# Development and implementation of a concept for automatic patient-specific DBS parameter identification

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Master-Thesis

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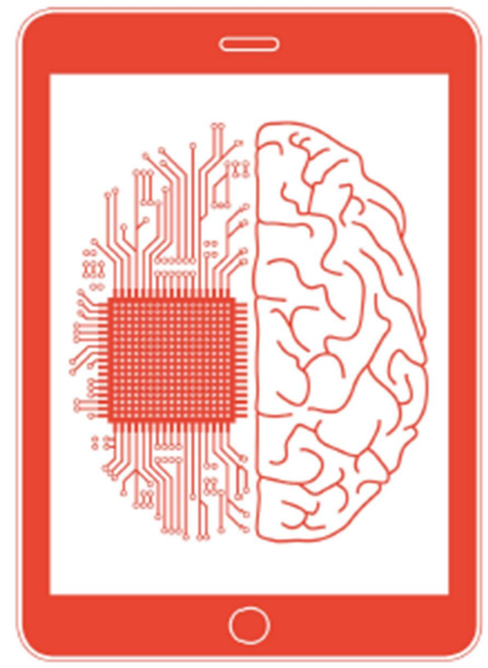

## Introduction

Deep brain stimulation (DBS) is a neurosurgical procedure which has become one of the most important therapies for relieving movement disorder symptoms such as the ones observed in essential tremor (ET), Parkinson's disease (PD) and dystonia. Even though the use of DBS is being extended to neuropsychiatric disorders such as obsessive-compulsive disorder and is already widely deployed for movement disorders, the fundamental mechanism(s) of action which elicit the clinical effects are still under investigation (Muthuraman et al., 2018). For movement disorder symptom treatment, electrodes are implanted in brain regions critical for the movement control (Hemm et al., 2016), but the targets can vary between surgical centers (Muthuraman et al., 2018). The optimal electrode position is typically located using a mix of preoperative planning based on anatomical images and of intraoperative testing on the conscious patient where the neurosurgeon notes the clinical and adverse effects manually (Hemm et al., 2016).

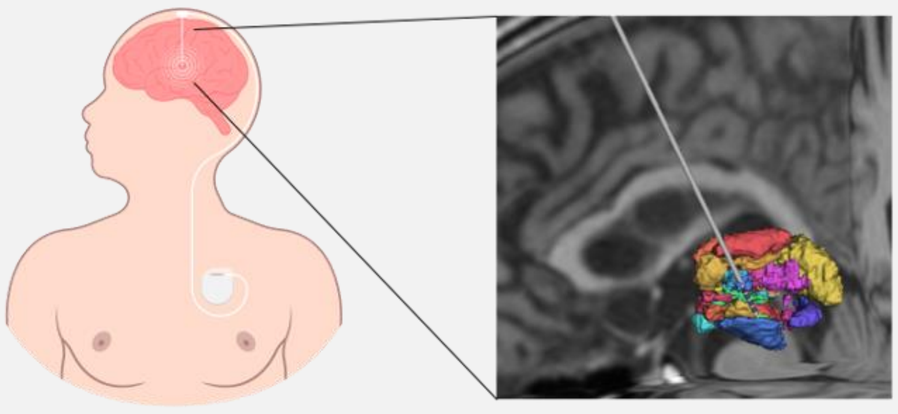

Fig. 1: DBS system with close-up showing the small size of the brain structures.

Objective evaluation of the optimal implant position was introduced by linking acceleration measurements from the patient to quantify tremor improvements to patient-specific simulations of the electric field (EF) around the stimulation electrode using the brain anatomy (Hemm et al., 2016, Shah et al., 2016). Using these EFs with associated stimulation effects, stimulation maps were compiled highlighting the involved brain regions. The stimulation maps from multiple patients were condensed to a disease specific atlas (Vogel, 2022). Programming of the chronically implanted lead is complex as todays implanted models usually have four or to eight stimulation contacts, allowing a wide variety of settings (Koeglsperger et al., 2019). New programming support tools are emerging visualizing the implanted lead and the EF for the chosen settings in the patient anatomy. However, no programming suggestions are being made so the neurologists still need to know which structures should be stimulated (or avoided) and test all settings to achieve the planned stimulation by themselves.

