

# A PORTABLE AND WIRELESS MECHANOMYOGRAPHIC INTERFACE TO THE WEB: A BEDSIDE SOLUTION

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## INTRODUCTION

For nonverbal individuals with motor impairments the ability to interact with their environment can be critical to their independence and quality of life. A system that provides portable and wireless bedside Internet access would not only provide a new opportunity for such patients, but also help to alleviate the clutter caused by diagnostic and life-sustaining equipment within complex continuing or critical care wards. This paper describes such a system that is currently being developed. The system relies on the voltage signals received by a microphone-accelerometer sensor pair. The microphone measures the mechanomyographic (MMG) signals produced by users' residual muscle movements. These signals are used to operate a custom-made web browser interface. The accelerometer detects noise produced by spastic movements and environmental disturbances. A segmentation algorithm has been developed and implemented on microcontroller to identify voluntary user contractions. The web browser interface has been developed for a Personal Digital Assistant, making the entire system portable. Wireless communication between the muscle switch and PDA is accomplished by using a Bluetooth cable replacement interface. The method, components and implementation are discussed.

## METHODOLOGY

### Microphone-Accelerometer Sensor Pair:

A microphone-accelerometer sensor pair as used by [1] is used to detect user input. The sensor is useful for applications where monitoring of low frequency (<1kHz) physio-mechanical signals is required [2]. The microphone picks up the MMG signals while the accelerometer is used to detect gross movement that occurs during spastic movements or environmental disturbances such as jolts or movement of the hospital bed by nurses/visitors. A segmentation algorithm that makes use of data from both input

channels allows for voluntary contractions to be identified and distinguished from noise.

### Segmentation Algorithm:

The purpose of the segmentation algorithm is to identify the onset of a muscular contraction as well as relaxation. The first step is to construct an envelope around the signal. In order to do this, a threshold is required. While a muscle is at rest, the signal measured by the microphone is merely a background noise signal that oscillates within a small range. This range is used to set a threshold.

$$T = 2 \times \max(|S_{\text{resting}}|) \quad (1)$$

Where  $\max(|S_{\text{resting}}|)$  represents the maximum of the absolute value of the MMG signal while the user's muscle is at rest.

Recordings of MMG data taken from the forearm extensor muscles of an able-bodied individual were made in MATLAB. Signals were sampled at 1000 Hz. Within each window of 80 samples (80 ms of data) the maximum of the absolute values of the data samples was found. By carrying on this procedure for each of the windows in the recorded signal the maximum absolute values from each window can be found:

$$M = \max(|S_i|); i = 1, \dots, 80 \quad (2)$$

Following the method used by [3], hard thresholding was applied to these maxima, such that

$$M = \begin{cases} M, & M > T \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

To construct the envelope the processed data is smoothed, using a five-point moving average [3]. The smoothed data represents the signal envelope.

In the simplest case, a segmented contraction can be recognized by the period of time during which the envelope amplitude is greater than zero. However, between contractions in fast succession, the envelope does not drop back to zero. Therefore, rather than simply detecting the departure of the envelope from

the basal level and its return, features of the envelope are used to gain information.

It was found that a noticeable peak in the envelope occurs upon contraction onset as well as during the onset of relaxation (see Figure 1). A second contraction starting before the transient activity from the last contraction has subsided can therefore be identified as a noticeable rise in the envelope from a local minimum. In other words, unless the envelope drops back to the basal level, the major peaks in the envelope alternatively indicate a new contraction, or onset of relaxation. In this way, input to the web browser from adept users can be detected. The minimum amount that the envelope must rise from a local minimum to indicate contraction onset or relaxation is expected to be a variable tuning parameter, configurable to the user.

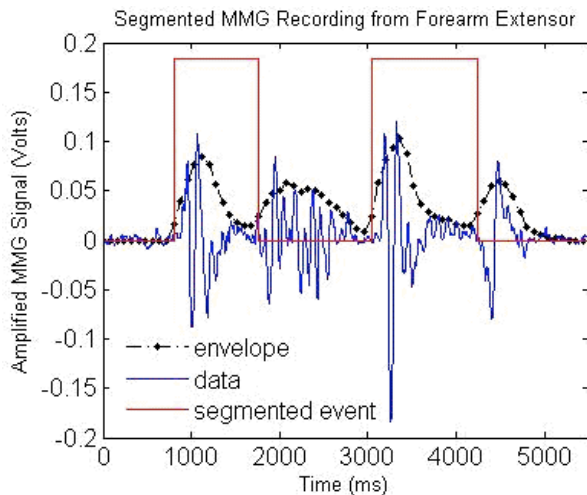


Figure 1: The segmentation algorithm has been used to identify two contractions performed in fast succession.

