Project title: “Medical ultrasound elastography: from tissue stiffness to cancer diagnosis” Supervisors: Fabrice Prieur, Andreas Austeng, Sverre Holm, IFI

Applicant background and competences: The candidate must have a master in a related field of Physics, Acoustics, or Mathematics and a solid background in signal processing and programming.

Main objective and summary of the project

Medical ultrasound elastography can estimate the stiffness of tissue. It is a crucial parameter to diagnose diseases such as cancer. The objective of the project is to participate in setting-up a system to produce in vivo elasticity maps with our ultrasound scanner, to estimate the impact of parasitic displacement, and elaborate methods to correct for it and improve the quality of the produced images. This project strengthens our existing research effort on cancer imaging and elastography that we pursue with our partners: King’s college London, Oslo University Hospital, and GE Vingmed Ultrasound. It has strong ties with the MEDIMA project, a strategic research initiative funded by our faculty, the FORCE project part of the Horizon 2020 program funded by the European Research Council, and the Centre for Innovative Ultrasound Solutions that includes the Norwegian University of Science and Technology. This particular project is a collaboration with the department of radiology at Charité medical university in Berlin.

Project background and scientific basis

If you break your leg you take an X-Ray examination. If you are pregnant you are followed up using ultrasound examination. If you are looking for a brain tumor you take a CT scan examination. If your back hurts due to an inflamed disc you take a Magnetic Resonance Imaging (MRI) examination. But what do you do with this hard lump you can feel in your breast? The above imaging modalities are not sensitive to the stiffness of tissue. A soft lump might be the sign of a benign tumor and a hard lump of a malignant tumor so it is crucial to identify how stiff your lump is (Figure 1).

In the past two decades, an imaging modality called tissue elastography has emerged providing a way to estimate the tissue stiffness quantitatively and non-invasively. The candidate’s task is to study a key component to establish higher resolution elastograms. Such elastograms which depict the details of elasticity variation in the tissue are required for clinical applications in tumors. As such professor Sack from Charité medical university in Berlin considers that “This study could open the door to future success of elastography in tumors”.

The principle of elastography is to generate a movement in the body that will “shake” the tissue under examination and analyze the tissue response to this shaking. The stiffer the tissue the smaller the displacement and the faster it propagates.

Figure 1: Elastography image (top) conventional ultrasonography (bottom) of papillary thyroid carcinoma, a malignant cancer. Conventional ultrasonography does not allow detection of the tumor. Reproduced from [10]
The main imaging modalities used to “track” the displacement induced in tissue and create an “elasticity map” are MRI and ultrasound [1] [2]. A limitation for the vast majority of the UltraSound Elastography (USE) methods is that it only tracks the displacement in a two-dimensional plane: if the imaging plane is horizontal USE can track the tissue displacement in this plane but if the tissue moves in the vertical direction USE cannot track this “out-of-plane” displacement which perturbs the tissue stiffness estimate. There is therefore a need to understand and attempt to minimize its impact on the elasticity estimate.

USE is a well-established diagnosis modality for examination of organs such as liver, breast, thyroid, gastrointestinal tract, pancreas, lymph nodes, and prostate [3]. This makes USE a very relevant research field supported by the industry. Our group has extensive expertise in ultrasound and our collaboration with the Charité medical university in Berlin and their extensive knowledge in magnetic resonance elastography (MRE) will give us high chances to answer many questions on USE.

Research questions and scientific challenges

In its infancy USE used external mechanical vibrators to generate shear waves in tissue as MRE does today (Figure 2). It then moved to using the acoustic radiation force that creates a localized “push” deep into the tissue [4] [5]. This pushing method has many advantages but presents some limitations coming from a reduced penetration depth and a low amplitude of the generated displacements.

A renewed interest for the use of external mechanical vibrators has recently emerged in USE. With it come a controlled excitation frequency and a large penetration depth. They allow imaging whole large organs such as the liver in patients for who USE using acoustic radiation force would fail (e.g. obese patients) [6] [7] [8] [9]. The reconstruction methods in this case that establish an elasticity map from the measured displacement can also benefit from the progress made in MRE reconstruction. However since only displacement in the imaging plane can be tracked in USE the out-of-plane displacement component becomes a perturbation. Our group has extended expertise in image reconstruction and analysis which are believed to be the keys to address the issue.

Our goals would include:

- Estimate the influence of the out-of-plane displacement and develop a method to compensate for it. Most existing methods consist in applying a bandpass filter around the expected spatial frequency of the in-plane shear wave. This only works for tissues with fairly homogeneous elasticity and does not get rid of the estimate bias introduced by out-of-plane displacement.
- Study the possibility to better control the directivity of shear wave created by external vibrator or the sensitivity of the tracking method to the out-of-plane displacement. Improve the sensitivity of the existing methods to the in-plane displacements. Today’s processing methods include many steps with many tunable parameters. A more direct method would be beneficial.
Scientific method

1. Participate in the group effort to set up USE with external vibrator in our lab.
2. Set up simulation tools (finite element modelling, spatial impulse response-based) to estimate effect of out-of-plane displacement on ultrasound image.
3. Conduct experiments in the lab on our ultrasound scanner to test methods to compensate for out-of-plane displacement (alternative beamforming/speckle tracking algorithms).
4. Explore state-of-the-art methods for image reconstruction and speckle tracking to improve the sensitivity to in-plane displacements (imaging using plane wave compounding).

Ethics: The project will record ultrasound data from humans, this will be done with consent from the subjects, and with personal information anonymized.

Project timeline

Year 1: fulfill mandatory course + 1 conference proceeding on simulation result.
Year 2: Submit 2 journal papers on results on lab experiments and compensation methods.
Year 3: Submit 1 journal paper on results on sensitivity improvements to in-plane displacements.

Literature references


