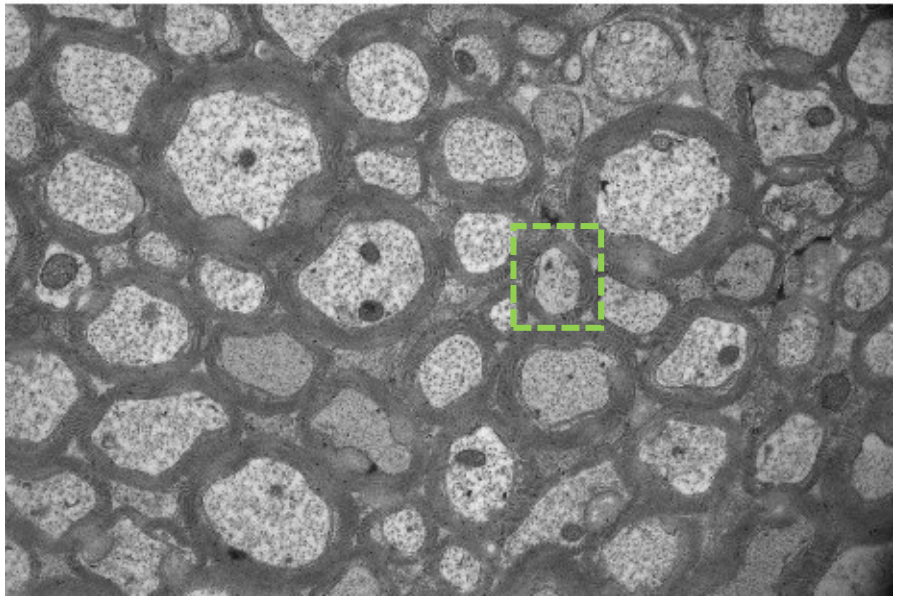
Project n°8

Segmentation of myelin in electron microscopy images

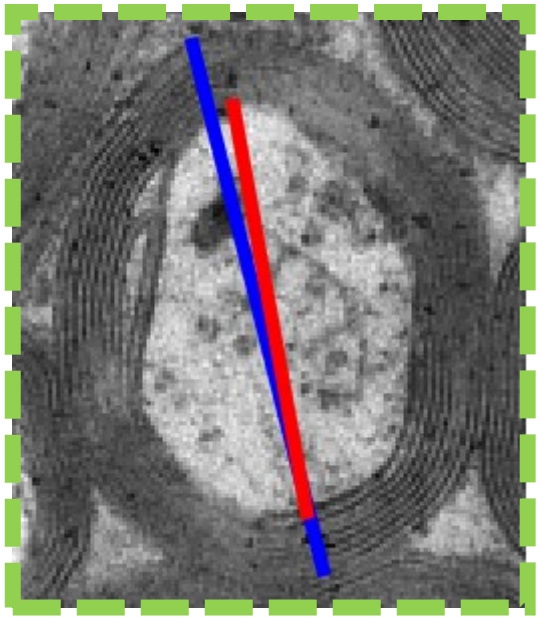
Context

- Partnership between Lisite (Florence Rossant) and Lariboisière hospital (Anne Joutel) on axon and myelin analysis on Electron Microscopy (EM) mice images.
- Myelin: membran, composed of protid and lipid layers, surrounding axons, aiming at isolating and protecting them, and speeding up the transmission of nerve impulses.
- Clinical stake: extract biological biomarkers such as the g-ratio, that is the ratio between the diameter of the axon and the diameter of its associated myelin sheat

