PhD Position – Fall 2018

Machine Learning & model-based registration for image-guided neurosurgery

Diploma
Doctorate in Computer Science, University of Grenoble Alpes, France

Location
Univ. Grenoble Alpes, TIMC-IMAG Lab, Grenoble France
Vanderbilt University, Dept. EECS, Nashville, TN, USA

Supervision
Matthieu Chabanas, Assistant Professor, Matthieu.Chabanas@univ-grenoble-alpes.fr
Jack Noble, Assistant Professor, Jack.Noble@vanderbilt.edu

Salary
1,415 € net per month, during 18 months in France
$2,500 net per month, during 18 months in the United States

Application
Master's degree or equivalent to a European Master’s (5-year duration)
CV, Cover letter, Last diploma. Letters of recommendation are welcome.
Deadline: July 23, 2018

Key words
Machine learning, Image registration, Biomechanical modeling, Image guided surgery

This project will involve research in the domain of medical image processing and biomechanical modeling for image guided brain surgery. In brain tumor surgery, it is essential that the surgeon can accurately identify malignant and healthy tissues to ensure the total resection of malignant tissue while reducing the morbidity on surrounding healthy tissues and eloquent cortex. Image-guided surgery technologies can aid the surgeon in this difficult task. Specifically, preoperative Magnetic Resonance (MR) images can be used to accurately delineate surgical targets preoperatively and optical trackers can be used intraoperatively to co-register the MR to the operating room and intraoperatively localize the position of surgical tools relative to the pre-operative plan. During surgery, however, significant movement and deformation of tissues occur due to gravity (called the “brain-shift” phenomenon), cerebrospinal fluid leakage, drugs and obviously the ongoing surgical actions such as manipulation, dissection or resection. Thus, the pre-operative MR cannot be used directly for intraoperative navigation since it no longer reflects the anatomical reality after resection. Intraoperative Ultrasound (iUS), a low-cost, portable and convenient system, can be used to image the progress of the resection and tissue deformation. However, these images are extremely noisy making difficult the accurate delineation of tissue contours and tumor margins, especially at the end of the procedure due to additional resection-induced artefacts.

The goal of this thesis is to develop a system to perform real-time non-rigid MR-to-iUS registration, to fuse the high-quality images and planning to the operating room configuration, in order to guide the surgeon and assist with the decision process in real time during surgery.
The project will involve the development and use of **Machine Learning** techniques, such as convolutional neural networks, for image segmentation and tissue classification. Such techniques have come into widespread use in the image processing community due to their high effectiveness even in difficult image analysis tasks. The project will also involve the development and use of **biomechanical model-based registration** techniques to fuse the preoperative MR with iUS images. The modeling methods are well suited for representing the physics of the deformations to the brain that occur during tumor resection; however they lack the high quality pre-to-intraoperative image matching method, which can be provided by medical image analysis techniques such as machine learning methods, necessary to guide the deformation of the brain model. The machine learning tools are capable of estimating correspondences between pre- and intraoperative images, but the intra-operative images are so noisy that regularization or constraint of the correspondences is necessary to obtain an accurate matching; and the physics model can be used to provide such regularization.

The PhD student will spend the first 18 months at Vanderbilt University and the final 18 months at Grenoble. The first portion of the project will be focused on developing iUS segmentation techniques, including the training of machine learning techniques using labeled iUS images and transfer learning, and registering the segmented iUS images to preoperative MR using standard geometric non-rigid warping functions as a first evaluation. The second portion of the project will be focused on developing biomechanical modeling techniques, including models that account for cutting and tissue removal during surgery. Finally, the two approaches will be combined into an integrated system, and performance of each component of the process will be systematically and comprehensively evaluated.