PhD proposal entitled

Inclusion of priors in deep networks for medical image segmentation

within LITIS, Université Rouen Normandie, LMI, INSA Rouen Normandie & Université Clermont Auvergne, CNRS, SIGMA Clermont, Institut Pascal

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(i) **Thesis description** :

Image segmentation is an essential computer vision process, especially for medical image analysis. While deep learning methods are particularly effective when large volumes of annotated data are available (—acquiring such databases is particularly difficult, especially in the context of three-dimensional medical image segmentation —), performance is degraded as soon as the mass of data is reduced or the framework is weakly supervised. The segmentations obtained are less accurate and exhibit artefacts such as inhomogeneities (isolated pixels) or topological inconsistencies (non-respect of contextual relations between objects). Motivated by this observation, the objective of this thesis is to provide a hybrid variational/deep learning framework - taking advantage of both the global and continuous character of variational methods and the good generalisation capabilities of deep learning methods- including geometric and topological constraints in a weakly supervised context, in order to overcome the data deficit and compensate for some limiting factors visible on medical images (weak boundary definition, class imbalance, inter-/intra-patient variability, or slice-dependent topology).
Several avenues will be considered:

(i) contribution of a methodological nature at the level of the network architecture, of the design of new loss functions or of the joint segmentation/registration approach. The state-of-the-art architectures will be investigated, namely fully convolutional ones, but also transformer based and hybrid architectures;

(i) contribution of a more applied nature, with in-depth evaluations on several applications of interest using optimised algorithms, quantitative and qualitative analysis, evaluation of the generalisation capacity and explainable character of the proposed method. More precisely, we will target the segmentation of myocardial infarction area in delayed-enhancement (DE) cardiac MRI, which is a hot topic that is currently raising a lot of interest as some recent datasets and challenges show (EMIDEC, MS-CMRSeg 2019, MyoPS 2020, MYOSAIQ 2023). In order to segment the infarct area, MR images are acquired several minutes after the injection of a contrast agent (gadolinium). CNN segmentation of DE-MRI produces a lot of false positive area, due to the heterogeneity of the signal along the exam and due to the presence of noise and artefacts; thus a help from prior constraint could improve the segmentation. In current clinical practice, cine MRI is acquired in addition to DE-MRI; hence, information coming from both sequences could be merged in order to strengthen the automatic processing, in particular in a joint segmentation and registration framework.

(ii) **Required skills**:

Competences in signal, image processing (medical imaging), deep-learning and more generally in applied mathematics (PDEs, variational methods, optimisation, hybridisation of variational-based and deep-learning oriented approaches, etc.) are required as well as solid scientific programming skills (Python, C/C++, Matlab, parallel computing), along with strong communication abilities.