Master Internships in Ultrasound Image Simulation

Medical context

Breast cancer is the most common malignancy among women with approximately 58,500 newly diagnosed cases and 12,000 deaths in 2017 in France. The mammography screening program initiated in 2004 led to increased diagnosis of nonpalpable lesions and, accordingly, to an increased need for preoperative localization (POL). POL is required to accurately identify and remove the lesion whenever breast conservative surgery is indicated. The current standard in POL is wire-guided localization, i.e., the placement of a flexible self-retaining wire under ultrasound (US) or stereotactic guidance. The surgeon uses the wire as a guide to locate and remove the tumor. However, this POL technique requires dedicated facilities and are source of patients' discomfort since it involves an invasive procedure prior to surgery. To partially overcome POL drawbacks, per operative localization of the lesion may have several strengths, particularly regarding preoperative schedule, overall cost and patient's discomfort.

The main objective of this project is to propose an innovative assistance procedure for nonpalpable breast cancer surgery, based on augmented reality (AR). AR, allowing real-time visualization of nonpalpable tumors, may theoretically overcome most of the limitations of both pre- and per-operative existing localization techniques. It will prevent the need for specific technical facilities, reduce patients' discomfort and avoid repeated imaging acquisitions at the time of tumor removal. However, real time noninvasive tumor tracking and visualization are particularly challenging in breast surgery: breast is a mobile and deformable organ whose shape changes with patient's position or histological composition, greatly different from one woman to another.


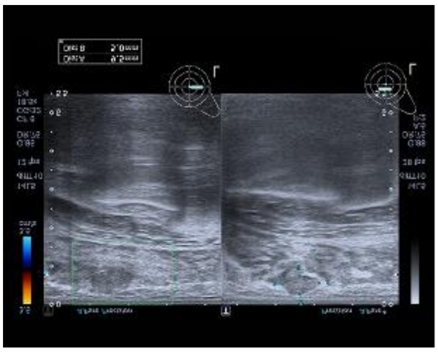

Figure: Ultrasound Imaging setup on Breasts

Main objective

During the exam, the US probe exerts an unknown compression of the breast, thus leading to local and non-homogeneous deformations. The main objective of this PhD thesis is to estimate the tissue deformations of the breast to provide relevant tumor information for 3D visualization.

Description of the work: We will perform the 3D reconstruction of the breasts by modelling their volumetric deformations using differential geometry. Such a modelling has been proven to be very efficient (in terms of both computation complexity and accuracy) in case of image-based reconstructions [1,2,3]. We will use a single, calibrated RGB camera to capture the surficial deformations of the breasts and propagate through the volume under the guidance of the ultrasound images.

Topic: Internship 1

Ultrasound image simulation is a common practice in research and training. Existing simulators generally follow the following steps: (i) generation of point scatterers with random amplitudes and positions, (ii) modeling of the ultrasound probe and its transmission and reception patterns, (iii) simulation of the RF signals resulting from the interaction between the ultrasound waves and the simulated scatterers. While these approaches are highly realistic and efficient in terms of two-dimensional calculations, their translation into 3D remains a major challenge. We have recently proposed a method, [4], for simulating 2D ultrasound images from a 3D medium in real time, a scenario that is very close to reality. However, this simulator does not take into account the deformation of the medium as it is explored by the probe. The aim of this internship is to model the deformation of the medium under the stress of the ultrasound probe, and its implementation in the existing simulator.

Topic: Internship 2

Traditionally, ultrasound imaging involves acquiring a series of 2D images, exploring the medium of interest with an ultrasound probe. Recently, the value of 3D ultrasound has been demonstrated in several clinical applications. However, 3D ultrasound imaging faces a number of challenges, notably linked to the manufacture of matrix probes and the management of the resulting large masses of data. One solution is to reconstruct 3D volumes from 2D slices acquired hands-free. There is a growing body of literature on this subject, including [5], which we have recently published. A major challenge is to take into account the deformation of tissues as they are examined by the ultrasound probe. This means that each slice represents a potentially different state of tissue deformation. The aim of this internship is to estimate this deformation, and integrate it into the 3D reconstruction algorithm we recently proposed.

References:
[1] Parashar et al, ICCV 2015. As-rigid-as-possible volumetric shape-from-template.
[2] Parashar et al, CVPR 2020. Local non-rigid structure-from-motion from diffeomorphic mappings.
[3] Parashar et al, TPAMI 2021. Robust Isometric Non-Rigid Structure-from-Motion.
[4] F. Gaits, N. Mellado, G. Bouyjou, D. Garcia, A. Basarab. Efficient stratified 3D scatterer sampling for freehand ultrasound simulation. IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, 71(1):127–140, 2024.

[5] F. Gaits, N. Mellado, A. Basarab. Ultrasound volume reconstruction from 2D Freehand acquisitions using neural implicit representations. In 21st IEEE International Symposium on Biomedical Imaging (ISBI 2024), Athènes, Greece, May 2024.

These two internships will be jointly supervised by Prof. Adrian Bassarab (CREATIS, Lyon) and Dr. Shaifali Parashar (LIRIS, Lyon). The location will be CREATIS, Lyon.

To apply, please send your CV and transcripts to adrian.basarab@creatis.insa-lyon.fr and shaifali.parashar@liris.cnrs.fr.

Requirements:
1. Strong background in computer vision, mathematics or any relevant field
2. Strong programming skills in C++ and python
3. Fluency in English

Project duration: 6 months
Tentative start date: February 2025
Location: Lyon, France