→ Need in an individual segmentation of all myelin sheats



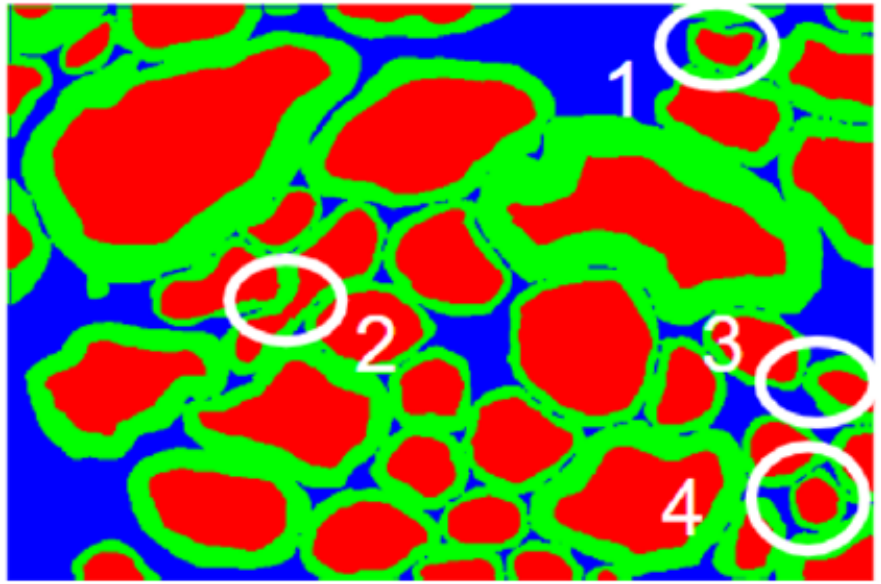
EM image



Zoomed EM image

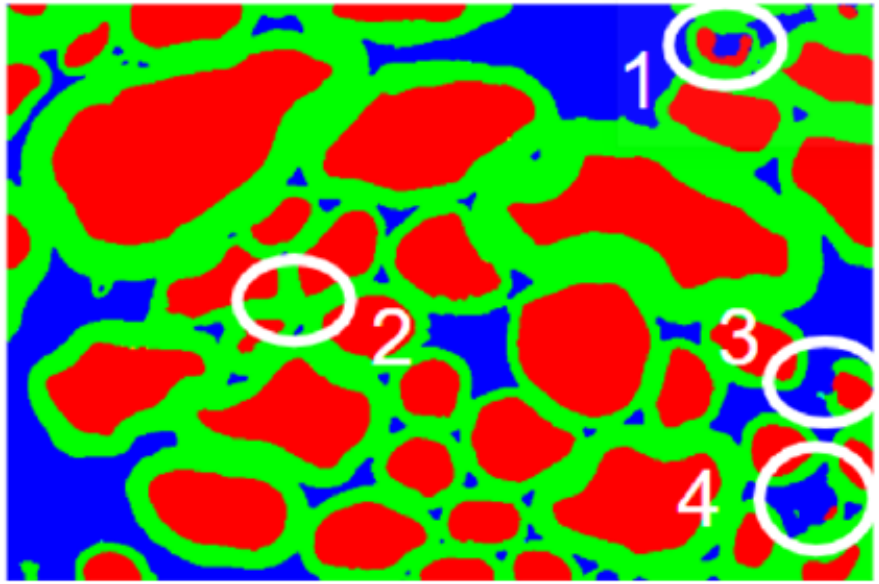
Preliminary results

- **[Le Couedic et al., 2020]:** Deep Learning based segmentation of EM images into **myelin**, **axon** and **background** using a U-Net-derived architecture (**[Ronneberger et al., 2015]**)
- Use of 23 mice EM images, associated with their 3-class manual segmentations:
  - 18 for training
  - 3 for validation
  - 2 for test
- Promising results, but room for improvements!



[Le Couedic et al., 2020]

Ground truth image with highlighted errors



Model segmented image with highlighted errors

1. Good segmentation but wrong classification
2. & 4. Wrong axon segmentation
3. & 4. Wrong myelin segmentation

→ **The addition of topological information could improve the segmentation!**

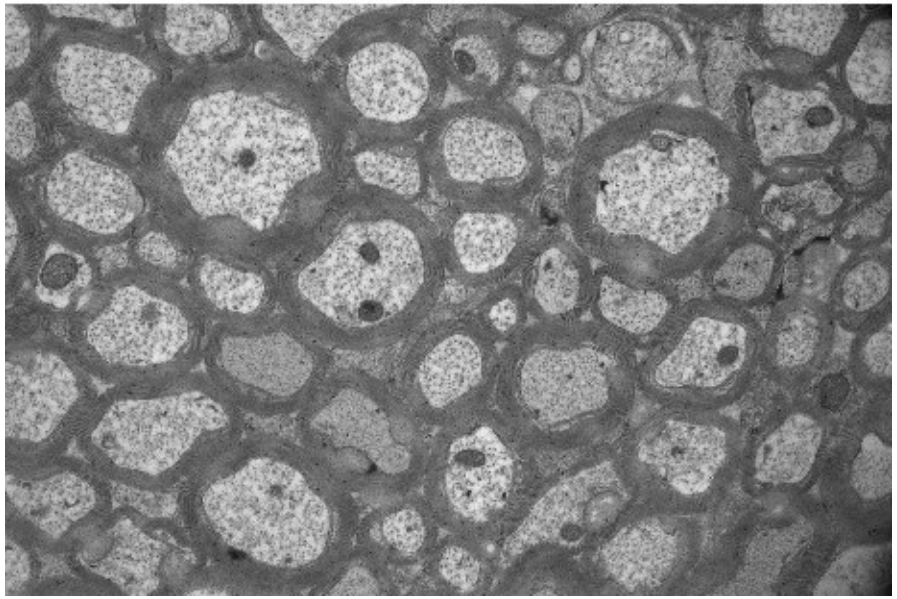
Topological hypotheses to investigate

- The hidden topological constraints:
  - Manually segmented axons cannot touch background areas
  - Each manually segmented axon is surrounded by myelin

