Filtering of Acceleration Data for a Countermovement Vertical Jump

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***Abstract*—This project explores a method of processing accelerometry data for a counter movement jump in order to remove high frequency noise while preserving the overall shape of the curve. A 4th order lowpass Butterworth filter with cutoff at 12 Hz was shown to remove noise from the acceleration signal while preserving the qualities of the acceleration signal.**

I. Introduction

The countermovement jump (CMJ), also known as the standing vertical jump, is a commonly used test in sports and rehabilitation contexts for measuring the explosive power output of athletes. A common method of evaluating a countermovement jump is by using a force plate to look at the force vs time characteristics of the jump. However, force plates are often expensive and inaccessible for a lot of people.

An alternative method for analyzing a CMJ is through the use of accelerometers affixed to the subject's body. Accelerometers have become ubiquitously available and are included in most modern smartphones. As such, obtaining acceleration data for vertical jump analysis could be as simple as affixing a phone to one's body and then jumping. However, this acceleration signal can often be subject to noise which can affect both quantitative and qualitative analysis of vertical jump signal data. This noise can contribute to error especially when trying to calculate power or work, which would require integration of the acceleration time signal. The objective of this project was to filter acceleration data from a vertical jump in an attempt to remove noise while preserving the overall shape of the signal so that the different aspects of the vertical jump could be determined.

II. Background

The countermovement vertical jump (CMJ) is a type of vertical jump where the subject jumps as high as they can from a standing position. This jump can be broken down into 5 different phases of acceleration. The first phase is the unweighting phase, where the subject drops downwards which results in their center of mass accelerating down towards the ground. The second phase is the braking phase where the subject slows their descent by applying force into the ground to accelerate upwards (their center of mass is still moving downwards but at an increasingly slower rate). The third phase is the propulsive phase where the subject is accelerating upwards and ascending by continuing to apply force into the ground. The fourth phase is flight where the subject is airborne and the only force acting on their body is the acceleration due to gravity which will eventually bring them back to the ground. The final phase is the landing phase where the subject applies force into the ground upon contact to counter the force of landing until they come to a stop. Ideally, each of these distinct phases of acceleration should be visible from acceleration data obtained from an accelerometer.

III. Method

A. *Data Collection*

Acceleration data for a CMJ was obtained from a Google Pixel smartphone using the linear acceleration function of the Physics Toolbox Sensor Suite application. The phone was affixed to the subject's lower back in a landscape position through the use of a belt phone holder in an attempt to minimize extraneous movement. While acceleration data is collected by the phone in three different coordinate axes, only acceleration data from the phone's x axis was used for this experiment. Acceleration data was collected at a rate of 50 Hz, which is the maximum sampling rate allowed by this smartphone.

B. *Filtering*

A Fast Fourier Transform (FFT) was performed on the accelerometer signal data in order to view its frequency components. Upon visual inspection, it was determined that a lowpass filter with a cutoff frequency of ~12 Hz would be sufficient to attenuate high frequency noise while preserving the distinct qualities of the signal. A 4th order Butterworth lowpass filter with cutoff frequency at 12 Hz was designed through bilinear transformation of an analog filter. This filter was then applied to the signal data. This filter was selected because it has no ripple and approximately linear phase in the passband in order to preserve the shape of the filtered signal. Edge effects were disregarded because absolute time does not matter in this application. A delayed signal has no effect on the quality of the CMJ data.

IV. RESULTS

A. Acceleration data

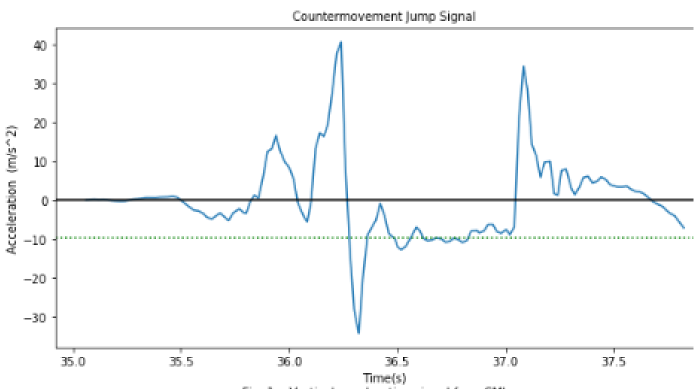


Fig. 1a. Vertical acceleration signal for a CMJ

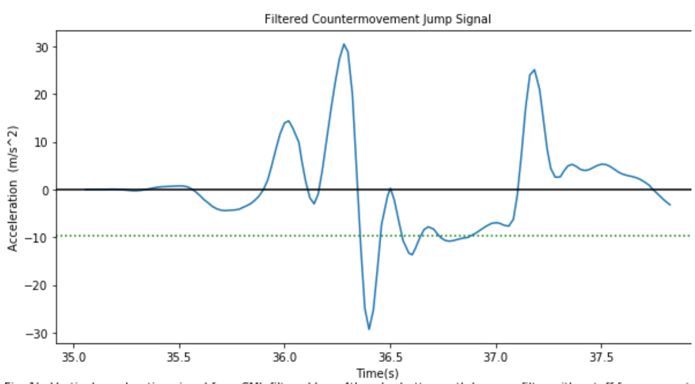


Fig. 1b. Vertical acceleration signal for a CMJ, filtered by a 4th order butterworth lowpass filter with cutoff frequency at

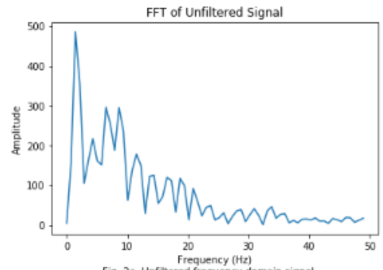


Fig. 2a. Unfiltered frequency domain signal.

