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Stride Time Calculation from EMG and Foot Switch Data and Finding Corelation between Them for Prosthetic Control

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Abstract. This paper presents the study to correlate different lower limb muscle EMG and foot switch timing data during normal gait cycle to extract stride information and subsequent gait phase. Use of foot switch and optical arrangement for gait phase detection is a common practice but it is unsuitable for prosthetic or orthotic application where a wearable stand alone system with high reliability is needed for developing control algorithm. For such application, use of EMG signal fused along with foot switch data may give a better result. This study is aimed for verifying if a strong enough correlation exists between EMG and foot switch timing parameter required for sensor fusion. EMG extraction is done through biopotential electrode and self designed wearable, wireless low power preamplifier Concept of state machine is used to detect gait phase from switch and EMG data.

Keywords: correlation, EMG, foot switch, gait phase, stride time

1. Introduction

EMG has been widely used as a tool to understand and distinguish between normal and pathological gait in adults and in children. EMG is muscle action potential signal which are bio signal of the order of few microvolt. The source of the SEMG signal is the motor unit action potential (MUAP). Action potentials are given off by each of the motor units activated during a given contraction The timing and intensity of the EMG during a phase or the entire gait cycle can tell us much about neurological control and muscle weakness [1].Temporal and spatial parameters such as stride length, cadence [2–5], and the timing of stance and swing periods [5–9] are commonly recorded along with EMG to describe, classify or identify normal and pathological gait. In the clinical environment, gait cycle determination is often performed by manually selecting the key points of foot contact and toe off at the beginning and end of the phases.

Gait is the term used to describe the process of walking. It comprises two basic phases, stance phase and swing phase Swing and stance phases are the important phases of walking pattern. Most of the popular prosthesis's performance depends on successful detection of these phases. The damping is decided by the control unit as per the determined phase.

Cross correlation between foot switch and any other sensor like gyro or accelerometer, joint kinematics, joint angle data etc have been carried out. Results are fair enough in normal application but for application such as prosthetic design for transfemoral or transtibial amputee, results are not satisfactory. EMG on the other hand being related with the subject's force, torque and other muscle activity may be a better choice to fuse with footswitch to detect gait phases and stride information.

EMG is extracted from six different muscles of left leg by an EMG extractor unit specially designed for prosthetic application. Design developed is quite unique and is specially suited for wearable prosthetic applications due to low power consumption, wireless design and display with biofeedback. EMG signal is acquired is rectified, filtered and averaged using moving window algorithm in visual studio platform.

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Potentiometer type foot switch was placed over shoe sole of left foot which could detect heel strike and thus stride time which is difference between two consecutive heel strikes while the subject walked on a treadmill at self defined speed and time. Stride length were also calculated from EMG data. Correlation analysis between data obtained from footswitch and EMG was done in MATLAB.

2. Experimental setup and Procedure

2.1. EMG extraction unit

The developed EMG system consists of disposable Biopotential electrode as sensor, a dual channel preamplifier module designed with AD623IC which amplifies the EMG signal, ATMEGA8 processor for data acquisition, RF module for wireless transmission and a computer with visual studio platform for signal processing and eight channel simultaneous real time display. The system is wearable and wireless, operates on single supply of only 3.3 volt and weights only a few grams.

