

Motor noise removal for determining gait events over treadmill walking using wavelet filter

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Abstract

The conventional method for filtering force plate data, low-pass filtering, does not always give accurate results when applied to force data from a custom-made, instrumented treadmill. Therefore, this study compares low-pass filtered data to the same data passed through a wavelet filter. We collected data with the treadmill running. However these include motor noise with ground reaction force at two force plates. We found that the proposed wavelet method eliminated motor noise to result in more accurate force plate data than the conventional low-pass filter, particularly at high speed motor operation. In this study we suggested the convolution wavelet (CNW) which was compared to that of a low-pass filter. The CNW showed better performance as compared to band-pass filtering particularly for low signal-to-noise ratios, and a lower computational load.

Key words : Wavelet, Treadmill, Gait, Motor noise, Ground reaction force

1. INTRODUCTION

The standard method to filter data acquired from force plates is a low pass filter, which is used in many gait studies[1][2]. This is sufficient for over-ground studies, but, in the case of a custom-made, instrumented treadmill moving at high speeds, the treadmill motors produce additional noise that is not always removed by a low-pass filter. Center of pressure data is calculated from ground reaction force(GRF), and the center of pressure is used in inverse dynamics to find the moments created by the GRF about the leg joints. Therefore, accurate GRF data is critical to the accuracy of inverse dynamics calculations.

Thus, noisy GRF data can be problematic in gait studies. Therefore, we seek to use a wavelet filter to remove the noise due to the treadmill, giving cleaner, more accurate GRF data. We hypothesize that the wavelet method will eliminate noise to result in more accurate force plate data than the low-pass filter, particularly at higher treadmill speeds.

2. METHODS

We obtained center of pressure data using a calibration stick with a marker at one end. With the calibration stick held close to vertical, the end with the marker was pressed against the moving treadmill track. The marker was to verify center of pressure data from the force plate using marker data given by a6-camera Vicon system. Marker position from camera data was compared with filtered force plate data using linear regression. To validate force measurements, separate trials were taken in which the treadmill was loaded with a calibration pole

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containing a force transducer. force transducer. Data from the transducer was compared with force data from the force plates. For both the calibration pole and calibration stick, we gathered data at 1m/s and 2m/s treadmill Data from the transducer was compared with force data from the force plates. For both the calibration pole and calibration stick, we gathered data at 1m/s and 2m/s treadmill speeds. Force data was processed in Matlab and filtered with two methods. Force data was first filtered with a standard method—a low-pass, four thorder, Butterworth filter with a threshold of 20Hz –to filter the raw force data.

The wavelet trans form is a convolution of the wavelet function $\psi(t)$ with the signal $x(t)$. Orthonormal dyadic discrete wavelets are associated with scaling functions $\phi(t)$. The scaling function can be convolved with the signal to produce approximation coefficients S. The discrete wavelet transform(DWT) can be written as:

$$T_{m,n} = \int_{-\infty}^{\infty} x(t)\psi_{m,n}(t)dt \quad (1)$$

In practice our discrete input signal $S_{0,n}$ is of finite length N , which is an integer power of 2: $N = 2^M$. Thus the range of scales that can be investigated is $0 < m < M$ [5]. A discrete approximation of the signal can be shown as

$$x_0(t) = x_M(t) + \sum_{m=1}^M d_m(t) \quad (2)$$

where the mean signal approximation at scale M is

$$x_M(t) = S_{M,n}\phi_{M,n}(t) \quad (3)$$

and the detail signal approximation corresponding to scale m is defined for a finite length signal as

$$d_m(t) = \sum_{n=0}^{2^{M-m}-1} T_{m,n}\psi_{m,n}(t) \quad (4)$$

The convolution wavelet method (CNW) method can reduce the computational complexity for real-time signal processing [6][7][8].

$$CNW(t) = \psi(t)_{k=3} * \phi(t)_{k=3} \quad (4)$$

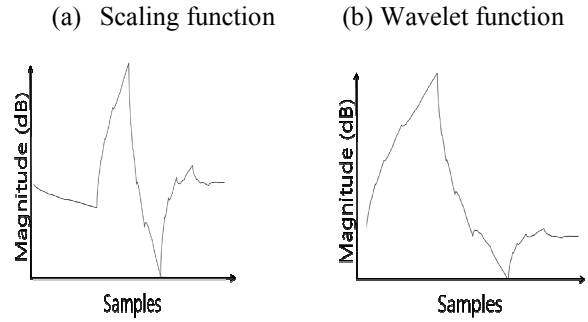


Fig. 1. The magnitude response of wavelet function and scaling function.

