Fall 2019 ME459 Final Project Report

University of Wisconsin-Madison

Implementation of Shear Wave Tensiometry Processing Algorithm in C

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**Abstract**

Shear wave tensiometry utilizes two miniature accelerometers to compute the shear wave speed in a soft tissue, which can, in turn, be used to compute the axial soft tissue stress [1]. The Neuromuscular Biomechanics Lab uses a variety of algorithms to process outputs from these two accelerometers to compute wave speed. Some of these include speckle tracking of B-mode ultrasound images, interpretation of radiofrequency (RF) ultrasound data, fast Fourier transformations, and, for the purpose of this project, correlations between the two accelerometer signals. However, all are written in MATLAB, which is an interpreted language, thus making the algorithms timely to execute and infeasible to use in real-time. The purpose of this project is to translate the post processing algorithms used to compute wave speed to C. By doing so, we can enhance the speed of the real-time computing of shear wave speed.

The text of the abstract comes here. Use font size 12 throughout the document.   
IMPORTANT NOTE: The name of the file for your Final Project report should be ME459FirstnameLastname.pdf. Like ME459DanNegrut.pdf. Drop this Final Project report in Canvas in the folder “FinalProject751” by Tuesday, December 14, at 2:45 PM. Do not go beyond 10 pages unless you really feel like you have to (page count doesn’t include TOC, abstract, etc.). Feel free to use a LaTeX source as long as you follow this format; in the end, you will be uploading a PDF anyway.

Please make sure that you include in this \*abstract\* a link to the git repo for your project. Using this link (i) we will fork the project code (particularly important for multi-student teams); (ii) we will look at the progress history for your project as documented by git.   
To verify that you provided the *right* git link, click on it. It should take you to your git repo.

[If this link to your repo is missing, your score can not be higher than 98%]

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# General information

* Home department: Mechanical Engineering
* Current status: PhD students
* Individuals working on Final Project: Jonathon Blank

Dylan Schmitz

* I am not interested in releasing my code as open source code.

# Problem statement

The purpose of this project was to convert an algorithm that is frequently used in our lab from Matlab to C. We did this because of the time efficiency that algorithms written in C can provide. To summarize, the code that we are converting is a post-processing algorithm that computes the time delay in a correlated acceleration in response to a mechanical excitation passing by the successive accelerometers. Specifically, we will focus on implementing a code wrapper that filters and computes a normalized cross-correlation of two data signals, before making computations in response to the sorted mechanical tap signal. By doing so, we can compute a shear wave speed, which we use as a proxy to gauge tendon and ligament stress in humans. Having a version of this code written in C could potentially allow our group to gauge these stresses in real-time due to the timing efficiencies that we can leverage.

# Solution description

Indicate how you went about implementing your solution. Explain data structures, algorithms used, code structure, function you implemented, etc. Provide a panoramic snapshot of your Final Project effort.

We began by constructing a wrapper file that the end-user can use to interface with the library of functions that we created. We then implemented a read function that loaded a LabVIEW file as a data matrix with three columns: the tap signal, the first accelerometer signal, and the second accelerometer signal. The next function implemented was a low and high pass Butterworth filter to eliminate noise in the accelerometer signals that would interfere with our cross-correlation. Then, we utilized a sorting algorithm to determine when “push” and “pull” tap events occurred, which corresponded to when a piezoelectric actuator pushed into and pulled away from the skin superficial to the tendon, respectively. Finally, we implemented a cross-correlation algorithm to compute the time delay in accelerometer wave arrival, which in turn was used to compute the shear wave speed for a known physical distance between the accelerometers.

# Overview of results. Demonstration of your project

Explain here what you obtained, explained why the results are good/bad. This is the place where you talk about the outcomes of your Final Project effort. It is not the end of the world if your code doesn’t work as anticipated. Explain here how far you have made it.

Most often, you have a comparison against sequential code, perhaps via a scaling analysis. Make sure you include plots and/or tables to show your results.

# Deliverables:

Discuss what is delivered for this Final Project. Important points:

* This report should be in Canvas.
  + On multi-student teams, each team member should submit a final report; i.e., this document. However, the code should be in one repo
* Tell us what is in your git repo and explain how we can run your code
  + If we cannot run your code, explain why that is the case

# Conclusions and Future Work

The code that we have provided is a useful tool that can be utilized to improve research efficiency within the Neuromuscular Biomechanics Lab. Continued work on this will seek to improve runtime efficiency so that it can be used as an executable in real-time with live tensiometry collections, which will provide a live visualization of results during experiments.

# References

[1] Martin, J.A., Brandon, S.C.E., Keuler, E.M. *et al.* Gauging force by tapping tendons. *Nat Commun* **9,**1592 (2018) doi:10.1038/s41467-018-03797-6.