Internship offer 2022

Topological constraints for hepatic vascular segmentation with transformers

Context

The development of non-invasive imaging technologies over the last decades has opened new horizons in studying the **abdominal anatomy**. Computational liver analysis from computed tomography (CT) images has become a crucial task for applications including computer-assisted diagnosis, surgery planning or image-guided interventions. Largely performed manually by clinicians, the quantitative analysis of **hepatic structures** is time-consuming and prone to high intra and inter-expert variability. Recent advances in deep learning (DL) suggest that liver analysis through computational resources can benefit from precise, fast and repeatable measurements carried out by convolutional neural networks (CNN) [1] and/or **transformers** [2]. Despite a good ability to extract solid visceral organ contours, their capacity to delineate liver vessels (Fig.1) remains a major issue. In particular, **vascular segmentation** faces limitations including class imbalance and appearance similarity between vascular and non-vascular tissues, complex multi-scale geometry with decreasing diameters and contrast along tree-like networks, variability in branching patterns...

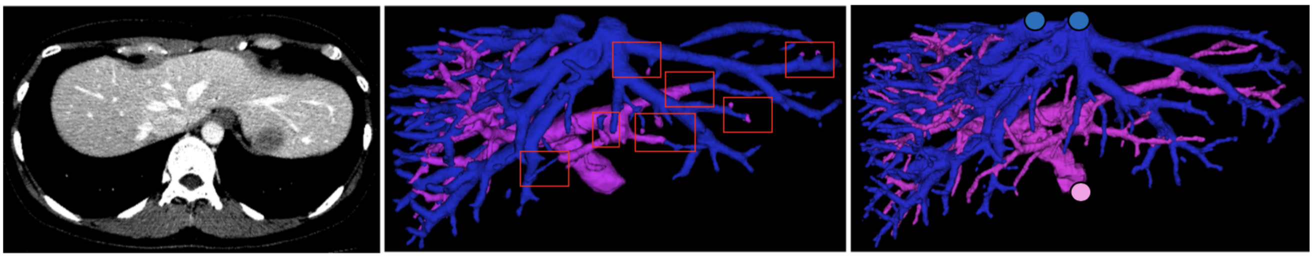

FIGURE 1 – DL-based segmentation of hepatic vessels from CT images, without and with topological constraints [7].

Internship topic

Several **blood vessel delineation** approaches have recently focused on the exploration of more sophisticated DL architectures than the standard U-Net [3] via multi-pathways [4], residual connections [5] or over-complete representations [6]. Nevertheless, one of the main limitations of these works lies in the still very local approach of segmentation, exploiting classical cost functions (cross entropy, Dice score) defined at the pixel level and which cannot reflect the topological impact of errors in predictions [7]. Constraining the extraction of vascular structures using **topological constraints** would allow to regularise predicted contours such that fine branches do no longer remain disconnected from main veins and arteries.

In the scope of this internship, we will focus on the integration of topological constraints into **transformers**-based segmentation pipelines [2, 8] by adding metrics based on the **connectivity** between pairs of vascular voxels to standard cost functions. A topological distance with respect to central vascular voxels [7] (Fig.1) as well as comparisons between high-level features derived from convolutional layers of one (or several) pre-trained network(s) [9] will be investigated. These constraints will penalise structures whose topological characteristics differ from those extracted from ground truth masks. As an application, the automatic extraction of arterial, supra-hepatic and portal venous systems will further divide the liver into height functionally independent areas known as the **Couinaud scheme** [10]. The developed methods will be mainly evaluated in the context of the management of patients with primary colorectal cancer with liver metastases.

Candidate profile

We are looking for a M2 student motivated by image analysis with a particular interest in DL applications. A background in biomedical or medical imaging and an experience with Python programming language and Pytorch package are a plus. Good communication and team working skills are also required as the intern will work in close collaboration with another intern from INSA Lyon / CREATIS laboratory located in Lyon, France. A good ability to communicate in English as well as a fluent English for reading and writing scientific articles are also required.

Internship information

- 6-month internship starting from January to March 2022
- Location : LaTIM laboratory[1], 22 avenue Camille Desmoulins, Brest, France
- Advisors : Dr. Pierre-Henri Conze (IMT Atlantique[2], LaTIM) and Dr. Odyssée Merveille (INSA Lyon, CREATIS)
- Applications by email to `pierre-henri.conze@imt-atlantique.fr` including :
  - full curriculum vitæ
  - cover letter stating your motivation and fit for this project
  - latest grade transcripts
  - (optional) recommendation letters or contacts from former teachers/advisors

Bibliography

[1] G. Litjens et al., *A survey on deep learning in medical image analysis.* Medical Image Analysis, 2017.

[2] J. Chen et al., *TransUNet : Transformers make strong encoders for medical image segmentation.* arXiv, 2021.

[3] O. Ronneberger et al., *U-Net : Convolutional networks for biomedical image segmentation.* International Conference on Medical Image Computing and Computer-Assisted Intervention, 2015.

[4] T. Kitrungrotsakul et al., *VesselNet : A deep convolutional neural network with multi pathways for robust hepatic vessel segmentation.* Computerized Medical Imaging and Graphics, 2019.

[5] W. Yu et al., *Liver vessels segmentation based on 3D residual U-Net.* IEEE International Conference on Image Processing, 2019.

[6] J. Valanarasu et al., *KiU-Net : Towards accurate segmentation of biomedical images using over-complete representations.* Int. Conference on Medical Image Computing and Computer-Assisted Interventions, 2020.

[7] D. Keshwani et al., *TopNet : Topology preserving metric learning for vessel tree reconstruction and labelling.* Int. Conference on Medical Image Computing and Computer-Assisted Interventions, 2020.

[8] J. Valanarasu et al., *Medical transformer : Gated axial-attention for medical image segmentation.* International Conference on Medical Image Computing and Computer-Assisted Interventions, 2021.

[9] A. Mosinska et al., *Beyond the pixel-wise loss for topology-aware delineation.* IEEE Conference on Computer Vision and Pattern Recognition, 2018.

[10] M.-A. Lebre et al., *Automatic segmentation methods for liver and hepatic vessels from CT and MRI volumes, applied to the Couinaud scheme.* Computers in Biology and Medicine, 2019.

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2. `https://www.imt-atlantique.fr/`