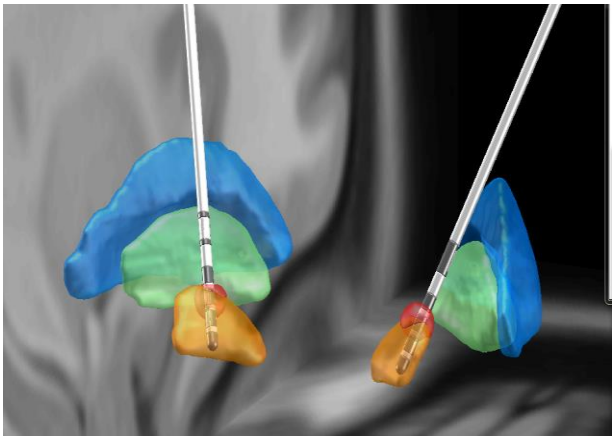
Exploring 3D Deep Learning for Stimulation Maps for Deep Brain Stimulation

Background Deep Brain Stimulation (DBS) is an established therapy for movement disorders such as Parkinson's disease. Stimulation leads are typically implanted in the subthalamic nucleus to apply electrical stimulation. This ameliorates the symptoms of the disease, but the exact mechanisms remain debated. To optimize the stimulation after implantation, the clinician and patient perform time-consuming stimulation programming and test many electrodes at different parameters.



On the right: Illustration of stimulation leads and subcortical structures. Subthalamic nucleus in orange and volume of tissue activated in red. These volumes activate the 'motor part' of the nucleus.

Assisted programming can reduce the time to find optimal stimulation settings by providing automated stimulation suggestions. To this end, *stimulation maps* identify sweet spots of stimulation, i.e., regions that are likely to result in beneficial outcome. These maps are built from patient data: the position of DBS leads in the brain, stimulation volumes and the corresponding clinical outcomes. In our current approach, this data is further processed with voxel-based statistical learning to determine sweet spots [1]. The sweet spot is finally used to provide stimulation suggestions. In this master thesis project, we will explore 3D deep learning to generate stimulation maps and determine sweet spots [2].

Aim First, the student will review the literature on 3D deep learning for medical images. Second, she/he will conceptualize three to five pipelines or approaches. One could think of the stimulation volumes inside the brains as 3D images with different clinical scores and extract features to have a feature map. Third, she/he will pilot and implement a shortlist of approaches and evaluate this with retrospective patient data from Inselspital. Finally, the student will evaluate the predictive power of the 3D deep learning approach to suggest stimulation settings against sweet-spot based or tract-based assisted programming.

Materials and Methods The student will estimate the stimulation volumes in Matlab with the open-source toolbox Lead-DBS. For the 3D deep learning, the student will evaluate e.g., TensorFlow, Keras, PyTorch.

Nature of the Thesis:
Literature review: 20%
Data analysis and programming: 60%
Writing: 20%

Requirements:
Interest in machine/statistical learning
Programming knowledge (e.g., Matlab, Python)

Supervisors:
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References:

[1] Nguyen TAK, Nowacki A, Debove I, Petermann K, Tinkhauser G, Wiest R, et al. Directional stimulation of subthalamic nucleus sweet spot predicts clinical efficacy: Proof of concept. Brain Stimul. Elsevier Ltd; 2019;12: 1127–1134. doi:10.1016/j.brs.2019.05.001
[2] Singh SP, Wang L, Gupta S, Goli H, Padmanabhan P, Gulyás B. 3D Deep Learning on Medical Images: A Review. Sensors. 2020; 20(18):5097. https://doi.org/10.3390/s20185097