### Disturbance Detection:

Accelerometer input provided a simple means to discern between voluntary user contractions and false positives. A simple thresholding approach was used. By finding the minimum peak value in the accelerometer data corresponding to gross movements, or applied jolts to the resting sensor, a threshold,  $T_a$ , was obtained.

Accelerometer data above threshold,  $T_a$ , indicated environmental disturbances or spastic movements. Contraction onsets are validated only when accelerometer data remains below  $T_a$ . If the accelerometer data exceeds  $T_a$ , then the contractions

are deemed false. After false contractions are identified, further contractions are not recognized until the MMG envelope has returned to its resting level.

### Implementation:

The algorithm was coded in the C programming language and implemented onto a microcontroller. A Bluetooth cable replacement interface allowed for wireless communication between the muscle switch and the web browser on the PDA.

One version of the toolbar of the custom web interface created by Flick Software is shown in Figure 2 below. One button of the toolbar is highlighted at a time. The dwell times are user configurable. When the button that the user wishes to select is highlighted, the muscle switch can be used to activate it. With this toolbar, the user can navigate through a series of links.

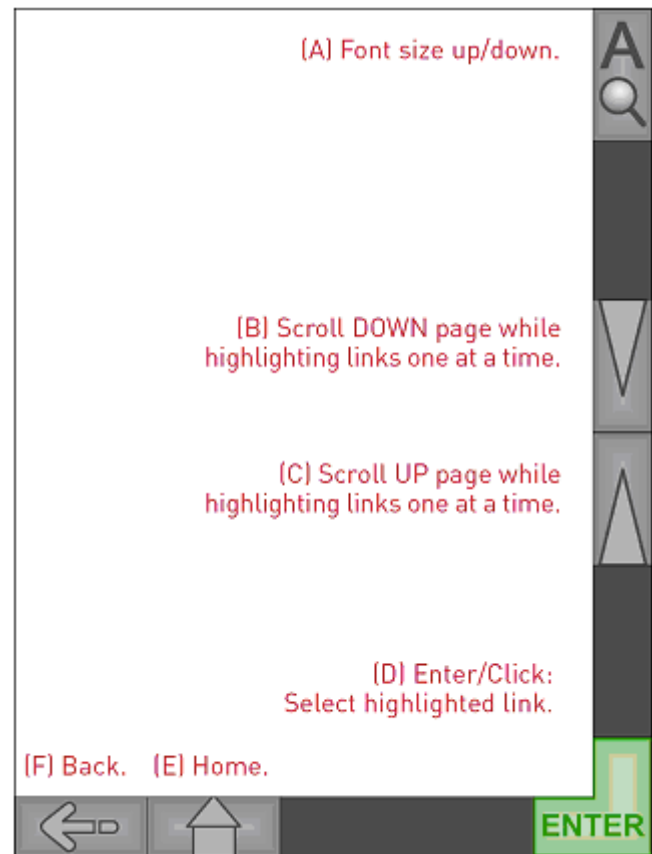


Figure 2: Toolbar for the custom-made web browser interface.

### Results:

The segmentation algorithm was tested with signals recorded in MATLAB. For individual contractions, the algorithm correctly identified contractions for 10 out of

11 trials. The failed trial is the result of the small window size used. A smaller window size tends to result in extraneous contractions being recognized due to brief periods where signal activity appears to have ceased and then resumes. A larger window size solves the problem. However, for contractions in rapid succession, the algorithm tends to aggregate events. A window size of 160 was used and tested with contractions performed in fast succession. In this case the algorithm successfully identified 14 out of 18 contractions and overlooked 4. These results suggest that the system will provide a high degree of accuracy for those requiring longer dwell times. These tests were performed using data taken from the forearm extensors. Real time client testing is yet to be performed. As well, the algorithm is yet to be tested using different control sites and while varying the tuning parameters discussed.

### Conclusion:

The system discussed makes use mainly of a simple event segmentation algorithm along with a microphone-accelerometer sensor pair to detect voluntary muscular contractions. This combined with the Bluetooth cable replacement interface and the Personal Digital Assistant with the web browser make for a fully portable and wireless device to provide bedside internet access to nonverbal individuals with limited motor function. Client testing to validate the system should be completed shortly.

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