2008-09 Academic year
Establishing the Sensitivity of Shear Stiffness Medical Imaging Data to Biomechanical Changes – Three possible Undergrad projects

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We work in tissue shear stiffness imaging. This project is inspired by the doctors' palpation exams where practitioners press against the skin to feel abnormal tissue. We target imaging prostate and breast tumors as well as imaging fibrosis of the liver. The medical technologies being developed by experimentalists with whom we work all have the following features: (1) a shear wave that propagates into the body is generated; (2) this wave may have a propagating front; it may be a time harmonic traveling wave; or it may be a traveling wave created by two sources oscillating at two different but nearby frequencies; (3) a movie is created of the displacement as the wave is traveling; the individual frames are created either by ultrasound or MRI; the movie is of the interior displacement on a fine set of grid points (.3 mm spacing), usually in a 2D image plane; (4) the propagating wave is an elastic wave and so there are three displacement components; we obtain one component if ultrasound is used to create the movie; we obtain 2 or 3 components if MRI is used to create the movie; the MRI data set is then richer but it is more expensive to obtain this data set; and (5) the data is very noisy; 10% to 20% noise is common.

The goal is to create an image of shear stiffness parameters; that is shear wave speed and viscoelastic properties, where the latter can be seen as frequency dependence of the shear wave speed. We have developed several algorithms that create images of these quantities; indeed we have had some remarkable success with laboratory data both from phantoms and also from *in vitro* (excised tissue) or *in vivo* (human subject tissue..not excised). We have overcome the appearance of noise artifacts with adaptive algorithms since the noise level can be different in different parts of the image plane.

However, we have not done a study to determine when the displacement changes rise above the noise level in the presence of tumors or abnormal tissue. We do however have a conjecture about what combination of size, stiffness change and frequency (when there is a time harmonic excitation or when there is a central frequency in the propagating wave) affects the displacement change. We also have code for the 2D elastic system where we can put in different values of wave speed and viscoelastic properties, different size inclusions, different placement of the inclusion (near the body surface…deep in the body, etc.). We also have purchased a new 8 processor, shared memory, 128 GB computer.

So the projects are:

1. Consider the time harmonic excitation experiment; Make synthetic data calculations for a set of possible configurations: size of inclusion, contrast of inclusion, frequency of excitation, frequency dependence in the mathematical model. Either verify the current conjecture or make a new conjecture about the combination that determines the displacement change that occurs because of all these changes. If time permits, establish your conjecture.
2. Consider the experiment where there are two sources oscillating at 2 different frequencies; the traveling wave that is produced has a speed that is a fraction of the shear wave speed where that

fraction is the frequency difference divided by one of the frequencies. As in the above project, make synthetic data calculations for a set of possible configurations: size of inclusion, contrast of inclusion, frequency of excitation, frequency dependence in the mathematical model. Based on the results of your calculations, make a conjecture about the combination that determines the measurement change that occurs because of all these changes. If time permits, establish your conjecture.

3. The 2D code has some interesting properties. For example, we create the code so that there are no reflections at the boundary of our computational domain (our method is referred to as PML, perfectly matched layer); we also use finite difference techniques which are easy to understand and to code. If there is interest in understanding the computational method, particularly the PML layer that is created so that there are no reflections at the boundary, and the advance of that method to 3D (on our new computer) that is also a possible project.

I have three students and one postdoc working on the stiffness imaging project so there will be opportunity to work with them during each of these projects. I also have another student who is working on a geophysical imaging project who is well versed in techniques that would help in the third project.