IIB Project Technical Abstract

Measuring Tissue Stiffness Using Ultrasound - Matthew Graham (JE)

Motivation

Tissue mechanical properties such as stiffness contain significant amounts of medically relevant information, with pathologies often being associated with a change in tissue stiffness in a region. Traditionally tissue stiffness has been assessed in clinical settings by manual palpation techniques which are inherently subjective in nature and limited to being applied to large, superficial structures.

This has motivated the development of a range of approaches to non-invasive imaging of tissue elasticity - also known as elastography. Within this field several approaches based on measuring tissue displacement responses using ultrasound imaging techniques have shown particular promise.

In quasi-static ultrasound elastography the tissue region being scanned is compressed with the probe face and static analysis techniques used to estimate tissue elastic properties from the measured deformation. It allows high resolution, real time imaging using only conventional ultrasound hardware however importantly without knowledge of the stress or stiffness boundary conditions in the region being scanned it can only provide relative measures of tissue stiffness, preventing quantitative diagnostic analysis.

Dynamic ultrasound elastography approaches are instead based on measuring the response of tissue to temporally varying excitations. Two particular techniques, pulsed transient elastography and supersonic shear imaging have been particularly successful, both based around imaging the propagation of shear wave fronts through a tissue region using a high speed ultrasound scanner. Both these approaches produce high resolution images of absolute tissue stiffness however they require specialist hardware both for the tissue excitation and ultrasound imaging.

Project contribution and aims

The aim of this project was to develop a hybrid ultrasound technique combining elements of both quasi-static and dynamic elastography approaches. If the absolute tissue stiffness values at a small set of points can be determined it was proposed these could then be used to calibrate a relative stiffness image computed using the quasi-static ultrasound approach. Importantly the aim was to achieve this using only conventional ultrasound equipment.

The novel contributions proposed to achieve this aim were to use a manual tap on the surface of the tissue as the excitation method and to scan the tissue using only a small subset of the ultrasound probe transducer elements. This gives displacement measurements reduced in spatial extent but with an increased temporal resolution, hopefully sufficient to characterise the dynamic displacement response of the tissue.

Report structure

The *Introduction* section begins with a more in-depth discussion of the motivation for stiffness imaging and a brief overview of the main elastography techniques. A more detailed discussion of the quasi-static and transient elastography approaches being used as the main basis for this work is then presented, this leading to an outline of the project aims and objectives.

In the *Theory* section relevant background material is presented and discussed. The assumptions about tissue mechanical behaviour being made are outlined and used to derive the governing equations of motion for the tissue mechanical model. A technique for directly inverting this governing equation to infer tissue elasticity from measured shear wave displacement responses is then presented. An alternative method based on tracking the propagation of wave fronts through the scan region is also discussed. Finally there is a brief discussion of the simulation method used to produce the synthetic displacement data sets used in this work.

The *Development of Method* section details the work done in investigating the feasibility and performance of the proposed hybrid method. The method of measuring displacements using a reduced scan sequence is discussed and brief details of the implementation used presented. An in-depth discussion of various problems encountered in using the manual tap tissue excitation method when scanning a tissue mimicking phantom is then presented and methods of overcoming these issues tested. This section ends with a discussion of the work done in developing implementations of the inversion and wave tracking approaches to infer elasticity estimates from measured displacement data.

In the *Results and Dicussion* section elasticity estimates made using the developed methods in regions of the phantom and an in-vivo region of calf muscle are presented and used to discuss the performance of methods developed.

A discussion of the overall success of the developed method with reference to the original project aims and suggestions for possible future areas of research is presented in the *Conclusions* section.

Main findings

The overall performance achieved with the developed method was poorer than originally hoped. Using the wave tracking approach plausible measurements of stiffness in both a region of the tissue mimicking phantom and of in-vivo calf muscle were produced, however no localisation of these estimates was achieved. The inversion method was not found to produce any useful results with the measured displacement data, even after introduction of several refinements to improve noise robustness, and it was left unclear if this approach could be made successful in practice with the sparse displacement response data sets obtainable with conventional ultrasound hardware.