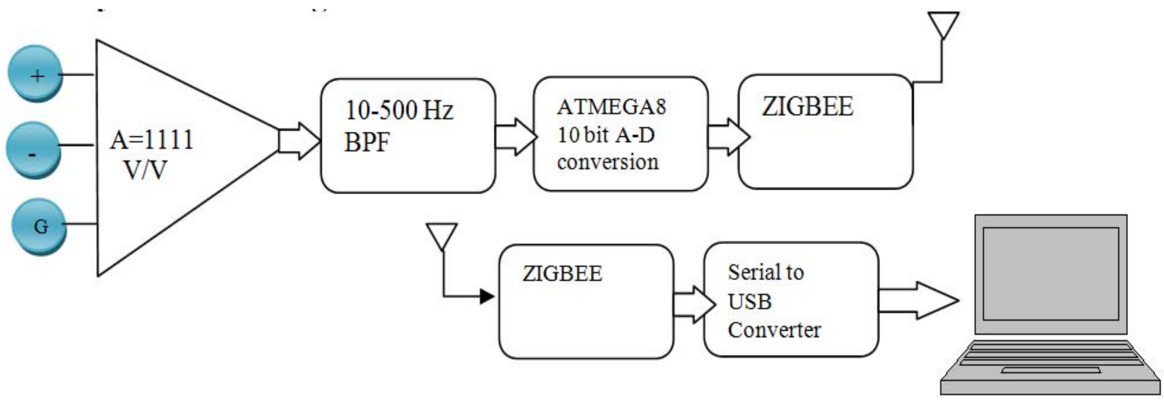


Fig. 1: EMG system block diagram

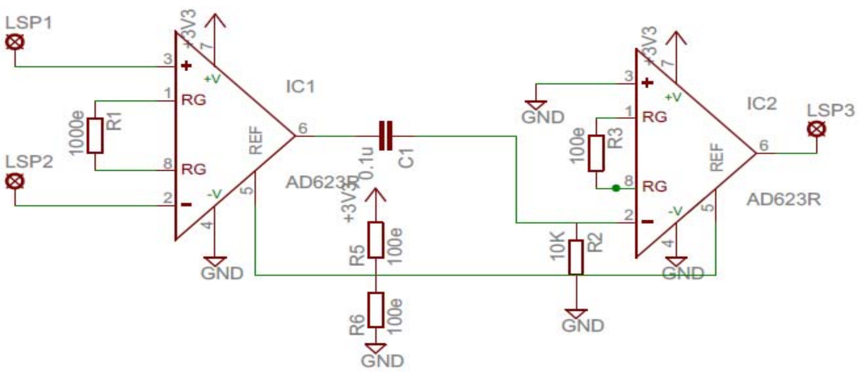


Fig. 2: Schematic of preamplifier unit

Differential signal from two active electrodes is amplified according to equation- $\mathbf{V_0 = (1+100K\Omega/R_G)*V_C}$.

Double stage amplification is done with a net gain of 5000.

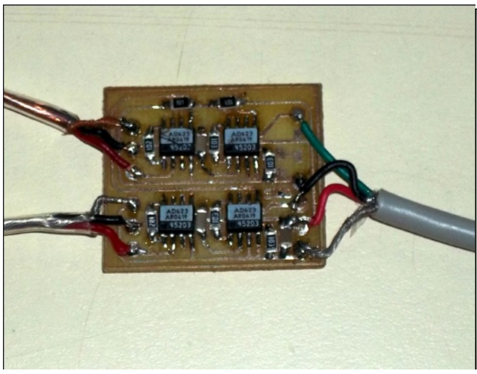


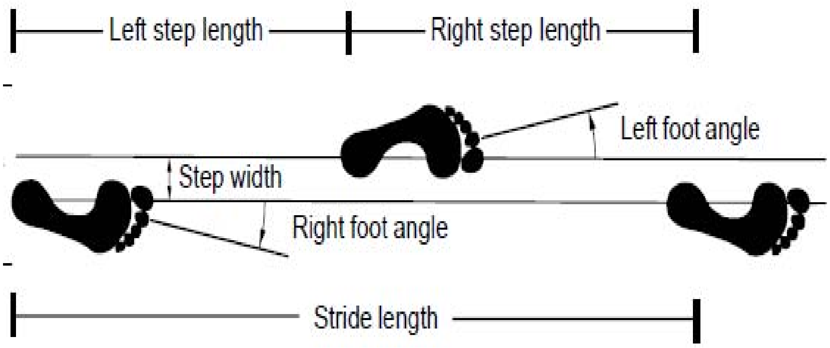
Fig. 3: Preamplifier board

Fig. 4: Microcontroller and XBee

Fig. 5: USB Xbee Traneceiver

2.2. Foot switches

Stride length: It is the distance travelled by a person during one stride (or cycle) and can be measured as the length between the heels from one heel strike to the next heel strike on the same side. Two step lengths (left plus right) make one stride length. With normal subjects, the two step lengths (left plus right) make one stride length.



