Development of innovative *in vivo* mechanical measurements using ultrasound-based elastography for abdominal Computer Assisted Surgery

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Summary

Recent technological advances have greatly contributed to the fast growth of both image-guided and *Computer-Assisted Surgery* (CAS) in both clinical and basic science research. In spite of recent progresses in 3D anatomical modelling, there is still a critical lack of knowledge of *in vivo* mechanical properties that would improve the realism of the per-operative simulators dedicated to abdominal surgery. **Mapping accurately the *in vivo* nonlinear mechanical properties of healthy, as well as pathological organs, is one of the leading challenges in CAS.** Over the past decades, the non-invasive mapping of the mechanical characteristics of the organs *in vivo* (elastography using medical imaging) has emerged has a major research topic in the field of medical diagnosis and assistance to surgical procedures. While the surgical practice involves large deformation of soft tissues (mostly linked with the nonlinear behavior), the vast majority of commercially-available tools and methods from research laboratories are restricted to the characterization of the mechanical response under small deformation (mostly linked with the linear behavior and pure elasticity).

This PhD thesis is part of the *UNILiverS* project (*Ultrasonic Nonlinear Indenter for Liver Surgery) aiming at* innovative development in elastography dedicated to CAS, *and* taking place within the IHU-Strasbourg (*Institut Hospitalo Universitaire, Institute for Image Guided Surgery*). In this project, we propose to develop mechanical-imaging methods for the quantification of the non-linear mechanical properties of the hepatic tissue. Relying on **innovative ultrasound-based indentation probes**, allowing to obtain unprecedented a posteriori *in vivo* mechanical parameters (such as nonlinear mechanical properties), the objective of the UNILiverS project is double: (1) Improving the realism of numerical models used per-operative simulation in augmented-realism surgery; (2) Providing a new surrogate for hepatic portal venous pressure and thus a novel biomarker for the follow-up of hepatic resections. We expect this project to have a high impact in the fields of surgical simulation and hepatic surgery.

Objectives

The main objective of this thesis is to **investigate, validate and demonstrate the clinical relevance of measuring the nonlinear mechanical properties of liver tissue *in vivo* for CAS using a novel ultrasonic elastography approach**, through four main tasks:

(1) Development of a 2D ultrasonic experimental nonlinear system for the nonlinear mechanical characterization;

(2) Use of this new mechanical characteristics for the improvement of liver Finite Element Models dedicated to per-operative numerical simulations of hepatic surgery. This step will be performed in collaboration with the MMB team (*Multiscale Materials and Biomechanics team*) of the ICube laboratory;

(3) Development of a 1D ultrasonic experimental nonlinear system for the nonlinear mechanical characterization. This step will be performed in close collaboration with an engineer devoted to this project and subcontract with industrials;

(4) Application of the new prototype for measurement of hepatic portal venous pressure. This step will be performed in close collaboration with surgeons and engineers of the IHU Strasbourg for validation and comparison with catheters and MRI protocols.

This strongly multidisciplinary thesis will involve the following fields/skills: Medical Imaging, and echography in particular (physics and pulse sequence programming); Biomechanics; Finite Element Modeling; Image processing; computer aided design. Presentations in international conferences and perspectives are expected from this PhD thesis in the scientific, industrial and medical communities.

Environment

The primary location for this thesis is the Medical robotics team of the ICube laboratory (located in the IRCAD building) as well as in the experimental platform of the IHU Strasbourg. The research team is composed of about 10 faculty members and about 10 PhD students, and covers a large variety of research activities revolving around Medical Imaging and Robotics. The team is located at the heart of the central Hospital, in the city center. With around 580 members, the ICube laboratory is a major driving force for research in Strasbourg in the fields of engineering science and computer science, with imaging as the unifying theme. A video presenting the activities of the ICube laboratory can found there. The PhD student will be affiliated with the MSII Doctoral School (Mathematics, Science for Information and Engineer) of the University of Strasbourg.

The environment for this project is exceptional: the Institute of Image-Guided Surgery of Strasbourg develops innovative surgery to deliver personalized patient care, combining the most advanced minimally invasive techniques and the latest medical imaging methods. This project benefits from a direct collaboration with the medical imaging manufacturer (Siemens Healthcare).

In the heart of Alsace, at the borders of Germany and Switzerland, Strasbourg is the second capital of Europe after Brussels (~272.000 residents). It is a very pleasant, highly international, middle-sized city with a major world-renowned university (including 12 engineer schools, ~60.000 students; international students from over 150 countries represent 20% of the student population at the University of Strasbourg). Founded in the 16th century, the University of Strasbourg has a long history of excellence in higher education (with four Nobel prizes) with 72 research units that encompass all disciplinary fields in biology, biotechnology, medicine, chemistry and material physics.

Requirements

The candidate should have a MS degree in engineering or in applied physics. He/She should want to work in a highly biomedical environment and should have excellent general scientific skills ranging from basic physics to programming (Matlab, Python, C++,…). English proficiency is required. Previous experience with medical imaging and/or biomechanics, as well as previous experience in a research laboratory, is a plus.

To apply, please send a CV, contact information of 2-3 references, and a cover letter to Simon Chatelin, schatelin@unistra.fr