PhD subject
Brain vascular network segmentation and modeling from MRA images

Context

Ischemic stroke (the blockage of an artery that supplies blood to the brain) is a major cause of disability and death worldwide [6]. Recently, Endovascular Thrombectomy (EVT) has been proved very effective to treat ischemic stroke, which has led to its widespread adoption in clinical routine. EVT consists of the mechanical removal of the blood clot under image guidance. This interventional gesture is very difficult and it is estimated that around 50% of EVT have a suboptimal outcome. The World Federation of Interventional and Therapeutic Neuroradiology recently recommended that simulation be integrated in this curriculum, with the *"ultimate goal of improving skills and reducing complications during patient management"* [9]. The PreSPIN ANR project aims at designing a simulator of the EVT intervention to help surgeons to train and plan for this difficult intervention (see Figure 1). To do so, geometrically accurate models of the brain vascular network of patients suffering from ischemic stroke are required. In this context, the subject of this PhD thesis is to develop solutions for segmenting and modeling the brain vascular network from Magnetic Resonance Angiography (MRA) images.

Subject

The goal of this thesis is to build geometrically and topologically accurate models of the brain vascular networks from MRA images. The main challenges will consist of designing robust methods, able to generate continuous vascular models of sufficient precision from millimetric-resolution data often corrupted by a low signal-to-noise ratio and physiological artifacts.

The 3D vascular model should consist of a 1D model with correct topology of the vascular structures (namely the centrelines of the vascular network) associated with a 3D smooth surface of the vessels. Several strategies may be investigated depending on the candidate interest combining classic and deep-learning strategies.

Regarding the complexity of the problem, prior knowledge will have to be modeled to compensate the insufficient information carried by the image signal. Prior information on the vessels rely in particular on connectedness hypotheses and differential properties (orientation, curvature, tortuosity, etc.) that may be obtained from further data analysis, or by (multi-)atlas knowledge [8] from annotated datasets. These priors could be integrated in vessel segmentation based on variational paradigms [5] as regularization terms or could be integrated in deep-learning frameworks [11] such as topological loss [3, 2], shape constraints [7] or multiscale architectures [4].

Centrerlines extraction could be develop from the fuzzy segmentation map using discrete geometry concepts such as critical kernel [1] or be directly extracted by end-to-end learning strategies [10]. Finally, 2D closed curve models, fitting the vessel border in each cross section along the centrelines, would be extracted to build the 3D continuous model.

A particular attention will be paid to the modeling of bifurcations that are crucial in simulations yet often forgotten in most segmentations and models of vascular networks.

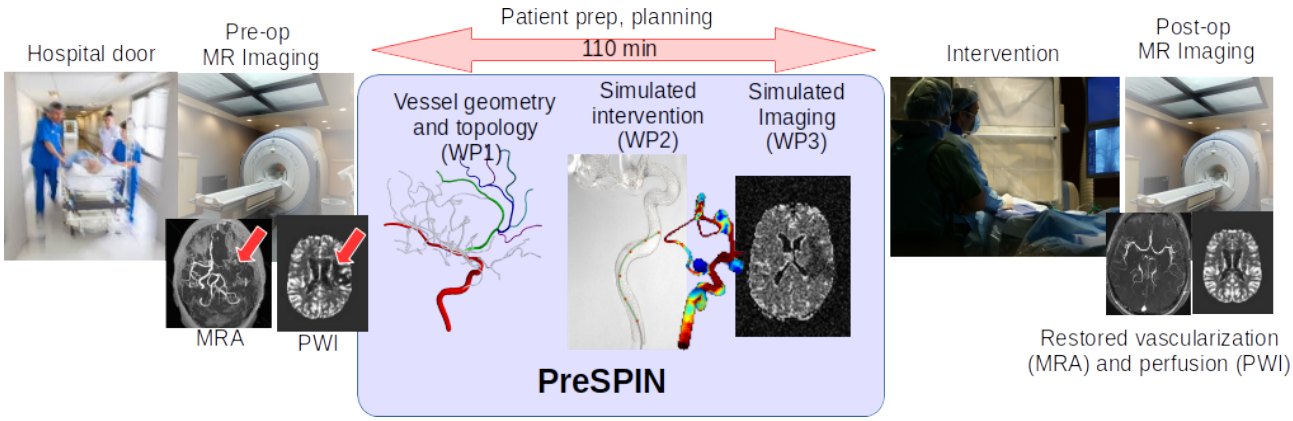

Figure 1: PreSPIN project overview

Candidate profile

The candidate should have an academic background in image processing or medical imaging. He/she should have at least one previous experience (internship, project) in medical image processing. The candidate should have good technical skills in Python programming and optionally in Pytorch or TensorFlow. He/she should be able to work on Linux computers and on remote clusters. The candidate will work inside the PreSPIN consortium and in close collaboration with multidisciplinary experts. He/she should be able to communicate on his/her work clearly with experts and non-experts of his/her field.

PhD thesis information

- 36 month funding from ANR (French National Research Agency).
- Location: Creatis laboratory in INSA Lyon.
- Advisors: Dr. Odyssée Merveille, Prof. Carole Frindel, Prof. Nicolas Passat
- Applications to be sent by mail to odyssee.merveille@creatis.insa-lyon.fr with a detailed CV, covering letter, and optionally recommendation letters from former advisors and latest grade transcripts.

References

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