We have used single foot switch in left foot to detect heel strike event Timing between 2 consecutive heel strikes is stride time

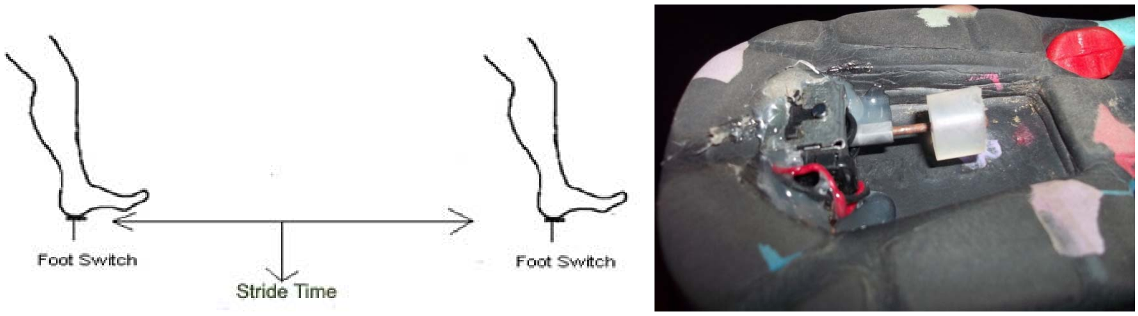


Fig. 6: Foot switch attached beneath shoe

2.3. Stride length from EMG

EMG readings from 3 different muscles were taken during normal walking in treadmill. Most of the limb muscle has a specific activation curve corresponding to different events in gait cycle. For example Gastrocnemius and Tibialis anterior muscle controls ankle movement during gait cycle, hence EMG activation of these muscle are highest during gait events were ankle plantaflexes or dorsiflexes. Raw EMG signal was processed in software and after filtering, rectification and envelope detection, waveform represented envelope of activation potential in form of peaks, each peak corresponding to 1 cycle in general. Timing between consecutive peaks gives stride time.

In some muscle after processing, more than one peak of varying amplitude may be present. Peak detection algorithm should be dynamic enough to distinguish multiple peak of same gait event and treat accordingly. EMG from 3 limb muscles namely Rectus Femoris, Medial Hamstring and Gastrocnemius were taken while walking in treadmill at speed of 3 km/hr for about 200 steps.

2.4. Data acquisition and system software

Acquisition and controlling is done by ATMEGA 8 microcontroller. Data is sampled at rate of 1 kHz with 10 bit resolution.

Software section is developed in Visual studio platform with c# programming. Software section process the raw EMG signal and generates the stride time. For EMG, from the processed signal, a percentage of the peak signal is used as a threshold to trigger a timer which will remain active till another threshold is detected in the next signal peak. For foot switch, we need only one threshold to be generated on detection of heel strike. Stride time is calculated by counting time encountered between two successive threshold detections.

3. Result and Analysis

Stride time was calculated in software through different algorithm for foot switch and EMG. From collected data of three different muscles and over 200 samples for each muscle .Correlation analysis was done between stride time calculated from foot switch data and EMG data for 3 different muscles taken. Correlation coefficient calculated in MATLAB from 2 sets of sample data gives the strength of correlation. A strong correlation indicates possibility of better result through sensor fusion.

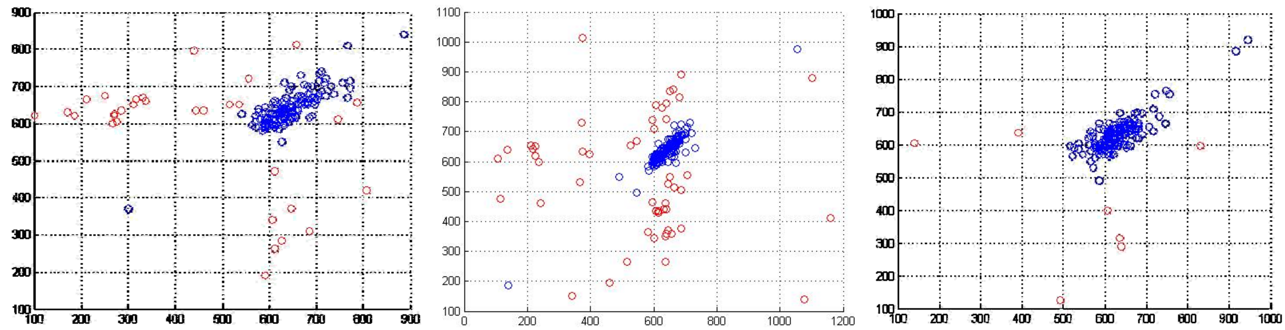


Fig. 8: Plot of time values from a. FS vs RF b. FS vs MH c. FS vs Gastrocnemius muscle (FS- Foot Switch)

TABLE 1: VARIANCE AND CORELATION COEFFICIENT OF DIFFERENT MUSCLES

Muscle name	Rectus femoris	Medialis hamstring	Gastrocnemius
variance	3.5265e-3	2.1098e-3	1.9299e-3
Correlation coefficient	0.9437	0.8327	0.8085

