

Title

Automated Modeling of Targeted Non-Invasive Electrical Stimulation of the Brain with Multiple Electrodes

Authors & Affiliations

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Introduction

Conventional transcranial direct current stimulation (tDCS) applies weak constant currents to the surface of the scalp. High-density tDCS aims to improve targeting by using a number of gel-based electrodes instead of the conventional saline-soaked large-pad sponges. To achieve maximal performance in clinical applications, it is important to apply an appropriate current to the region of interest accurately through correctly placed electrodes. The goal of this study is to develop a fully automated targeting software for high-density tDCS. This software can establish a head model for a given subject, compute the optimal electrode configuration and simulate the current flows through each electrode and the brain.

Methods & Results

Structural magnetic resonance imaging (MRI) data of the brain was used as the basis for an anatomical model of tissue conductivities. The MRI (T1-weighted) was segmented into six tissue types with different electrical conductances: gray matter, white matter, cerebrospinal fluid (CSF), bone, soft tissue (skin) and air. The segmentation was performed using a probabilistic segmentation routine ("newsegment") which runs on Statistical Parametric Mapping 8 (SPM8). An improved Tissue Probability Map (TPM) with 6 tissue types covering head and neck was developed at the Center for Advanced Brain Imaging and was used in the segmentation. After SPM8 automated segmentation the resulting six segments were then edited, both manually and automatically to correct segmentation errors, such as "floating" and "empty" voxels, discontinuities in the CSF, and other corrections necessary to insure accurate current flow modeling. Manual "clean-up" was performed using ScanIP, which required days to weeks of user interaction and familiarity with anatomical MRI. Automated "clean-up" was based on morphological criteria such as continuity of CSF, connectivity, adjacency of tissues, minimal structure sizes, etc. These were implemented using morphological operations in Matlab. Then, again using Matlab, 89 electrodes and gels were automatically placed on the head following the conventions of the standard 10-10 international system (nasion, inion, pre-auricular points are provided by the user). Four additional electrodes are placed on the neck to provide distant references. After this, the six segments, plus placed electrodes and gels, were imported into ScanFE to generate a tetrahedral mesh with each segment defining an area of uniform conductivity. This mesh was then imported into Abaqus to solve for the current distribution in the head using finite element model (FEM) techniques for a specific pair of electrodes (Fp1 and Iz were chosen). The final current distributions computed with the FEM were compared between manual and automated segmentations. The whole process is shown in Fig. 1, and the results are shown in Fig. 2 – Fig. 6.

Conclusion

The automated method can achieve comparable performances in the "clean-up" of segments and the final current simulation. This means that the manual correction can be replaced by automated algorithm, thus the whole process can be automated. Then the software user can select any pair of electrodes to see the current distribution between them when doing tDCS therapy.

Clinical Relevance

tDCS is currently used as a therapy for certain brain disorders such as depression and stroke. This software can be used as a potential tool for doctors to guide the tDCS therapy for optimal focality and intensity in a subject-specific brain area.

Presentation category, please mark your preference []Cancer []Cardiac []Nano []Neuro

