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► **To cite this version:**

Dorian Vogel, Karin Wårdell, Jerome Coste, Jean-Jacques Lemaire, Simone Hemm. Learning from the Past: Probabilistic Deep Brain Stimulation Atlas Based on Intra-Operative Data. 11th International IEEE EMBS Conference on Neural Engineering, Apr 2023, Baltimore, MD, United States. IEEE, IEEE NER 2023 proceedings, 2023 11th International IEEE/EMBS Conference on Neural Engineering (NER), page 41 / id #1570881542, 2023, 10.1109/NER52421.2023.10123756 . hal-04064543

HAL Id: hal-04064543

<https://hal.science/hal-04064543>

Submitted on 11 Apr 2023

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Learning from the Past: Probabilistic Deep Brain Stimulation Atlas Based on Intra-Operative Data.

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Background

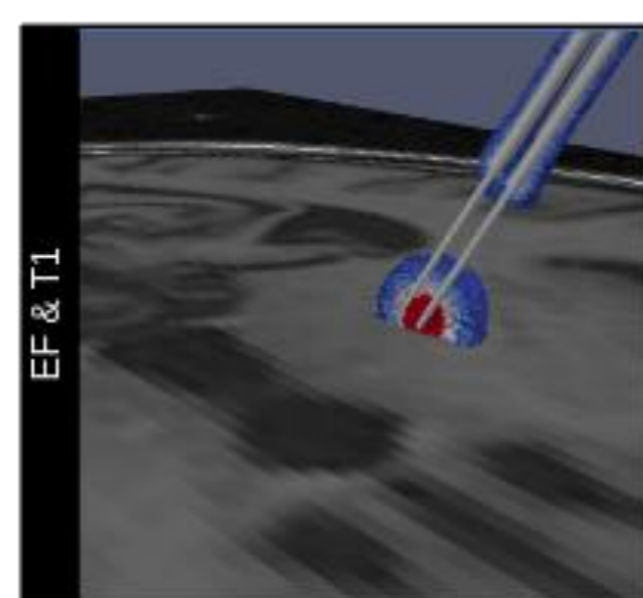
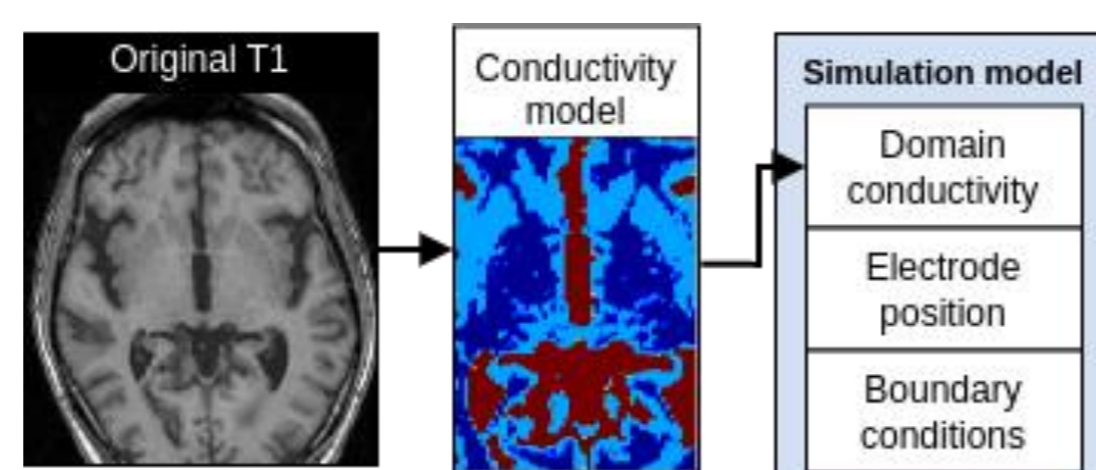
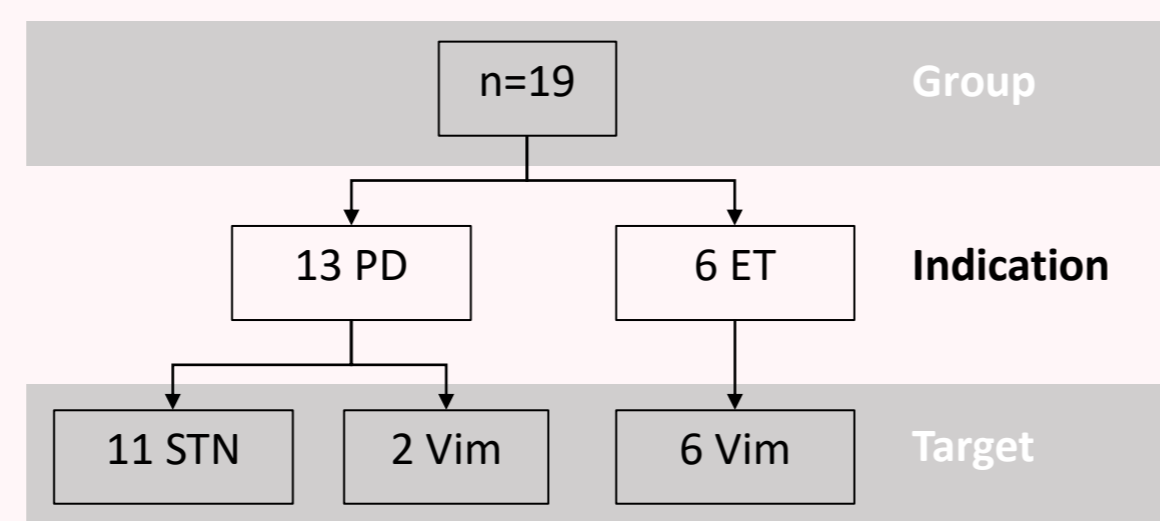
- The placement of the Deep Brain Stimulation (DBS) electrode at the most effective location in the brain for the control of symptoms of movements disorders is challenging.
- The use of intra-operative tests stimulation has been the standard and stays very common despite the strong trend towards implantation under general anesthesia.
- To better understand the mechanisms behind DBS, normative analysis has a great potential. These allow analyzing the stimulation-effect relationship at a group level resulting in probabilistic stimulation maps (PSMs).

