PhD Thesis proposal - University of Strasbourg
Topological and relational guidance for modelling complex anatomical structures

Supervisors

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Working environment

The student will be part of of the IMAGeS team (http://images.icube.unistra.fr/) in the ICube laboratory in Illkirch.

Funding

Starting date : Fall 2020.
Duration of funding : 3 years

Candidate profile

Master's degree in computer science, image analysis or applied mathematics
Experience in image analysis and deep learning
Programming in Python, C++

Thesis description

In the field of image analysis, segmentation is often an essential prerequisite for the implementation of high-level analysis procedures. In particular, in the field of medical imaging, the segmentation of anatomical structures is used for the three-dimensional reconstruction of objects and the calculation of quantitative information on these structures.

However, with recent advances in deep learning techniques, the segmentation step may become optional. For example, in vascular segmentation, the segmentation binary mask is used to model the vessels by calculating their center line (or skeleton) and associated radii. This step can lead to inaccuracy errors, since the segmentation is defined in the (discrete) input space of the image, whereas the points of the center line are defined in continuous space. Deep learning approaches can allow direct inference of this information without the need for prior segmentation.

However, the effectiveness of neural network-based methods relies mainly on two prerequisites : (1) the availability of sufficiently numerous annotated data, and (2) a form of invariance between the interpretable data from the field truth provided in annotation.

In the case of complex anatomical structures, those prerequisites are sometimes difficult to obtain. For example, in the case of vascular networks, the structures of interest present morphological (size, shape), spatial (positions, orientation), and topological (branch variability) properties, which make reliable image annotation particularly difficult, and induce significantly greater variations than for other structures. Thus, for such objects, deep learning approaches still suffer from a lack of robustness (see Figure 1).

The objective of this thesis is to explore ways to increase the reliability of neural network-based approaches for modeling complex anatomical structures, such as vascular networks (but also potentially other structures with similar properties that may defeat classical segmentation paradigms).

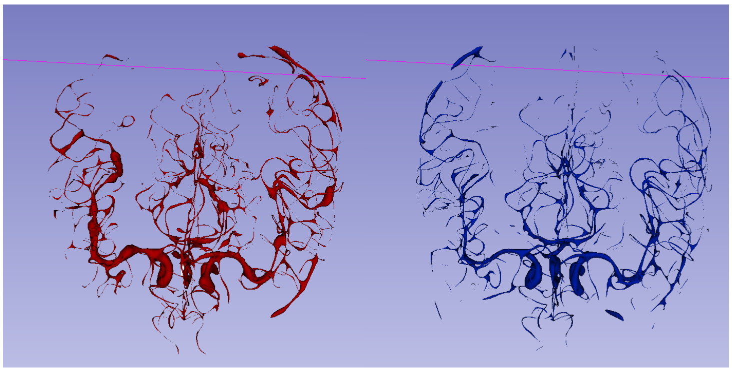

FIGURE 1 – Segmentation of a cerebral vascular network in MRI imaging [1]. Left : Result of automatic segmentation by convolutional neural networks. Right : Ground truth. The automatic segmentation still suffers from certain defects (disconnections, missing parts, etc.).

The first angle of research will be to guide deep learning approaches through high-level knowledge, which may not be directly inferred from data annotated as segmentation ground truths. In this perspective, several recent works propose methods to integrate topological constraints in neural networks. [2, 3, 4, 5, 6] or model a priori shape or anatomical constraints [7, 8].

The second angle of research will consist of exploring the possibility of extracting high-level information directly from neural networks, in order to free oneself from a segmentation step that may lack robustness and whose precision is limited by the resolution of the initial image. This research could be based in particular on the work of [9], which allows sub-pixel accuracy to be obtained for the measurement of vessel wall thickness.

Application

The applicant will have to provide a file including :

- graduations, results and rankings for the master diploma ;
- graduations and results for diplomas obtained before the master's degree ;
- complete resume ;
- motivation letter.

Références

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[3] R. J. Araújo, J. S. Cardoso, and H. P. Oliveira, "A Deep Learning Design for Improving Topology Coherence in Blood Vessel Segmentation," in *Medical Image Computing and Computer Assisted Intervention – MICCAI 2019* (D. Shen, T. Liu, T. M. Peters, L. H. Staib, C. Essert, S. Zhou, P.-T. Yap, and A. Khan, eds.), Lecture Notes in Computer Science, (Cham), pp. 93–101, Springer International Publishing, 2019.

[4] J. R. Clough, I. Oksuz, N. Byrne, V. A. Zimmer, J. A. Schnabel, and A. P. King, "A Topological Loss Function for Deep-Learning based Image Segmentation using Persistent Homology," *arXiv :1910.01877*, Oct. 2019.

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[8] A. J. Larrazabal, C. Martinez, and E. Ferrante, "Anatomical Priors for Image Segmentation via Post-processing with Denoising Autoencoders," in *Medical Image Computing and Computer Assisted Intervention – MICCAI 2019* (D. Shen, T. Liu, T. M. Peters, L. H. Staib, C. Essert, S. Zhou, P.-T. Yap, and A. Khan, eds.), LNCS, (Cham), pp. 585–593, Springer International Publishing, 2019.

[9] K. M. van Hespen, J. J. M. Zwanenburg, J. Hendrikse, and H. J. Kuijf, “Subvoxel vessel wall thickness measurements from vessel wall MR images,” in *Medical Imaging 2019 : Image Processing*, vol. 10949, p. 109491Z, International Society for Optics and Photonics, Mar. 2019.

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[11] U. Wickramasinghe, G. Knott, and P. Fua, “Probabilistic Atlases to Enforce Topological Constraints,” *arXiv :1909.08330*, Sept. 2019.