PhD Position / Thesis offer (M/F)
Reference: DS_MAZ_IVES_0922

Research topics	**Advanced Machine Learning Tools for Cerebrovascular Image Segmentation**
Departement	Data Science
Publication date	September 1st 2022
Start date	Jan 1st 2023
Duration	Duration of the thesis

Description

The Data Science Department is opening a PhD position on advanced machine learning tools for cerebrovascular image segmentation from multi-modal images.

Context. 3D brain vessel segmentation is a crucial task for the diagnosis, management, treatment and intervention of a wide range of conditions with a vast population-level impact [1]. Due to the intricate morphology of the cerebrovascular tree, a highly bifurcated, convoluted and variable structure [2], its manual segmentation from 3D multi-modal scans is a very challenging task [3]. Thanks to the progress seen by machine learning in medical image analysis tasks, learning-based techniques have surged as an alternative to classical approaches [4]. In spite of the high reported accuracies, the use of learning-based methods to assist 3D cerebrovascular segmentation in clinical practice remains hindered by two key factors: data-greediness and lack of inter-modality generalization.

Data-greediness refers to the fact that highly accurate segmentations can only be granted if the learning-based models are trained with large datasets containing high quality annotations. On one hand, large amounts of data can be difficult and expensive to collect. On the other one, manual voxel-wise annotation of 3D vessel images is a demanding and time-consuming procedure that requires high expertise and that lacks intra- and inter-operator repeatability and reproducibility. Lack of inter-modality generalization refers to the fact that, as classic approaches, learning-based methods for 3D blood vessel segmentation are modality specific. They cannot be seamlessly used across different imaging modalities, which is particularly limiting towards the broad use and adoption of automated learning-based 3D vessel segmentation tools in clinical practice.

Main objective. The goal of this PhD project is to develop novel interactive, collaborative and generalizable learning-based segmentation framework that tackles data-greediness one of the current problems of 3D cerebrovascular segmentation hindering its wide use in clinical routine.

Description of the work. This project builds upon the recently proposed Vessel-CAPTCHA framework for efficient 3D vessel annotation and segmentation [5]. The tools developed during the PhD will be integrated into the framework. The project will be structured around the following tasks:

1) *Enabling continual learning*. This task will extend the current annotation procedure of the Vessel-CAPTCHA to enable the incremental building of the training set as new relevant data becomes available. At this step, active learning techniques will be investigated to find optimal subsets in the new data to propose to the user for weak annotation. Continual learning will be also addressed through annotation refinement via the iterative

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interaction with a current model's prediction, since current approaches focus on the refinement of the segmentation of an unseen image, without providing any feedback to the segmenter model.

2) *Integration within a collaborative setup*. In this task, the Vessel-CAPTCHA framework will be formulated within the federated learning (FL) paradigm, securely deployed across different centers, without requiring data sharing or a centralized storage, thus enabling the use of larger databases. The framework will leverage on the technology of Fed-BioMed, a software framework developed by Inria for FL applications in biomedical data analysis [6]. Since the federated Vessel-CAPTCHA model will represent a consensus across the segmentation tasks of the centers, there will be need of an adaptation step to specialize to each one's specific segmentation task. This adaptation will requires extending classical FL training strategies to account for the specificity of imaging protocols and annotation standards in each clinical site.
3) *Validation*. The complete framework will be validated by deploying it across centers in different locations and countries using a large set of public and private datasets. The students will be actively involved in the setup and execution of the large-scale study.

Environment. This PhD project is part of a recently funded ANR JCJC project to develop novel machine learning tools for cerebrovascular image analysis. The PhD student will be hosted by the Data Science department at EURECOM under the supervision of Dr. Maria A. Zuluaga. The PhD student will have the opportunity to exchange and collaborate with project partners, which include INRIA Sophia Antipolis, Grenoble Institut de Neurosciences, University College London (UK) and Siena University (Italy).

Bibliography.

1. World Health Organization. Global health estimates. Available: https://bit.ly/2HFaFzY (Accessed Mar 21 2022)
2. JHG Helthuis et al. Branching Pattern of the Cerebral Arterial Tree. Anat Rec 302:1434–1446 (2019) [link]
3. D. Lesage et al. A review of 3D vessel lumen segmentation techniques: Models, features and extraction schemes. Med Image Anal 13:819–845 (2009)
4. S. Moccia et al. Blood vessel segmentation algorithms—review of methods, datasets and evaluation metrics. Comput Methods Programs Biomed 158:71–91 (2018) [link]
5. V. Dang et al. Vessel-CAPTCHA: an efficient learning framework for vessel annotation and segmentation. Medical Image Analysis 75, 102263 (2022) [link]
6. S. Silva et al. Fed-BioMed: A general open-source front-end framework for federated learning in healthcare. In: 1st Workshop on Distributed and Collaborative Learning (2020) [link]

Requirements

- Masters' degree in a relevant discipline (e.g., computer science, mathematics, physics, biomedical engineering or related fields).
- Strong theoretical/practical knowledge in applied mathematics, statistics, machine learning, image processing and data science in general.
- Strong programming skills (e.g., in Python).
- Organizational skills and ability to work independently
- Good command of English for reading/writing scientific articles and delivering oral presentations.

Application

Applications should be sent by e-mail to maria.zuluaga[at]eurecom.fr with the reference **DS_MAZ_IVES_0922** and the must include the following documents (in English):

- Curriculum vitae,
- Transcript of grades obtained in Bachelor's and Master's degrees,
- A cover letter stating your motivation and fit for this project,

- Contact information of 2 references who can evaluate the candidate's ability (e.g., your supervisor for Master's thesis).

Application Deadline: Oct 1st 2022

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