PhD position: « Optimization of trajectories of multiple surgical tools using deep learning for percutaneous surgery and SEEG »

Location: ICUBE/IMAGeS, Université de Strasbourg (https://icube.unistra.fr)
PhD advisor: Caroline Essert (http://dpt-info.u-strasbg.fr/~essert)
Starting: Sept. 1st, 2020
Duration: 3 years
Salary: gross salary approx. 1680€ per month
Possibility of teaching (extra 400€ per month)

Description:

In this PhD, we propose to study new methods of computer assistance to preoperative surgical planning, for an optimal placement of numerous needles or electrodes. To achieve this, we will work on the development of algorithms based on deep learning. The objective is to propose an optimal strategy of intervention, specific to the patient and the type of operation, thanks to an automatic computation based on the expertise of the field, the preoperative data, retrospective data for the training phase, and a precise simulation and prediction of the effects of the treatment during surgery.

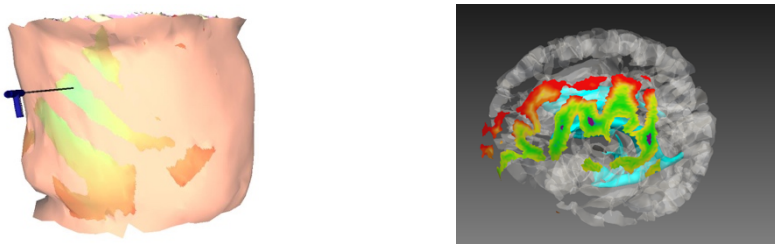
In surgery, planning an intervention is a decisive task. The chances of success of a surgical operation depend strongly on a good preoperative planning, and the choice of the most appropriate strategy. Nowadays, the clinician relies mostly on medical image to plan an intervention. A few days before the surgery, CT or MR images of the patient are acquired, then the physician elaborates his intervention plan from these sets of preoperative 2D slices. It is a difficult task, as the physician has to build a mental representation of a 3D model of the anatomy of the patient and the position of pathologies. In the case of an intervention involving the planning of a path for a needle or electrode, the surgeon has to estimate a secure tridimensional path that will ensure a maximal efficiency. When planning multiple trajectories, the task is even more complex as there are possible interactions between the surgical tools.

This work will rely on previous results of IMAGeS group in ICUBE, that has a high expertise and track record on trajectory optimization. It will be done in collaboration with various academic and clinical partners. In this PhD, deep learning techniques based on multiple retrospective cases will be considered. Deep learning will be used at several levels. First, it will be used for the annotation of the retrospective cases, by facilitating the automatic segmentation of needles or electrodes positions. Secondly, the annotated cases will be used to train the networks in order to propose solutions for the new cases. The challenge then will not be to classify if a potential solution is valid or not, but in a prospective way to suggest solutions. Moreover, we will also study traditional multiple-objective optimization methods, based for instance on Pareto-front or evolutionary algorithms, able to handle a large quantity of variables to optimize, with fast computation times compatible with clinical routine. Both approaches will then be compared in terms of computation times and accuracy.

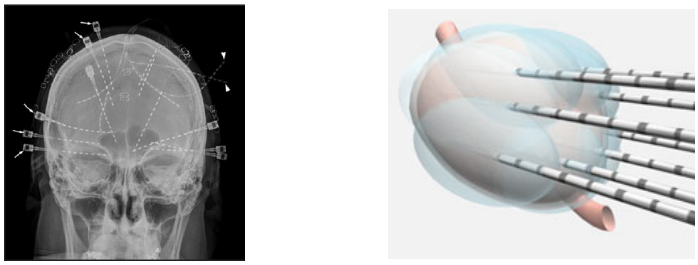
Another difficulty in this kind of planning is that in many cases there is not one single solution but several solutions of comparable quality. The challenge is then to define how to visualize and navigate through the numerous possible solutions in an interactive and intuitive way. A task of the research work will also be to search for innovative interaction techniques to browse the solutions.

In terms of application, we will focus mainly on two types of interventions: the treatment of tumors by percutaneous cryoablation (renal and desmoïd tumors), and the placement of SEEG recording electrodes in neurosurgery for the treatment of epilepsy. However, we will keep concerned by the genericity of the approach thanks to a formalization of the concepts, that led the works of our group in the fields of surgical planning so far.

This work will require an immersion of the candidate in the fields of medicine and surgery, deep learning, evolutionary algorithms, geometric constraint solving and formalization, multi-objective optimization, simulation, and interaction, which makes it a multi-disciplinary work.



Previous works on surgical tools trajectory planning



SEEG (left) and cryoablation (right)

The methods proposed during this PhD will be implemented in the planning software and will be compared. Particular attention will be given to the presentation of the results in an intuitive and ergonomic way. A rigorous retrospective validation will be performed in collaboration with radiologists of the University Hospital of Strasbourg for the cryoablation application, and with neurosurgeons from the University Hospitals of Rennes, Strasbourg and Hôpital de la Pitié Salpêtrière of Paris for SEEG. The candidate will also interact with academic partners at LTSI Rennes, ICM Paris, and SPL Boston.

Qualifications: Master / Diploma with a technical and scientific background, in Computer Science / Engineering. Strong skills in C++ programming are required. Good communication skills as well as a good level of English are expected. Expertise in computer graphics and deep learning is also expected. Expertise in Numerical methods would be a plus.

To apply: send electronically a resume, a one-page letter of motivation, graduation documents and grades **with ranking**, the Master's thesis, and names/addresses of at least two references to: Caroline ESSERT: mailto:essert@unistra.fr

Note that incomplete applications without ranking information will not be considered.