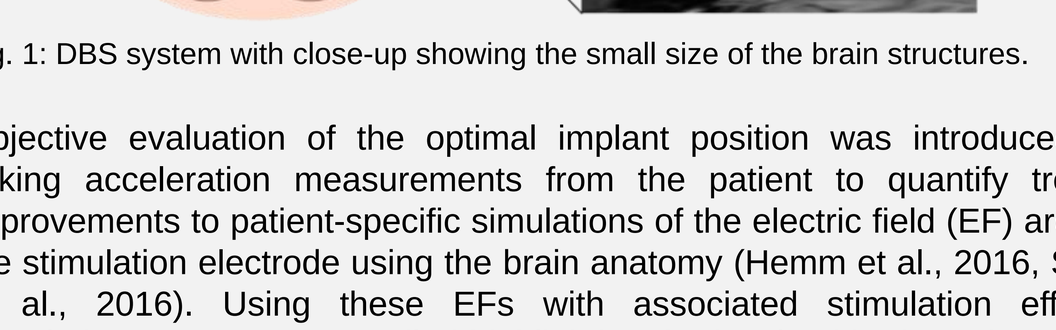


Fig. 2: Visualization of different programming parameters. **A**. Amplitude, **B**. Contact selection, **C**. Stimulation polarity, **D**. Stimulation frequency, **E**. Stimulation pulse-width.

## Concept Development

The concept consists of three main parts: an analysis pipeline, a database, and a visualization application. In a first step the input data is preprocessed in the StIM²Analysis-pipeline and saved in a dedicated database. The database is then used to provide all the data needed for the analysis in the second half of the pipeline where the configured options are tested by generating EFs. At the end of the analysis pipeline the generated fields are assigned evaluation metrics. These values are again saved in the database which is then used for the visualization with the StIM²Slicer-plugin. The concept workflow is visualized in figure 3.

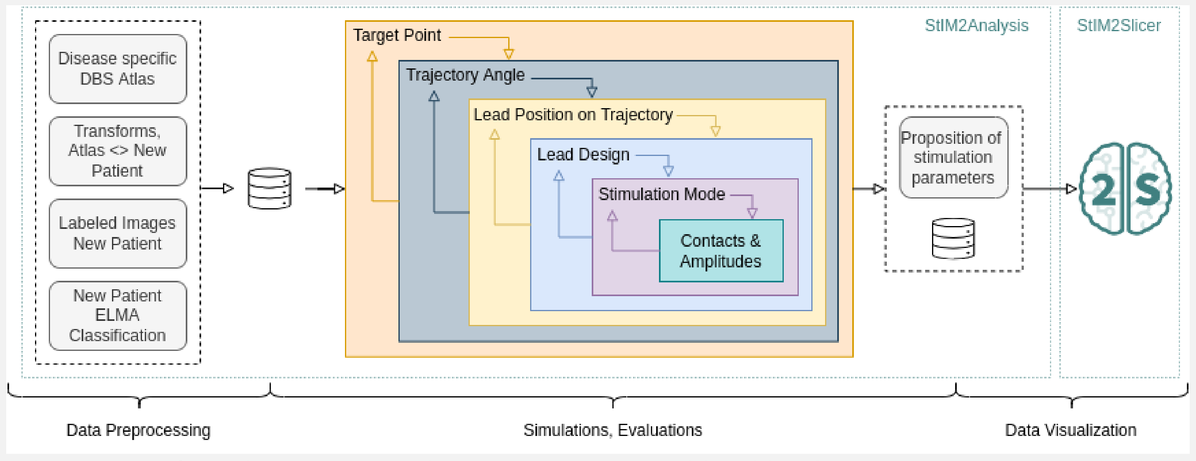


Fig. 3: Developed concept for the DBS parameter identification.

