

ALGORITHM FOR IDENTIFICATION OF RUNNING, WALKING, AND STANDING ACTIVITY IN FOOT FORCE DATA

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INTRODUCTION

In-shoe total foot force data collected with a portable device, can provide valuable insight into a subject's free daily activity both in and outside of the laboratory (Hurkmans et al, 2006). However, as the length of data collection increases, the feasibility of manually classifying ground reaction forces (GRFs) into different activities decreases.

The accuracy of a magnitude-based activity identification algorithm can be compromised by the pseudo-random activity of subjects. For example, transferring weight between feet during rocking could incorrectly indicate walking.

A spectral-based method can be inherently problematic due to the relatively small differences and/or overlap in the fundamental frequencies of walking and running. (Figure 1, Table 1).

The following must be considered in the development of an algorithm that utilizes both frequency and magnitude criteria: 1) Running can have harmonics with significant magnitude content outside of the running and walking band (Figure 1). 2) A large transient movement, like a sudden jumping motion, can have broad frequency content that "spreads" frequency content into the running/walking band. 3) The base

frequency peak of running and walking can vary with locomotion speed.

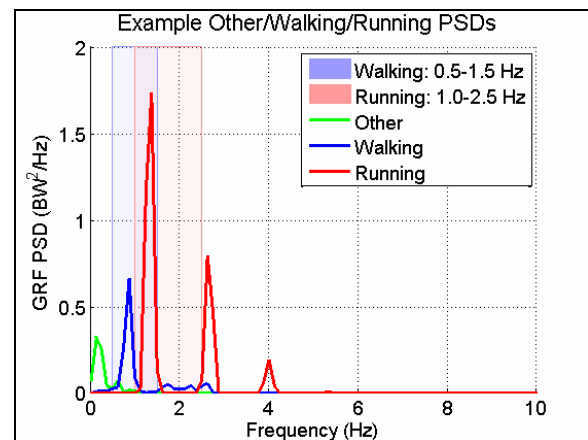


Figure 1: Typical power spectral density (PSD) of standing, walking, and running.

Therefore, an adaptive comb filter algorithm that utilizes both frequency and magnitude criteria for the identification of activity type from total foot force data has been developed. This algorithm can be utilized in either real-time applications or in post-processing.

METHODS

The GRF data used for the development of the algorithm was collected at 128Hz during a previous experiment (Cavanagh et al. 2004) in which subjects wore Pedar force measuring insoles (NOVEL GmbH, Munich, Germany) for entire typical work days. Data were collected using a wearable, portable computer, normalized to body weight (BW)

and downloaded for data analysis completed using custom Matlab software (Mathworks Inc. Natick MA).

The GRF data was analyzed in 8 sec. increments, shifting every 0.1 sec. The PSD of the GRF data was calculated using a Discrete Fast Fourier Transform (DFFT) to find the peak frequency. If the peak frequency was within the defined band for running or walking, the data was further investigated. Using the peak frequency as the first harmonic (or fundamental) and a user selected filter bandwidth, 5 harmonic bands were calculated (Figure 2).

The magnitudes of the GRF in these bands were calculated using Parsevals theorem:

$$M_{RMS} = \sum_1^k \sqrt{\int_{f_{peak}(k)-w}^{f_{peak}(k)+w} PSD(GRF)} \quad [1]$$

k = number of harmonics
w = comb filter half band width
f_{peak} = peak base frequency (fundamental)

SUMMARY

The authors have performed parameter sensitivity analyses on factors such as sample rate, number of points in the DFFT, and varying activity types to demonstrate the robustness of the algorithm. While it is currently used in numerical post processing, the spectral analytical basis of the algorithm lends itself to straightforward deployment in a real-time digital signal processing (DSP) chip.

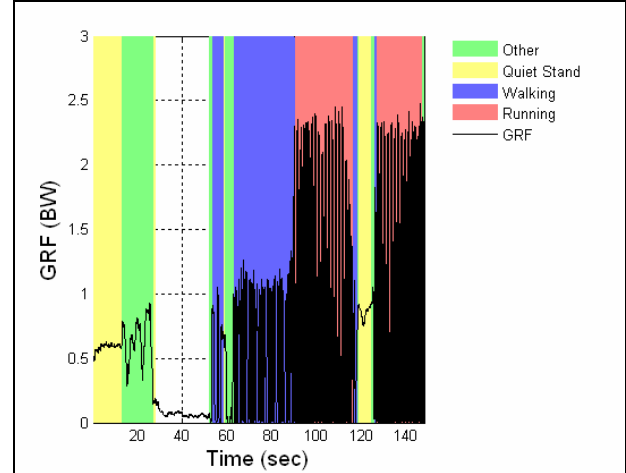


Figure 2: Typical GRF data separated into standing, walking, running and other activities by the algorithm.

The algorithm has been successfully utilized to expeditiously identify activity type in long duration data sets (Figure 2). While there are numerous practical applications for the algorithm, it was specifically developed to identify activity type for calculation of an enhanced Daily Load Stimulus (eDLS), a method of quantifying daily stress histories on the feet which are relevant to bone homeostasis.

REFERENCES

- Cavanagh P.R. et al. (2004). *50th Annual Orthopaedic Research Society Meeting*.
Hurkmans H.L.P. et al. (2006). *J Biomechanics*, **39**, 110-118.

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Table 1: Peak frequency and magnitude in PSD of running and walking from collected data.

Activity	Peak Frequency (Hz)	Magnitude at Peak Frequency (BW)
Walking:	0.5 – 1.5	0.6 – 1.6
Running:	1.0 – 3.0	1.4 – 2.6