampling and multi-channel measurement. Using wearable EMG sensors combined with a microcontroller unit and a Wi-Fi module, the measured surface EMG signal samples can be forwarded immediately to the host for further processing and additional applications. Besides, the proposed system was validated by applying the commercial EMG detection system. The results show that all the correlation coefficients are over 0.8 that represent moderate to high relative agreement between the commercial and the proposed system.**

Index Terms—**electromyogram, sEMG, EMG acquisition system, wireless transmission, flow control**

I. Introduction

Bioelectrical signals obtained from the human body have been under special attention in recent years. One of these important signals is the electrical manifestation of the human muscles known as EMG signals. EMG signals have been used to evaluate the functional status of skeletal muscles and assist in neuromuscular training and rehabilitation. Nowadays, there are two ways for EMG signal measurement including intramuscular EMG and surface EMG (sEMG). Among them considering health risk and accessibility, much of the current myoelectric control literature focuses on developing surface signals.

Recently, many kinds of research have been conducted toward the low-cost design and application of the sEMG measurement. Youn et al. [1] developed a compact-size and wireless sEMG measurement system using Bluetooth technology to cope with this problem. Ishak et al. [2] designed a wireless sEMG acquisition system which consists of the preamplifier, filters, DSPs, and components that transmits data to the computer via X-Bee module. While achieving the development of wireless sEMG acquisition systems successfully, both of them are not realized for multi-channel measurement. This is because the data rate of Bluetooth and X-Bee are not sufficient for high-sampling and multi-channel measurement.

The purpose of this paper is to implement a low-cost sEMG acquisition system for high-sampling and multi-channel measurement. In this research, sEMG acquisition systems are divided into two parts, a measurement module and a host. The communication interface between the measurement module and the host is Wi-Fi. The measurement module is responsible for capturing the sEMG signals and transmission. The host receives, filters, and visualizes the sEMG data from the measurement module. By using wearable EMG sensors combined with an MCU, the measured sEMG signal samples can be forwarded to the computer for further processing, including interference mitigation and EMG signal-based applications. Figure 1 illustrates an overview of the proposed system.

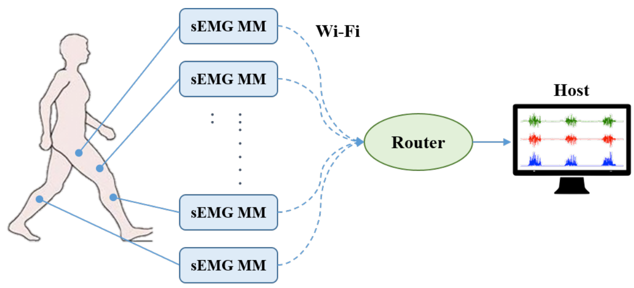

Fig. 1. Overview of the proposed sEMG acquisition system. Place the sEMG measurement module (sEMG MM) on target muscles and each module will detect the EMG signal and transmit the signal to host.

II. Implementation Method

The sEMG acquisition system realizes the processing and recording of the surface biological signal. The signals collected from the skin surface of human skeletal muscles are transformed into digital signal sequences which are transmitted to the corresponding processing unit after amplification, filtering, and other processing. In this paper, the proposed system is composed of two parts: a measurement module and a host. The measurement module captures the analog EMG signals through surface electrodes on the skin over the muscles and then transmit the EMG data to the host using wireless for further processing.

A. Measurement Module Design

The architecture of EMG measurement module is illustrated in Fig. 2. The weak sEMG signals from the skin surface of human muscles are collected with the sEMG electrodes, and then through the muscle sensors amplifying and filtering in Muscle Sensor Unit. After amplifying and filtering, the sEMG signals pass through the ADC sampling in the MCU to get the original sEMG sequences. Moreover, the digital signals will be sent to the Wi-Fi module using UART interface. The Wi-Fi module transmits the sEMG signals to the computer with TCP/IP protocol stack. The whole system uses 300 mAh lithium battery as the main power supply.