Figures and tables

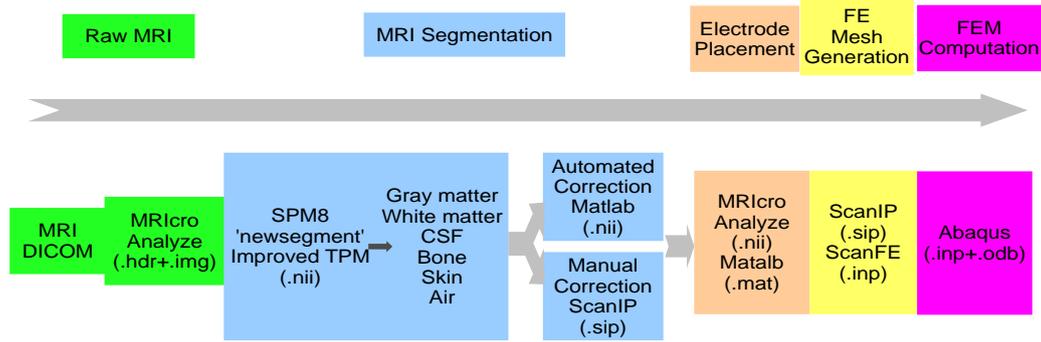


Fig.1 The Processing Flowchart of the Targeting Software

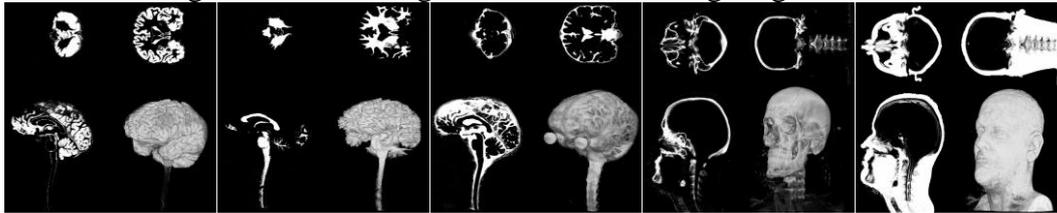


Fig.2 The results after SPM8 segmentation (gray matter, white matter, CSF, bone, skin)



Fig.3 The results of manual "clean-up" on the segments in Fig. 2

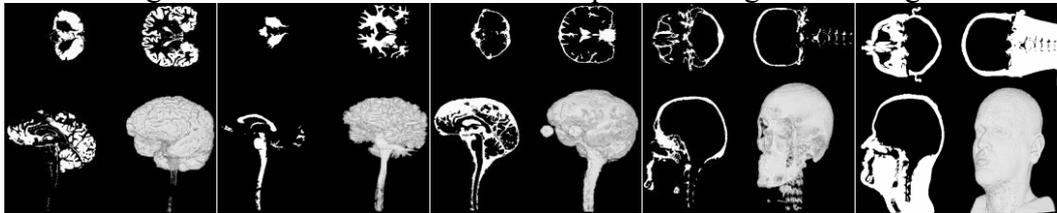


Fig.4 The results of automated "clean-up" on the segments in Fig. 2

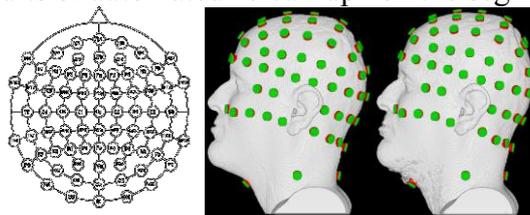


Fig.5 (Left) The full 10% 74-channel arrangement from Easy Cap; (Middle, Right) Results of electrode placement on the skins from manual and automated methods, respectively

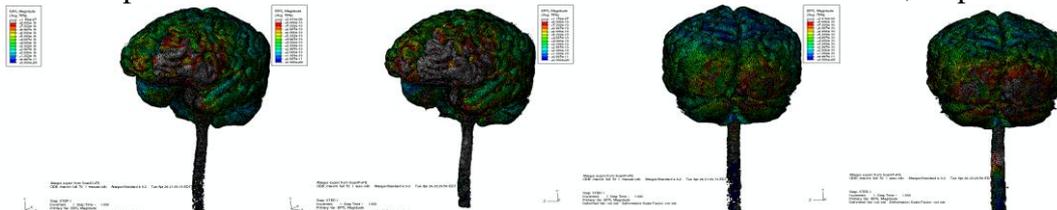


Fig.6 The simulated current distributions from stimulating electrode (Fp1, above left eye) to reference electrode (Iz, at theinion). From left: currents around Fp1 in gray and white matter from manual and automated methods; currents around Iz from manual and automated methods