Laboratoire Traitement du Signal et Image, INSERM U1099

Machine learning image processing tools for image guided Video-Assisted Thoracic Surgery

Keywords: lung and lobes segmentation in CBCT and registration by deep learning ; shape characterization by shape models.

Context:

The clinical problem is the localization of pulmonary nodule during minimally invasive Video-Assisted Thoracic lung surgery. The nodule is located on CT scans before the operation (Fig. 1-left). However, during surgery, the lung partially deflates and the surgeon loses the position of the nodule due to the change of imaging modality and the high lung deformation (Fig. 1-middle). At Rennes University Hospital, (CHU Rennes) the surgeon partner of the project, propose to use an intraoperative robotized Cone Beam CT (CBCT) to help him to locate the nodule inside the deflated lung and so to reach him under fluoroscopy guidance. However, the nodule may not be visible on the CBCT image (Fig. 1-right). The idea is then to digitally simulate the deflation of the lung in order to predict the position of the nodule in the deflated lung and then to transfer this location on the endoscopic view for augmented reality.

A first thesis, in the context of LabEx CAMI, on the lung biomechanical simulation has been finished on 2020. Based on the results of this Thesis, we applied and were selected for a French National ANR project: VATSop (ANR-20-CE19-0015), on the localization of the nodule by modeling the lung and its follow-up by augmented reality. This project is a collaboration between LTSI-Rennes, TIMC-Grenoble and Mimesis-INRIA-Strasbourg.

Figure 1. Gauche : scanner préopératoire avec localisation du nodule ; Milieu : vue endoscopique du poumon dégonflé ; Droite : CBCT du poumon dégonflé

Workplan:
The topic of this thesis is to deal with several hard image processing aspects related to the project.

- Segmentation of the lung (lobes, bronchi and vascularization) in CT and CBCT using deep-learning approaches. If this segmentation has already been the subject of several works for CT, this segmentation is more difficult in CBCT volumes (truncated lung, noise and low contrast, change of morphology and very large deformations, ...) (see Fig. 1-right). Approaches based on transfer learning can be considered;
- The implementation of an image-based elastic registration solution between CT and CBCT with unsupervised Deep-Leaning aspects;
- Statistical modeling of the lung shapes. The idea is to model the different deformation modes of the lung using a statistical tool (e.g. Statismo) and then predict the most likely deformation for a given CBCT;
- The implementation of a 3D endoscope calibration tool;
- The implementation of these software inside an operation room.

Financial and practical aspects:
The thesis is co-financed by a regional grant (ARED Bretagne) and the ANR project VaTSop. The Salary is on the classical level of academic PhDs.
The work will take place at the LTSI, UMR INSERM 1099, bat 22, Beaulieu campus, University of Rennes 1, Rennes.

Prerequisites:
Master or engineers in image processing or machine learning are preferred.
An experience in image processing, machine learning and deep learning is required.
This project will require a computer implementation of the methods requiring knowledge and easy handling of computer tools (Linux, use of graphics cards clusters for deep learning, use of specialized libraries). A solid prior knowledge of C++ and/or Python would greatly facilitate the beginning of the thesis

References :
Alvarez P., Rouzé S., Miga M., Payan Y., Dillenseger J.-L., Chabanas M., “A hybrid, image-based and biomechanics-based registration approach to markerless intraoperative nodule localization during video-assisted thoracoscopic surgery”, Medical Image Analysis, 69, 2021, 101983, doi: 10.1016/j.media.2021.101983 (hal-03127302).

For a presentation of the project (in french):
https://hal.archives-ouvertes.fr/hal-03032410/file/presentationDillenseger.mp4

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