4. Discussion

From the correlation curve plotted in MATLAB for 3 different muscles, correlation coefficient of all three data sets shows strong positive correlation of value 0.8 and above. This is a clear indication that if sensor fusion of foot switch and EMG data are considered together for any controlling purpose, result will be much better than the sensors working alone. Correlation coefficient calculated from three different muscle shows little variation with same foot switch data. Rectus femoris muscle shows the strongest correlation indicating its importance and contribution in gait analysis. Thus if we need to chose any muscle for deriving EMG activation for prosthetic control ,Rectus femoris muscle will be a better choice for controlling gait parameters in comparison to Medialis hamstring and Gastrocnemius muscle.

5. References

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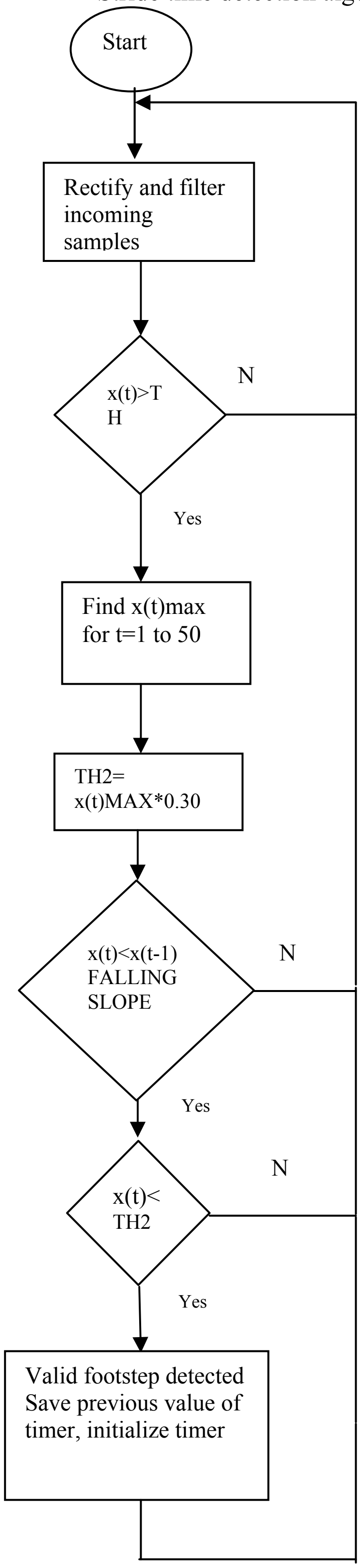
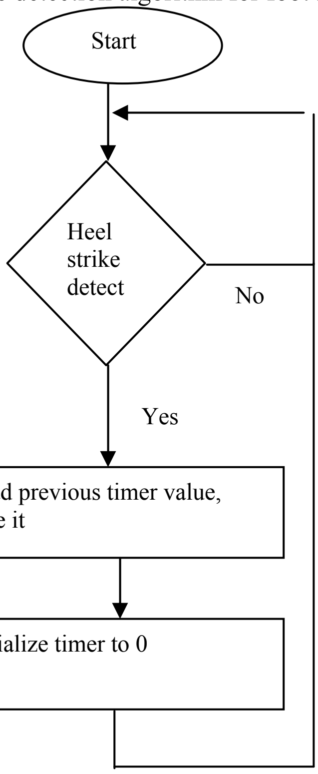
Stride time detection algorithm from EMG



Stride time detection algorithm for foot switch



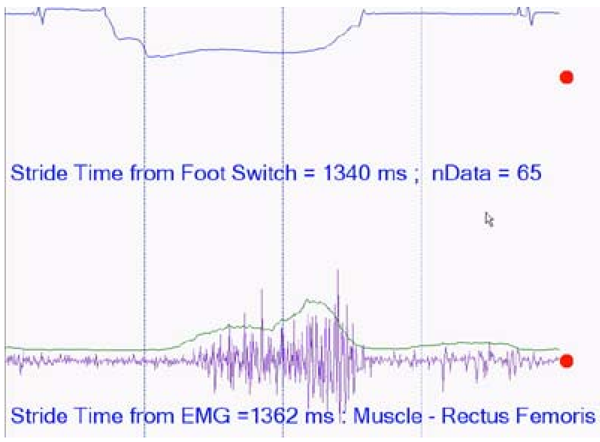


Fig. 7: Snapshot of the acquisition window. Switch Waveform (top) and EMG waveform (Bottom).