A COMPARISON OF VARIOUS DIGITAL FILTERING TECHNIQUES APPLIED ON PLANTAR SURFACE PRESSURE AND SHEAR DATA

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Introduction

Occurrence of ulcers on the plantar surfaces of the diabetic patients' foot can lead to serious medical complications, including limb amputation. We have employed a transducer array to measure the plantar surface pressures and shear forces whose combination may give rise to diabetic foot ulceration. However data produced by the equipment includes noise that needs to be filtered in order to perform subsequent data analyses. The aim of this study is to investigate and compare the common spatial, temporal and wavelet signal denoising procedures on the plantar surface pressure and shear force data.

Methods

The device (Figure 1) has 80 transducers that are based on strain gauge technology and capable of collecting all three force components (vertical, mediolateral and anteroposterior) simultaneously. It was designed in an 8 x 10 array architecture with 10 mm x 10 mm measuring transducers. Data were obtained at 50Hz for 2 seconds during steady state gait without adjusting step lengths prior to contact with the platform. To achieve spatial domain filtering the shear data were converted into an 8 x 10 pixel resolution 8-bit grayscale image. The median filter in Matlab's (MathWorks, Nattick, MA) image processing toolbox and a 2D Wiener filter were then employed on the spatial data. Two time domain filters, moving average and second order Butterworth, were also operated on the time series data. Cut-off frequency for Butterworth filter was calculated according to Wells *et al* (1). We utilized the Rice Wavelet Toolbox, an open source wavelet toolbox developed by the Digital Signal Processing Group at Rice University, to carry out wavelet filtering of the shear data (2).

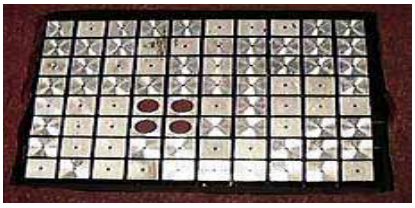

Figure 1. The transducer platform used to obtain pressure and shear data. The overall size is 14.2 cm by 11.4 cm

Results and Discussion

In order to compare the performance of the methods employed, average signal-to-noise ratio (SNR) was calculated for each filtering process. The results of SNR calculations are given in Table 1. The SNR values indicate that the wavelet filtering yielded the best noise removal. Spatial filtering was found to be inappropriate with the shear data. Figure 2 shows a representative set of results for the five filtering techniques. Temporal filtering of the shear data produced intermediate noise elimination.

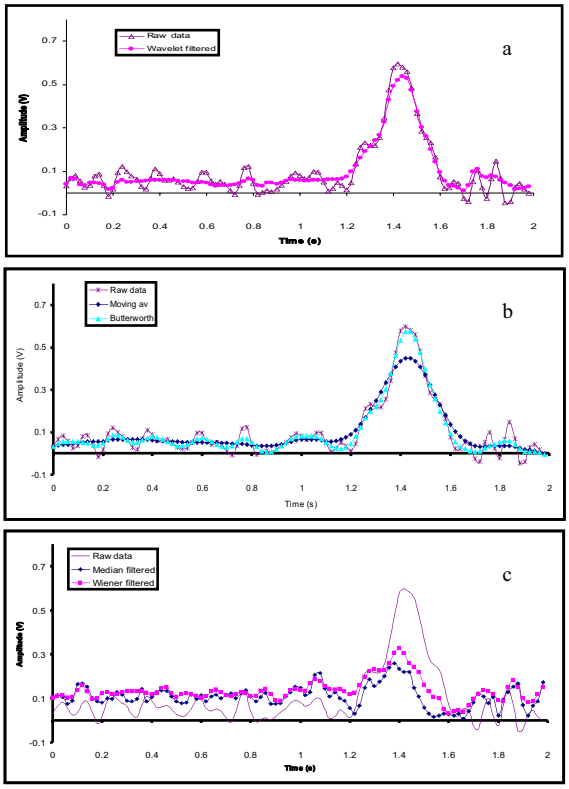

Figure 2. Results of a. wavelet filtering, b. time domain filtering, c. spatial filtering of shear data

Table 1. SNR values for each filtering process

Filter	SNR (dB)
Wavelet	8.97
Butterworth	7.13
Moving Average	4.96
Wiener	0.12
Median	-0.19

Conclusions

Wavelets were observed to perform high quality shear data filtering due to their ability to analyze both spectral and temporal information in the data compared with other noise removal procedures. Spatial filtering did not perform well, most probably due to spatial resolution of the transducer array.

References

1. Wells RP, Winter DA. Proceedings of the first Congress of the Canadian Society of Biomechanics. Human Locomotion I, Waterloo, 1980:92-93.
2. http://www.dsp.rice.edu/software/rwt.shtml

Acknowledgment

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