Aim: Develop and Setup a pipeline for group-analysis to evaluate the potential of intra-operative test data for the generation of PSMs.

Method

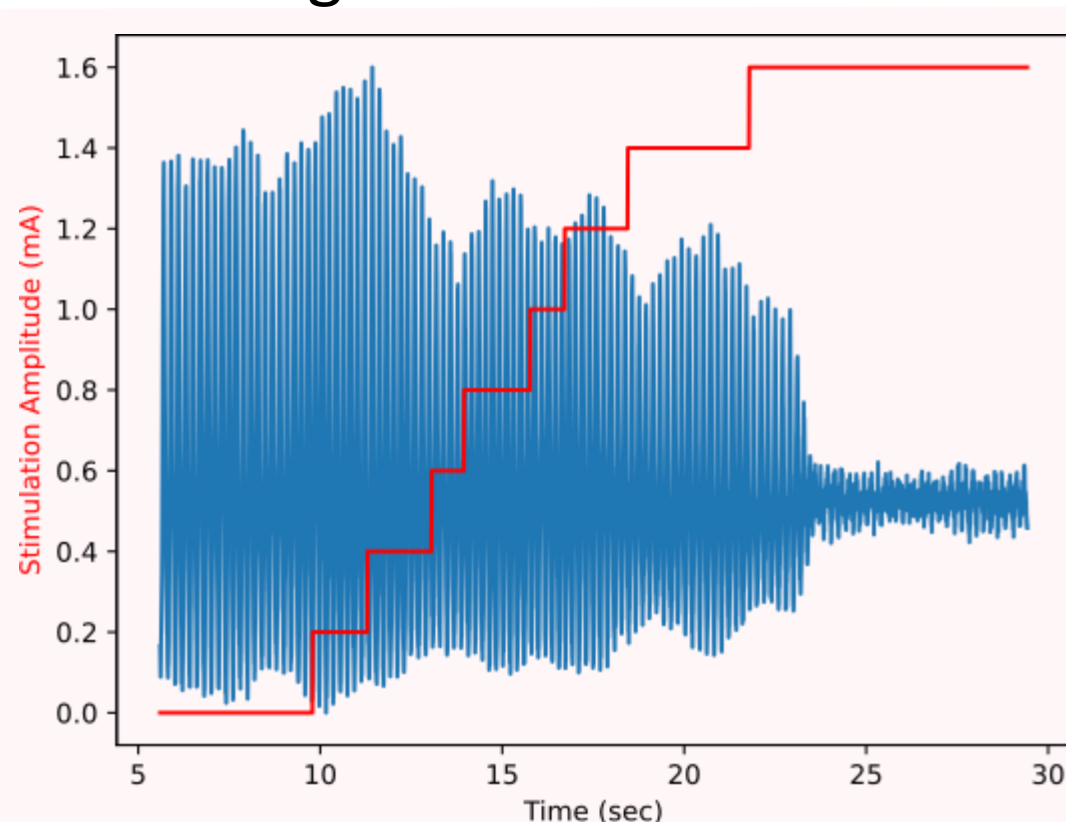
Clinical Data:

- 19 patients implanted under local anesthesia with MER and test stimulation (2 parallel electrodes)
- Imaging: preoperative stereotactic T1 and WAIR (white matter attenuated inverse recovery).



Volume of tissue activated:

- Patient-specific isotropic conductivity model based on T1 contrast.
- Electrode placed based on intraoperative Leksell Frame settings.



Symptoms scores:

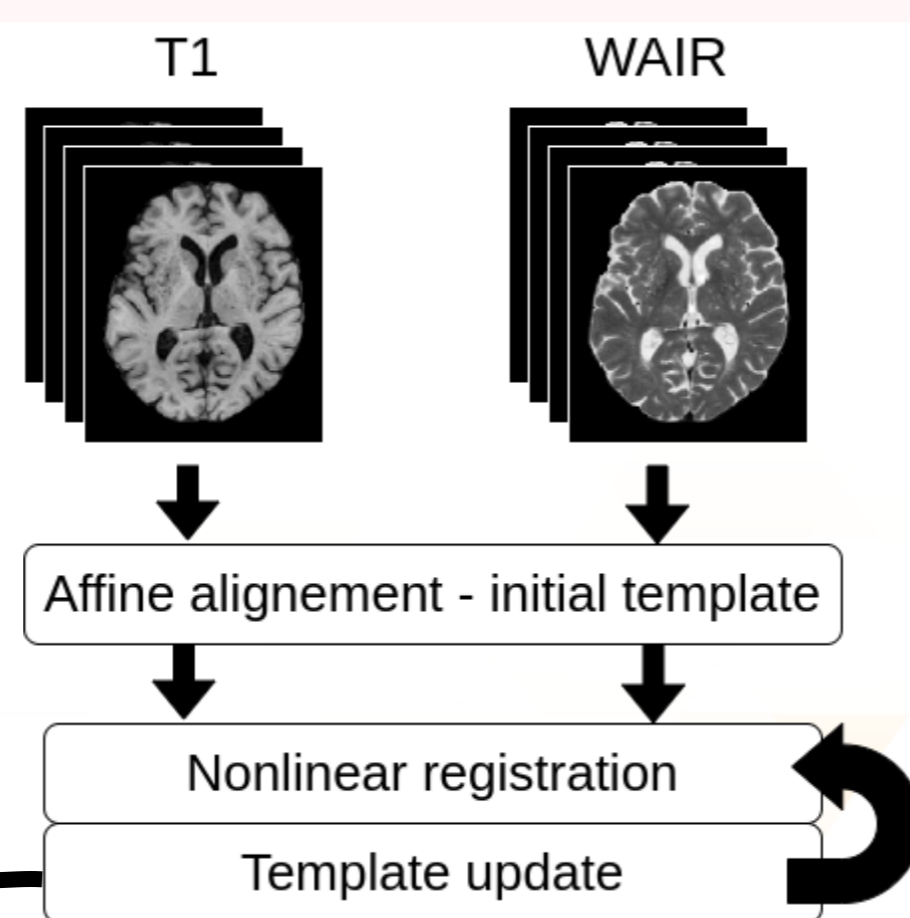
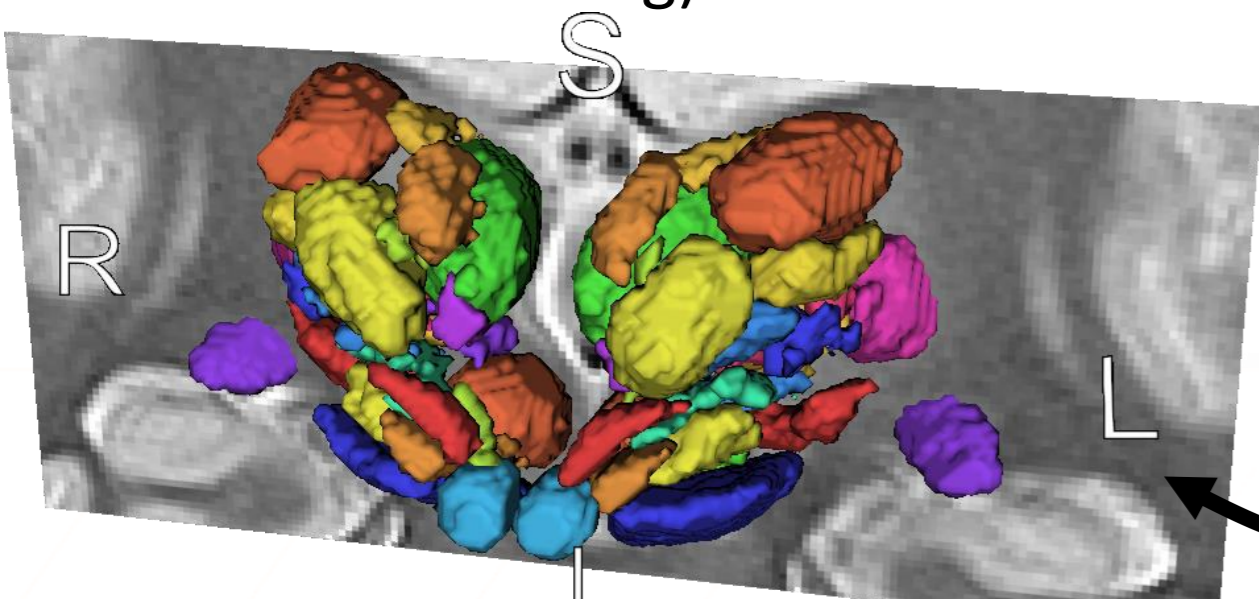
Quantitative tremor scoring based on wrist-worn 3D acceleration sensor (400Hz). Synced with stimulation amplitude changes.

Metrics: standard deviation of magnitude, amplitude at peak frequency, signal energy.

Anatomical Normalization:

Group-specific template

- Iterative mixed-modality pipeline
- 37 deep brain structures defined (based on patient-specific, single-expert manual labeling).



