Supporting Deep Brain Stimulation Interventions by Fusing Microelectrode Recordings with Imaging Data

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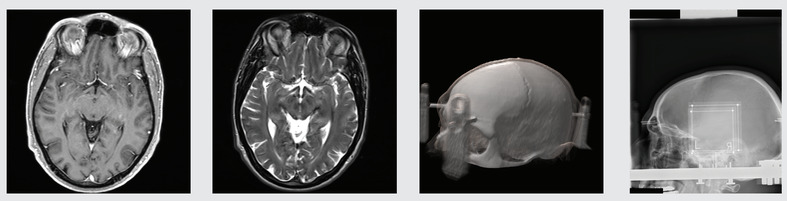
What is Deep Brain Stimulation?

Deep Brain Stimulation (DBS) is a neurological procedure to reduce tremor and other motor disfunctions arising from diseases like Parkinson's Disease.
In the procedure small electrodes are implated into very small regions of the patient's brain which is then stimulated. Precise placement of the electrodes is extremely important for the success of the operation.

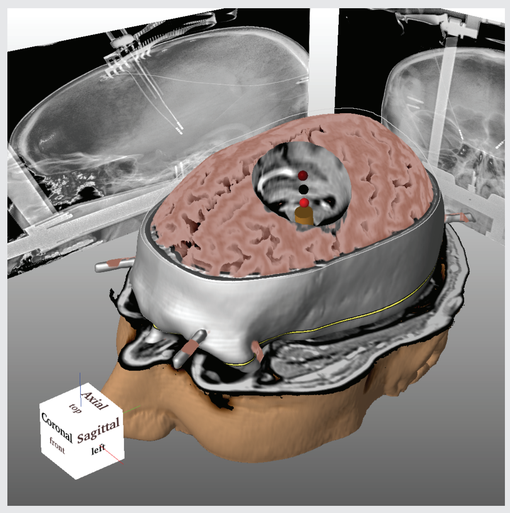
Acquisition of Pre-Operative Imaging Data



T_1-weighted MRI | T_2-weighted MRI | CT | X-Ray

Problem: The target region is not visible in any modality and its position can therefore only be estimated heuristically.

Multimodal Rendering



The rendering of all available modalities serves as the connecting view between all of our system's components.

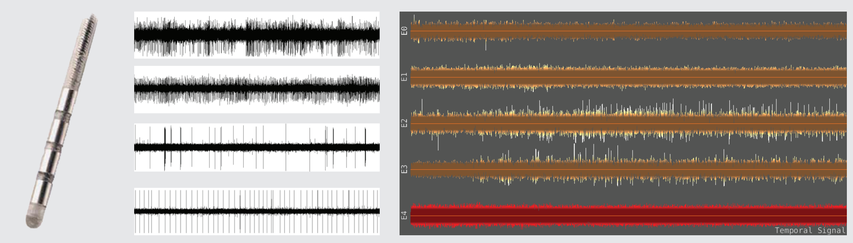
Patient Checks

After placing and activating the stimulating electrode, patient checks are perfomed to verify the electrode's position. The surrounding regions react differently to stimulation and these reactions, e.g. temporary memory loss, increased tremor, can be tested.
All data points from the patient checks lie on the access path, which spans from the burr hole in the head to the target region, and have an uncertainty with them.

Problem: The surgeon needs to keep track of the information from different checks in his head and relate them to the other information sources.

Micro Electrode Recording

An MER is obtained by advancing a small electrode towards the intended target region while recording the brains electric field. The discharge pattern of neutrons is distinct for each functional region and can thereby be used to distinguish functional areas.



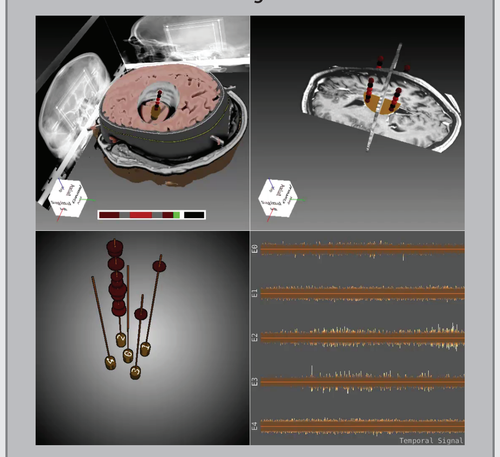
Electrode | Exemplatory Discharge Patterns | Traditional presentation of MER signal from 5 electrodes

Problem: The surgeon needs to maintain a mental registration between the oscillogram and the spatial position of the electrodes which requires concentration and is error-prone.

Results

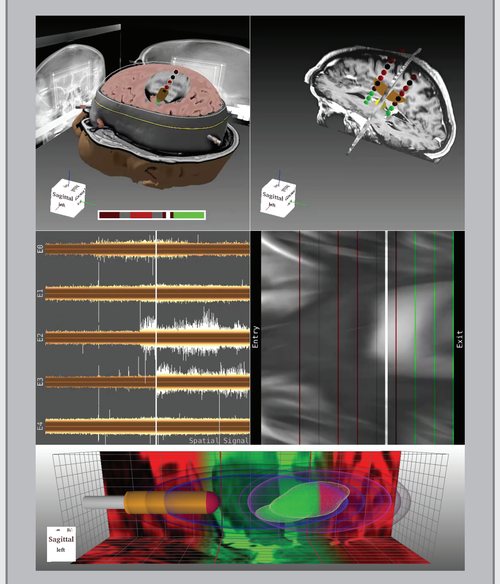
We combine all data into two major views, one for the MER recording phase (left figure), the other for the electrode placement phase (right figure). Each of the views reuses components to create a mental registration between them. This frees some of the surgeon's mental capacity to perform a better operation.

Recording Phase



In the recording phase, the MER signals are analyed and the resprective regions are represented by colored beads trailing the electrode (upper part). The lower part allows for direct access to the raw data and, hence, more detailed inspection.

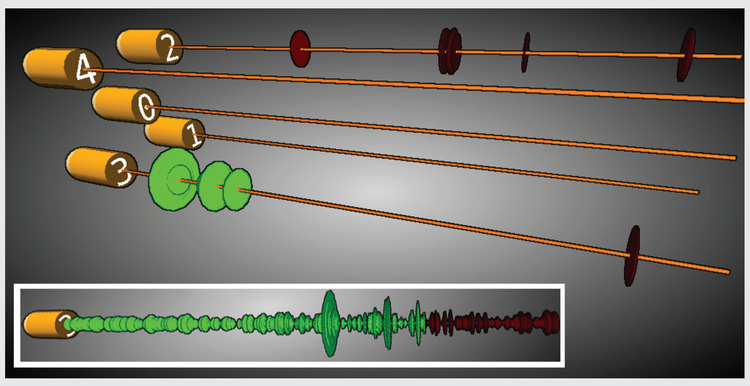
Placement Phase



In the placement phase, the stimulating electrode is advanced and the patient checks are performed. All previously recorded data is still available for inspection to find the optimal placement position.
The lowest image shows the combined information from the MER scans (red/green colormapping), the electrode, and the results from the patient checks (ellipses with transparent outer shells showing the uncertainty.

3D Spatiotemporal Audio Visualization

By combining knowledge about the electrodes' location and orientation with the detected signal, we relieve the surgeon or the burden of the need to fuse these information in his head.



As the high amplitude peaks are of importance, we discard every measurement point that is below a, user-definable, threshold. The rendering in the inset shows a lower threshold.

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