## Implementation

The input data preprocessing included in the StIM2Analysis-pipeline consists of reading the data, convert it to common coordinate systems and adding everything to the database. Compared to the concept four of the five loops iterating over the configuration factors are implemented as fixed values. Two factors remain variable: the target position and the stimulation amplitudes. EFs are generated for all the available configuration factor combinations using a Comsol LiveLink - Matlab application. The generated fields are evaluated with sweet spot extracted from the input stimulation atlas. For the evaluation, the overlap-based similarity metric dice coefficient is calculated after obtaining the intersection between the sweet spot and the field defining the overlap volume. As second metric, the mean surface distance (MSD) is between the two surfaces is used. A 3D Slicer plugin was implemented that allows visualization of the input data and the generated EFs simply by selecting the desired set from the database.

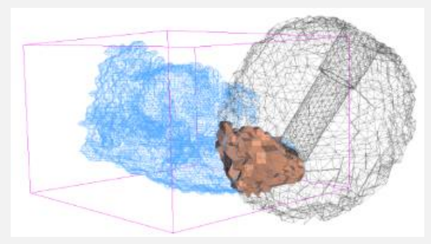

Fig. 4: Blue: sweet spot, black: EF, orange: intersection

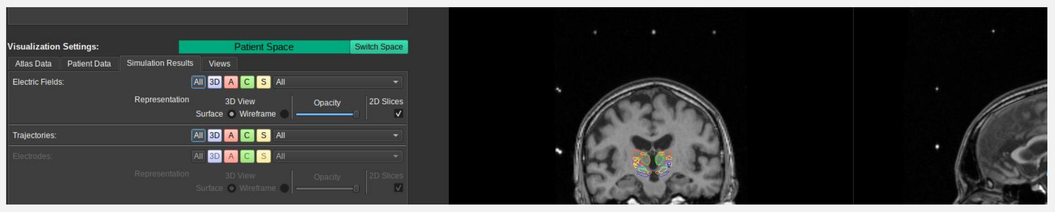


Fig. 5: Screenshot of part of the StIM²Slicer-plugin, the QR code leads to a demo video.

## Validation Results

For each patient, the fields at the positions with the maximum single dice, the maximum median dice and minimum MSD are were noted as best positions and compared to the position evaluated best by the clinicians. The different positioning between the clinical data and the pipeline output is visualized in figure 6 and shows big deviations between the left and right hemispheres. The maximum dice metrics performs inferior to the others.

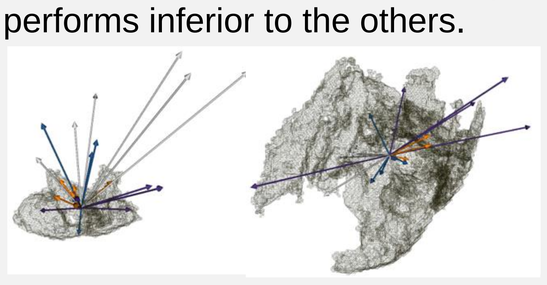

Fig. 6: sweet spot (left and right) with CoM vectors (clinical data, max dice, max median dice, min MSD)

## Conclusions

First results using the dice coefficient and the MSD between a sweet spot and simulated EFs suggest that there is some kind correlation between these metrics and a good position, but the CoM deviation needs to be reduced for good prediction results of the pipeline.
The current implementation fixes most of the configuration factors to predefined values. Nonetheless, a first prototype was achieved closing the loop between input data, preprocessing, EF simulation and evaluation, and even an interface for direct result visualization was achieved. The presented the-sis was a preliminary work leading towards the SNF project «Prediction of Patient-specific Deep Brain Stimulation parameters ».

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