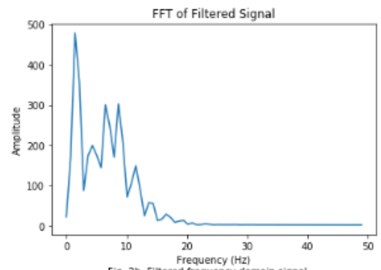
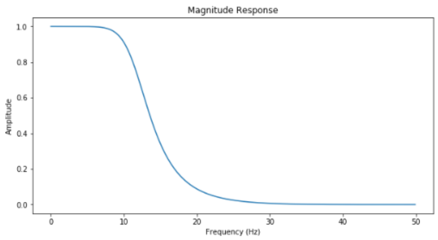
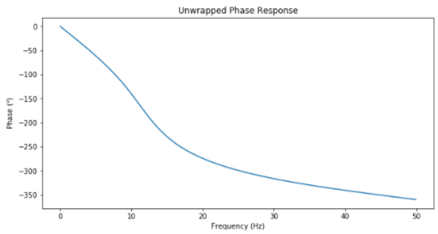
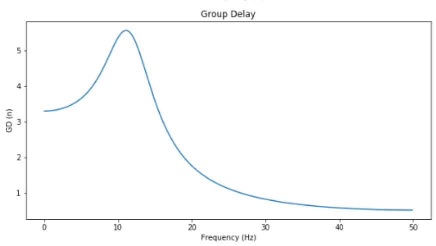


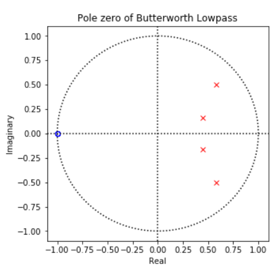
Fig. 2b. Filtered frequency domain signal.

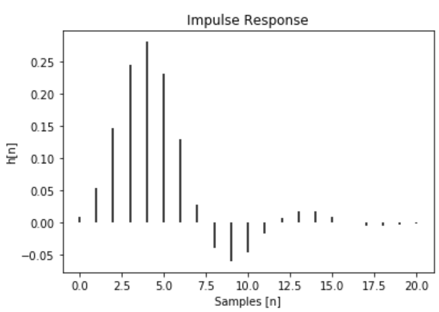
B. *Filter Characteristics*





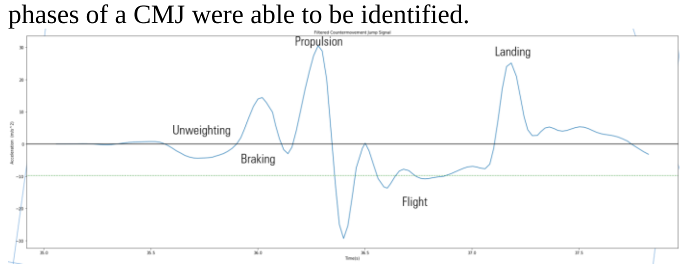






V. Discussion

The 4th order lowpass Butterworth filter implementation was successful in reducing high frequency noise in the CMJ acceleration data. This was achieved while minimizing ripple and phase distortion in the lower frequency passband. In the filtered signal, the different acceleration phases of a CMJ were able to be identified.



Previous studies suggested that a 2nd order Butterworth lowpass filter with an 8-13 Hz cutoff was sufficient to filter smartphone accelerometer data while minimizing over filtering effects[1], so the results obtained in this experiment seem reasonable. Future investigations may be done to investigate how different filters quantitatively affect acceleration data to see if power output can be accurately measured through a smartphone accelerometer. This could lead to a more accessible method for athletes to easily track their power output during a CMJ through a smartphone application rather than through the use of a force plate.

VI. Conclusion

A 4th order Butterworth lowpass filter with cutoff of ~12 Hz was sufficient to reduce high frequency noise in acceleration data obtained from a smartphone accelerometer during a countermovement jump. This filtering was achieved while simultaneously preserving the qualitative shape of the acceleration signal. This allowed for identification of the distinct acceleration phases during a CMJ.

References

[1] De la Fuente, C., Carlos Cruz-Montencinos, C., Pena y Lillo, R., Chamorro, C., Henriquez, H. and Ramirez-Campillo, R., 2018. An Eight to Thirteen Hertz Cut-Off Low Pass Filter is More Appropriate to Treat Isoinertial Accelerometry Signals During Jumping. *Asian Journal of Sports Medicine*, [online] 9. Available at: <https://sites.kowsarpub.com/asjsm/articles/12351.html> [Accessed 10 December 2020].