Tractography Modelling of Deep Brain Stimulation for Parkinson's Disease

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Background

Parkinson's disease (PD) is a common neurodegenerative disorder. DBS is a neurosurgical procedure in which a thin lead with several electrode contacts at the tip is chronically implanted in deep brain structures, and delivers electrical pulses at high frequency to surrounding brain tissue. DBS programming is performed manually, but computer assissted programming (CAP) could guide and simplify the postoperative DBS programming.

One approach for CAP is to use tractography-based pathway activation models for DBS parameter suggestions. DBS is a neurosurgical therapy in which a thin lead with a number of electrode contacts at the tip is chronically implanted in deep brain structures, and delivers electrical pulses at high frequency to surrounding brain tissue through one or a combination of electrode contacts.

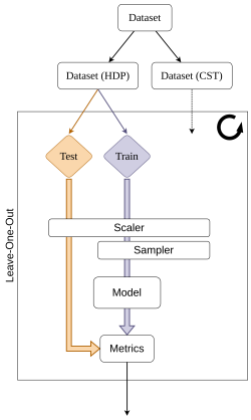

Fig. 1 Overview of the pipeline to modelize both of the motor pathways. Data are split to modelize each pathway individualy

Objectives

The aim of the project was to develop pathway activation models to suggest DBS stimulation parameters for (1) evaluating different models and how feature selection influences the results, and (2) comparing the results to an existing baseline model.

Materials and Methods

Hyperdirect pathway (HDP) and Corticospial tract (CST) motor pathways' activation, stimulation intensity, and distance from electrode contacts to the subthalamic nuclei (STN) data were extracted from patient-specific tractography, and post-operative image.

Using the gathered data, multiple models were trained combining different scaler, sampler, classifier, and feature combination. Models were then ranked using five different ranking method, thereafter non-significant element were discarded. Finally, the best ranked model for each method were compared to a baseline on classification score, and 'combined level' score — a score that reflect the accuracy against chosen parameters from the postoperative DBS programming.

Results

In analysis of the features' implication in the models, results showed that pathways activation and stimulation intensity were revealed to constitute good predictors of the stimulation outcome. The scalers had no impact on the results. A combination of over-sampling and under-sampling helped to improve classification performances when modelling the HDP. Four classifiers were retained: Logistic Regression (LogReg), linear Support Vector Machine (SVM), and LDA and QDA.

All model selected from the ranking methods displayed more accurate classification prediction. However, they were outperformed by the baseline on 'combined level' score.

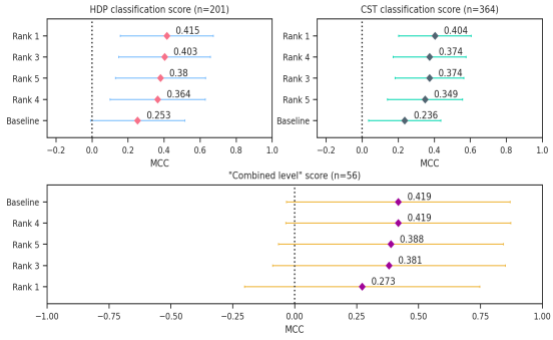

Fig. 2 Results for each selected model, against the baseline model

Discussion

Model classification accuracy has improved greatly, with the right com- bination of features. Nonetheless, given the small sample size of the study dataset, further evaluations are required for the best/worst level score.