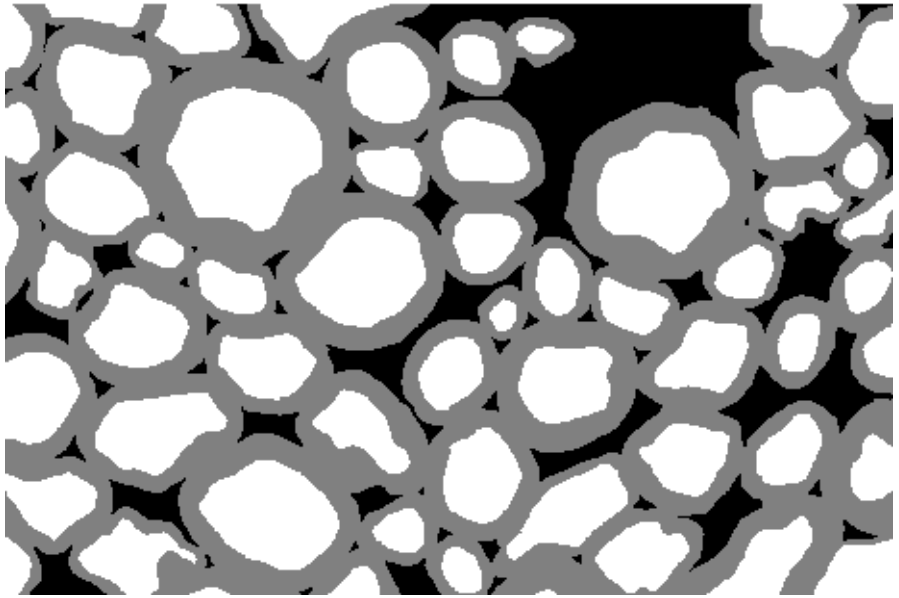
→ Supposing we get a pretty accurate binary segmentation of the myelin, each remaining region (connected component) can be further classified into axon or background using Machine Learning (ML)

→ We hope that focusing on myelin for the segmentation helps 'closing' its contours (error 3)

→ The ML part can also correct the misclassification of connected components (error 1)



EM image



Associated manual segmentation

Expected outputs

- The goal of the project is to deliver a robust a two-phase algorithm
  - Phase 1: A Deep learning-based binary segmentation of the myelin
  - Phase 2: A Machine Learning-based classification into background and axon of the remaining regions (connected components of the complement image of the binary segmentation of the myelin)

- Provided data and tools:
  - EM mice images and their associated manual segmentation into axon, background and myelin
  - A jupyter notebook of the 3-class segmentation of EM images (Monai library)

- The notebook should be modified to:
  - Use the binary segmentation of the myelin
  - Implement topological losses (almost **[Hu et al., 2019]**, if time **[Kervadec et al., 2019]**, or other articles you find interesting)
  - Include quantitative results during validation and test (Dice's similarity coefficient)

- Expected work:
  - Read and present the works of **[Hu et al., 2019]**
  - Present your work on the project during a final presentation
  - Give back your modified code

Some references

Articles
[1] Hu, Xiaoling, et al. "Topology-preserving deep image segmentation." *arXiv preprint arXiv:1906.05404* (2019).
[2] Kervadec, Hoel, et al. "Boundary loss for highly unbalanced segmentation." *International conference on medical imaging with deep learning*. PMLR, 2019.
[3] Le Couedic, Thomas, et al. "Deep-learning based segmentation of challenging myelin sheaths." *2020 Tenth International Conference on Image Processing Theory, Tools and Applications (IPTA)*. IEEE, 2020.
[4] Ronneberger, O., Fischer, P., & Brox, T. (2015, October). U-net: Convolutional networks for biomedical image segmentation. In *International Conference on Medical image computing and computer-assisted intervention* (pp. 234-241). Springer, Cham.

Sites web
Pytorch implementation of [1]: https://github.com/HuXiaoling/TopoLoss/blob/master/topoloss_pytorch.py
Monai tutorials: https://monai.io/start.html#MONAITutorials