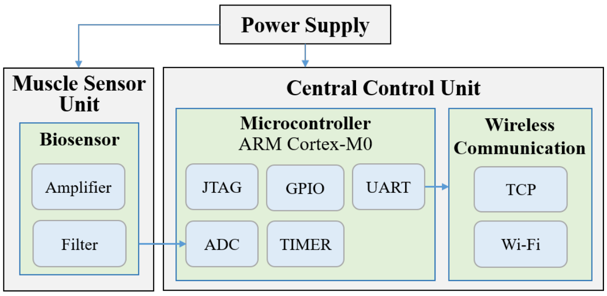

Fig. 2. EMG measurement module architecture.

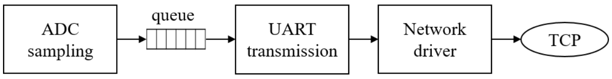

Fig. 3. Software EMG data flow.

The EMG signals are stochastic in nature. The usable energy of the EMG signals is between 0 Hz to 500 Hz frequencies. According to Nyquist sampling theorem, the minimum sampling frequency is 1KHz. In this paper, ADC is set in the software, the sampling rate of the single channel is 2 KHz, and the sampling resolution is 12 bits. The original EMG signal sequences transformed by ADC are transferred to the buffers instead of transmitting to the Wi-Fi module directly, then sent to the Wi-Fi module using UART with flow controls. The purpose is to avoid data loss when MCU is sending continuous data to the Wi-Fi module, and suddenly the wireless connection between the Wi-Fi module and PC network card turns down for some reason. The signals are encapsulated into TCP datagram and transmitted to the network by the network driver afterward. The EMG data transmission flow is illustrated in Fig. 3.

B. Host Processing

EMG provides valuable information to evaluate the functional status of skeletal muscles. Therefore, the EMG signals must be clearly represented and filtered to remove all distracting noises and artifacts. In the host process, the EMG signals from measurement module will be filtered out unwanted components and got specify useful parts of the signals.

The range of the EMG signals amplitude is very weak. When passing through various tissues, the EMG signals are contaminated by various noises. The major source of noises is the electromagnetic interference caused by AC power lines with the main frequency component at 60Hz. An infinite impulse response (IIR) notch filter was used to eliminate this noise. In addition, the signals such as ocular EOG, ECG, and artifact noises also interfere with the EMG signals. The frequency range of the energy of each above mentioned interfering signals and artifacts are lower than 20 Hz. Therefore, a Butterworth band pass IIR filter with a bandwidth of (20-500) Hz was used to eliminate the interfering signals and the artifacts.

TABLE I
THE CORRELATION COEFFICIENT FOR EACH EMG SIGNAL BETWEEN COMMERCIAL AND PROPOSED DEVICE.

Muscles	CC(mean)±STD	MVIC CC	Mean CC	Peak CC
VL	0.863±0.078	0.960	0.890	0.890
BF	0.811±0.095	0.863	0.855	0.864

MVIC: MVIC values for each subject; **Mean**: mean value of each EMG data; **Peak**: maximum values of each EMG data.

III. Experiment And Result

In this part, the EMG data from the proposed system was validated. A commercial wireless EMG system (TrignoTM Wireless Systems and Smart Sensors, Delsys, Inc., USA) was used as the criterion reference. In the experiments, there were 5 subjects participate in the study, and the channels were connected with the muscles which were Vastus Lateralis (VL) and Biceps Femoris(BF) of the right leg of subjects respectively. The EMG data from the two systems were acquired concurrently on VL and BF during maximal voluntary isometric contraction (MVIC) as well as during the exercise which is level walking [3]. In order to compare the EMG signals from each system more correctly, the mean absolute value (MAV) method was used to extract EMG features. After processing MAV, all the EMG data were normalized by MVIC value. After aforementioned processing, the EMG signals from each system were compared. The correlation coefficient (CC) for the EMG signals is illustrated in Table I.

In the comparison result, all correlation coefficients are over 0.8 that represented moderate to high relative agreement between the commercial and the proposed system across the exercises.

IV. Conclusion And Discussions

In this paper, the low-cost wireless multi-channel sEMG acquisition system was developed. The EMG wearable sensor, ADC, lithium battery, and wireless transmission technology were integrated into sEMG acquisition devices. Moreover, the measurement devices are very lightweight (size: 50*20*17mm, weight: 20g), so that is portable and flexible during the measuring. Meantime, the experimental results show that both systems have moderate to high correlation, that denotes the proposed system can be used for the analysis and processing of EMG signals, which create an acquisition signals system for the research of the follow up the sEMG.

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