Probabilistic Stimulation Maps for Deep Brain Stimulation

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Introduction

Deep brain stimulation (DBS) is an established neurosurgical treatment for Parkinson's disease. The preferred target in the subcortex is the subthalamic nucleus. In clinical routine, the search of the optimal stimulation parameters is a time consuming (up to 8 hours per patient) trial-and-error method. DBS parameters optimization based on probabilistic stimulation mapping may reduce the duration of this process and improve the outcome of the therapy, thus benefiting both clinician and patients.
Previous studies developed methods using estimation of the volume of tissue activated and processing voxel-wise significance tests to find a sweet spot. They could demonstrate that activation of the sweet spot positively correlated with clinical improvement. This work aimed to refine existing probabilistic stimulation maps.

Materials and Methods

The state of the art methods were implemented in a MATLAB class allowing fast implementation of new algorithms. A multicentric dataset of patients from Bern and Cologne centers was used to train and test the models. The proposed methods consisted in regularized voxel-wise regression and classification models. The state of the art and proposed methods were assessed using a 10-fold cross-validation. The coefficient of determination (R2) between the ground truth and the predictions was used to assess the models.

Results

The overall model comparison showed that the best model was an adaptation of the logistic regression to be used as a regression model with a median R2 value of 39%.

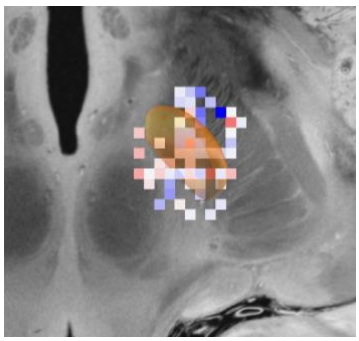

Fig. 1 *Axial slice heatmap of the regression coefficients in the subthalamic nucleus (in orange) region*

Voxel-wise regression analysis performed better than the previous sweet spot mapping methods. Classification models reached 78% accuracy to recognise stimulation settings with full-effect from settings with partial/null-effect.

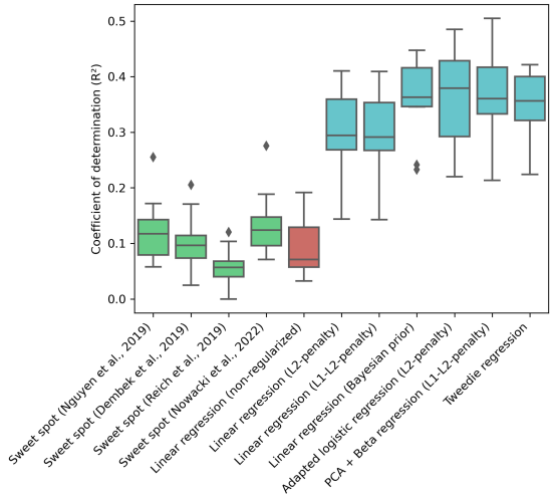

Fig. 2 10-fold cross-validation summary of the probabilistic stimulation mapping methods (sweet spot methods in green, non-regularized linear regression in red, proposed approaches in blue).

Discussion

Sweet spot mapping method are very dependent on the dataset and all groups seem to have a sweet spot generation method adapted to their own dataset. The proposed approach for probabilistic stimulation mapping may be a more complex and less intuitive approach than the previous approach with sweet spot, but provides better estimation of the clinical outcome and is not computationally more expensive.

References

[1] T. A. Nguyen et al., Directional stimulation of subthalamic nucleus sweet spot predicts clinical efficacy: Proof of concept, Brain Stimulation, 12(5):1127-1134, 2019.

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