On Detecting and Adaptive Timing for Electromyogram Based Control Signals

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Abstract – **The purpose of this study was to develop and evaluate a signal-processing algorithm for controlling electromechanical devices by use of electromyogram (EMG) signals acquired with surface electrodes. The goal was to provide a robust trigger pulse with an appropriate duty cycle that, to some extent, reflects the duration of the muscle contraction. The EMG signal was amplified, digitized, and processed by an 8-bit microprocessor. The Multiplication of Backward Differences (MOBD) algorithm, originally designed to detect the QRS complexes in the electrocardiogram, was used to detect the on-set of the EMG signal. An adaptive refractory period scheme was devised to adjust the trigger pulse width based on EMG activities after the on-set point. This paper describes the development of the microprocessor based system and the preliminary test results.**

I. Introduction

An electromyogram (EMG) signal is the measurement of the electrical activity from a contracting muscle. The surface myoelectric signals have been used to control assistive devices such as wheelchairs and prosthetic limbs [1, 2]. This study is built upon previous undergraduate capstone design projects [3, 4], which used EMG signals from the left and right forearms to navigate a remote-control toy car. The present study consists of two parts: 1) development and refinement of a microprocessor based EMG system using surface electrodes, and 2) improvement of a detection algorithm with a focus on the adaptive trigger pulse width in response to quick twitches and sustained contractions.

II. Methods

A. EMG Instrumentation

Each EMG channel was acquired by using three surface electrodes: two for differential signals and one for reference (ground). The two signal electrodes were placed about one inch apart at the belly of one of the three muscles in the forearm: brachioradialis, flexor carpi radialis, and flexor carpi ulnaris. The third electrode was usually attached to the subject's elbow serving as a voltage reference point. Before applying them, it was found that a much better signal could be obtained by whipping the skin with an alcohol pad to increase skin conductivity. Each EMG signal was amplified by a custom-made amplifier that uses an instrumentation amplifier

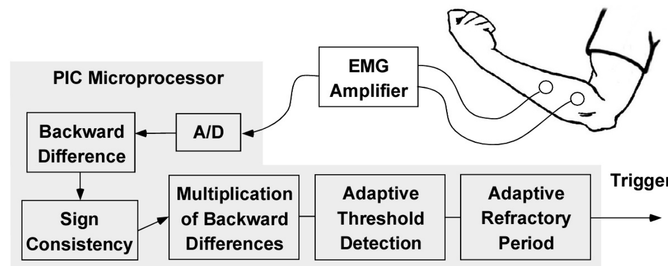

Fig. 1. Block diagram of the microprocessor based system and the signal processing stages for outputting a trigger signal based on surface myoelectric activities.

(AD620, Analog Devices, Norwood. MA) as the front-end stage. Figure 1 shows a block diagram of the microprocessor based instrumentation and the signal processor stages for outputting a trigger signal based on the surface myoelectric activities. The microprocessor was the PIC18F452 (Microchip Technology, Chandler, AZ) running at a clock rate of 4 MHz. The signal-processing algorithm was implemented with an embedded C++ language using the MPLab software development tool.

B. Detection Algorithm and Adaptive Timing

The detection of the on-set of a myoelectric activity was accomplished by adapting a previously developed algorithm, the Multiplication of Backward Differences (MOBD) [5]. Originally developed for detecting QRS complexes of the electrocardiogram, the MOBD consists of four processing stages: backward difference, sign consistency test for consecutive differences, multiplication of the backward differences with a consistent sign, and adaptive thresholding. A 3-point MOBD algorithm was adapted to the EMG detection. If the nonlinear transform after the multiplication of three sign-consistent differences exceeds a threshold, the microprocessor outputs a trigger signal.

In the original MOBD algorithm the duty cycle of the trigger pulse is a constant, called the refractory period. In this study we further explores the use of an adaptive refractory period, thereby varying the width of the trigger pulse. One approach is to monitor the myoelectric activity immediately after the refractory period. If the myoelectric activity persists,

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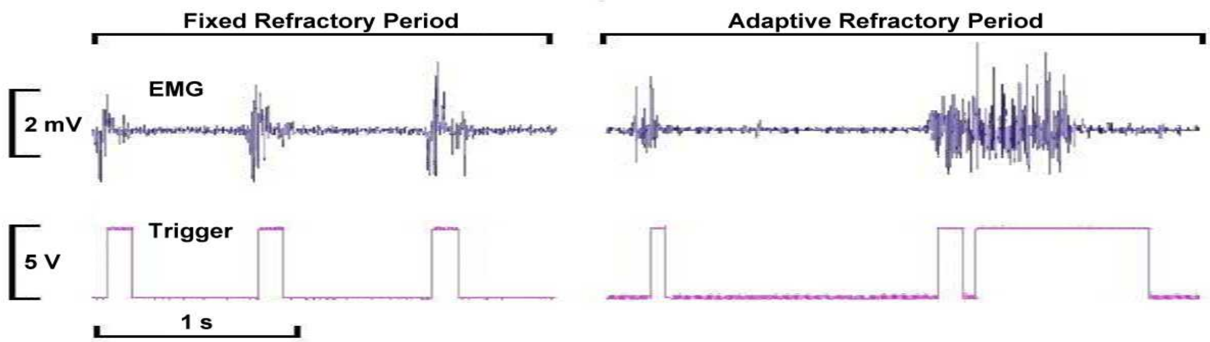

Fig. 2. EMG signal (top) and trigger (bottom) by using of a fixed refractory period and an adaptive refractory period.

the refractory period switches to a longer one for the next detection. This is accomplished as follows.

When a peak from the transformed EMG signal triggers a response, a refractory period is set to avoid any extraneous detection, also representing the duration of the triggered response. In order to distinguish between short twitches and sustained muscle contractions, the system was designed in an adaptive manor. If multiple peaks were detected close together (within 10 ms of each other) then the refractory period would adjust to a longer duration to represent a sustained contraction.

C. Testing

The experimental setup followed the guidelines of the Institutional Review Board (IRB) for use of human subjects. A prior IRB approval was obtained for this study. First we tested the effectiveness of the on-set detecting algorithm, taking note of any cases where it was under or over responsive. Reasons for these errors were mainly due to the threshold chosen for the algorithm. Based on our observations we were able to tune onto an effective threshold which varied between different peopleThen we began testing with the adaptive portion for sustained muscle contraction. By adjusting to an acceptable time interval between peaks to constitute a sustained contraction, we were able to control the duration of the triggered response for longer contractions. This proved to result in smoother controls for devices such as a remote control car or power chair as opposed to multiple short responses which is choppy.

III. RESULTS

Figure 2 shows the difference between the use of a fixed refractory period and an adaptive refractory period for the trigger output. In the latter case, the algorithm detects a sustained contraction and change the refractory period (the trigger pulse width) from a short one to a longer one. The modified MOBD algorithm performed satisfactorily to produce sensitive and robust detection of the myoelectric activities.

IV. DISCUSSION

This study was focused on the detection of surface myoelectric activities by use of a microprocessor-based system. Using the Multiplication of Backward Differences (MOBD) algorithm as a basis, an adaptive scheme was incorporated to adjust the width of the trigger pulse in response to the duration of the muscle contraction. The result of this study should be useful for applications that require the differentiation of quick twitches and sustained contractions. It should also be useful for controls of electromechanical devices such as powered wheelchairs and prosthetic limbs.

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