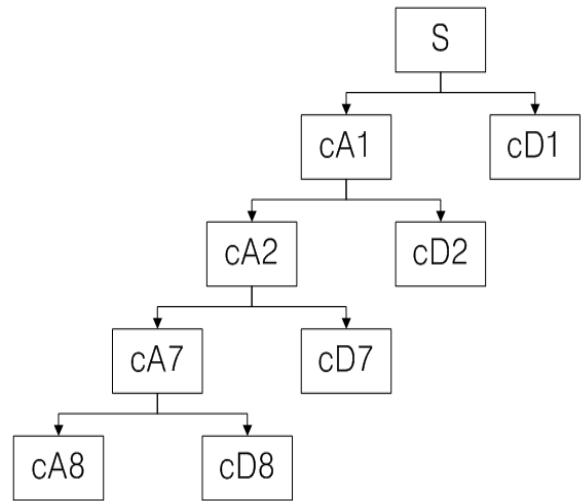


Fig 2. Diagram of 8 Level Decomposition

We selected and reconstructed $cD8, cD7, cD6, cD5$ which turned out to have the most of desired components through on 8-Levels Decomposition. Based on the experiment, we selected and reconstructed $cD8, cD7$ and $cD6, cD5$.

3. RESULTS AND DISCUSSION

The linear regression in Fig. 2 indicate that, while errors in center of pressure data after low-pass filtering may be acceptable at 1m/s, these errors become too large when the treadmill runs at 2m/s. This confirms that a different filter is necessary. We found that the result of CNW

eliminated the noise while retaining all of the important components of the signal.

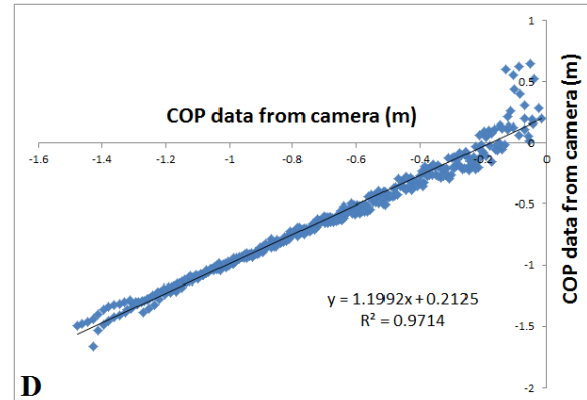
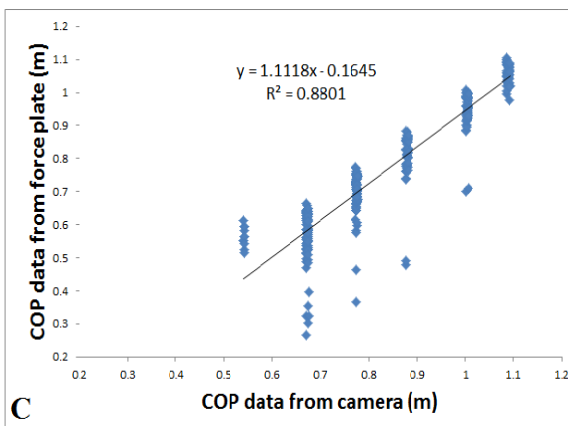
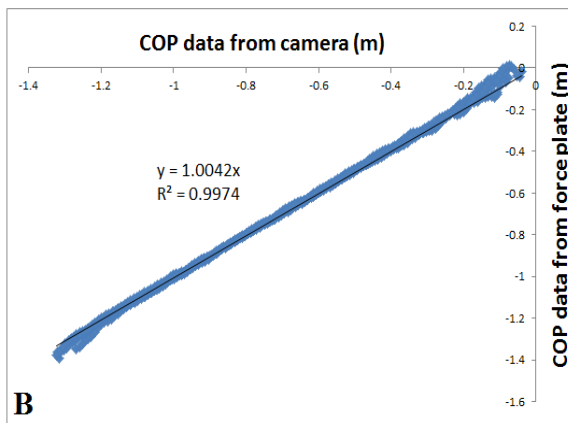
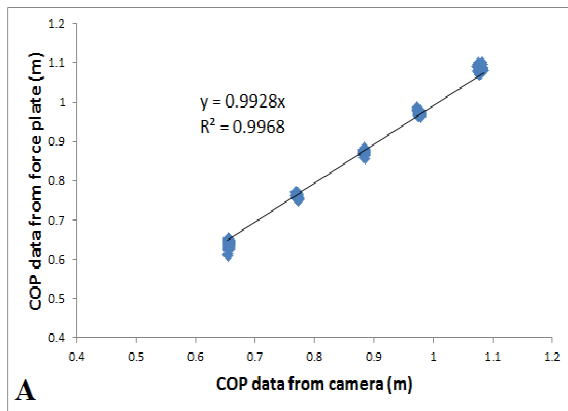


Fig. 3. The medial-lateral coordinate (A) and anterior-posterior coordinate (B) of COP at 1m/s and the medial-lateral coordinate (C) and anterior-posterior coordinate (D) of COP at 2m/s.

The instrumented treadmill can facilitate many types of biomechanical studies of human locomotion and measure vertical and horizontal ground-reaction forces during gait. Since wavelet filtering allows for more accurate force measurement at high speeds, it makes the instrumented treadmill a more powerful tool for gait analysis.

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