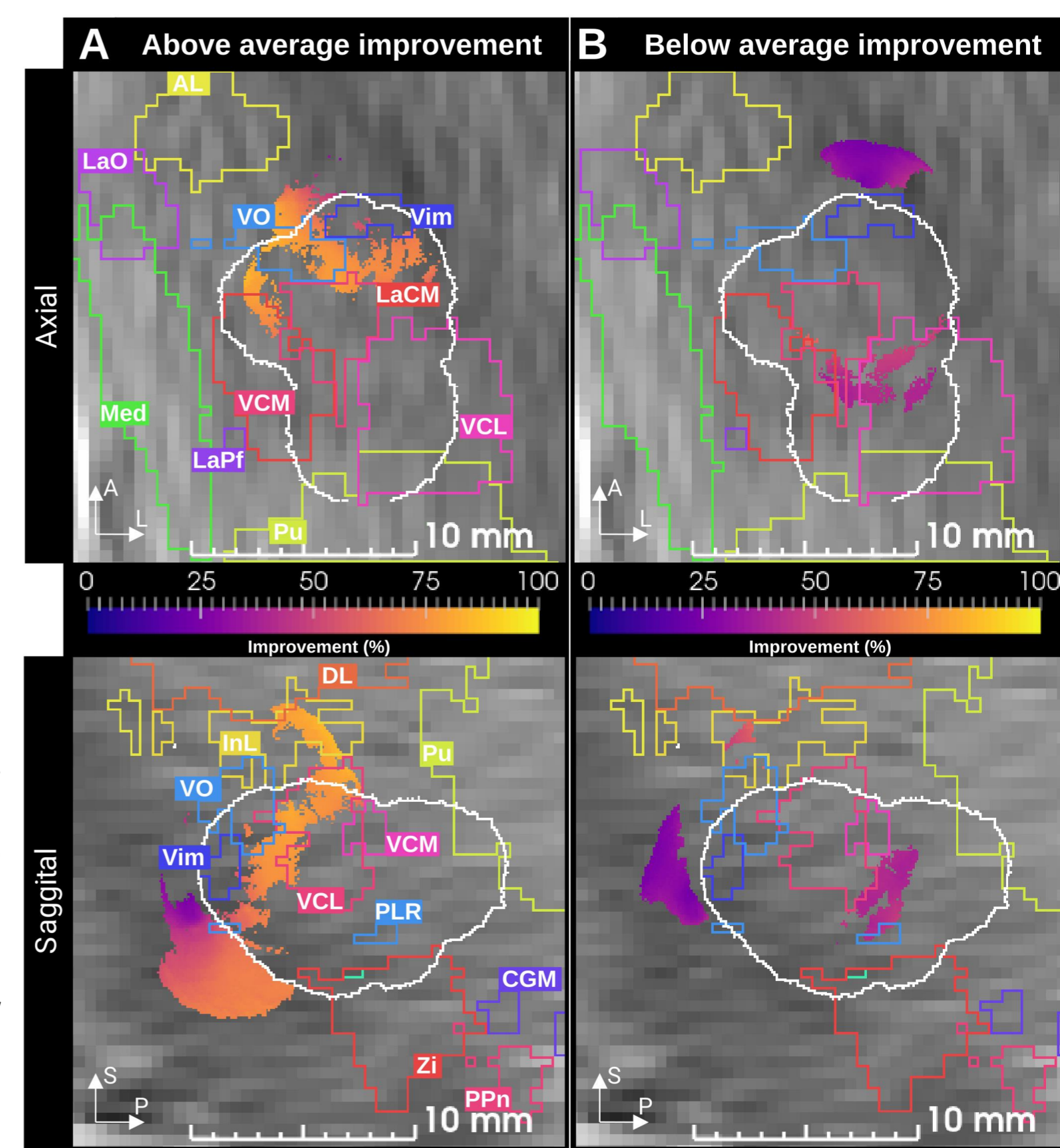
Probabilistic Stimulation maps

Resolution of overlap between VTAs associated with different tremor scores after transformation in template space. Analysis for the 6 Essential tremor patients only.

- Number of stimulations for each voxel: nMap
- Best overall outcome for each voxel: maxMap
- Voxels significant for greater tremor reduction: weighted mean map + signed t-test (against average improvement) per patient & majority voting.

All maps visualized in atlas space, with anatomical labels from the group.

Results



Weighted mean Map masked with the result of the significance test result (t-test). A: significant for tremor reduction above average; B: significant for tremor reduction below average.

- 1708 stimulation tests in 6 patients simulated, normalized and analyzed.
- Regions with above average improvements located posterior to Vim-Vo and anterior to VCL-VCM, extending down in the Posterior subthalamic Area (Zona incerta).
- Regions associated with worst improvement at the anterior and posterior limits of the ROI.
- Automatic and reproducible pipeline

Conclusion

- Design and implementation of reproducible, automatic group-specific analysis pipeline for analyzing outcomes during intraoperative DBS tests.
- Promising results obtained despite the small number of patients.
- Outlook:
 - better statistics methods in the weighted mean map.
 - more patients (acquisition in progress).