LAB : Institut Pascal (UMR6602 UCA/CNRS) – Group Image Guided Therapies/Cardio-Vascular Interventional Therapy and Imaging

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Title of PhD : Unsupervised 2D and 3D multi-modal and temporal registration of vascular networks via hybrid methods combining variational and physical principles, graph-based approaches and deep-learning models.

Abstract: Image registration aims at matching two or more images in terms of intensity if the images are of the same modality (mono-modal) and/or salient components if the images are acquired through different mechanisms (multi-modal) *via* a physically feasible geometric transformation. It is therefore a cornerstone step for medical image analysis especially when complementary information is found in different images such as images acquired at different times, with different angles or by different mechanisms, to cite only a few examples. This task thus shows a great clinical impact with many applications such as shape tracking (organs, tumors, *etc*.); fusion of anatomical information (CT, MRI) with functional one (fMRI, PET, SPECT) which is called multi-modal fusion to facilitate intervention and treatment planning; computer-aided diagnosis and disease follow-up such as tumors; *etc*. In this PhD, we will focus on multi-modal intra-patient CT/MRI registration of thin structures such as vascular networks simplifying the diagnosis and follow-up of cardiovascular pathologies and potentially leading to the creation of atlas after an inter-patient statistical study. Another application consists in a longitudinal / temporal analysis of a patient in both mono and multi-modal settings. A statistical study of inter-patient temporal trajectory variability will make the prediction of the clinical cardio-vascular pathologies evolution easier. The thinness, low contrast, complexity and inter-patient variability of such structures make this task difficult and closely related to the problem of automatic reconstruction of the vascular network. The objective of this PhD will therefore be to combine the variational methods including deformation models that are physically consistent that is orientation and topology preserving, graph structures for efficient extraction and reconstruction of the vascular network and deep learning models to extract relevant features facilitating the matching of fine structures in order to propose hybrid and joint unsupervised models for multimodal registration and vascular reconstruction. Indeed, no ground truth exists for deformations. Two applications are considered in this project: the 2D retinal vascular network with the use of the public databases STARE and DRIVE, as well as the hepatic vascular network (3D) with the use of the databases resulting from the ANR- R-Vessel-X project.

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