ROAST, a free, fully-automated pipeline for realistic TES simulation based on volumetric approach.

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Introduction:

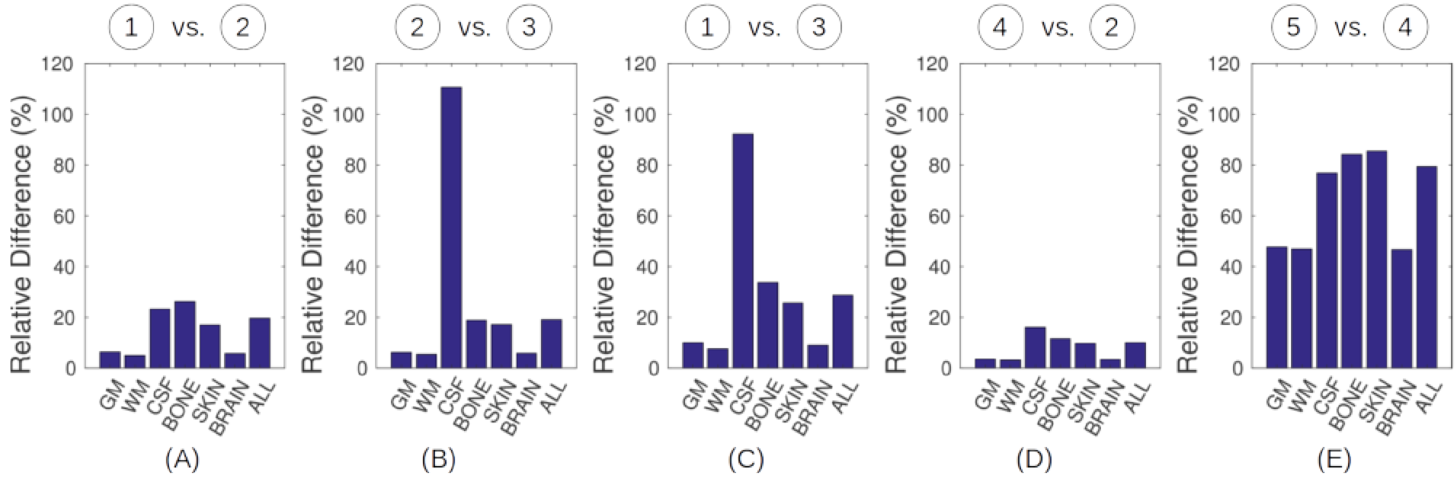
Research in the area of transcranial electrical stimulation (TES) often relies on computational models of current flow in the brain. To build such a model, the magnetic resonance images (MRI) of the human head have to be segmented, virtual electrodes have to be placed, the volume is then tessellated into a mesh, and the finite element model is solved numerically to estimate the current flow. Various software tools are available for each step, as well as processing pipelines that connect these tools for batch processing. However, existing pipelines are either not fully automated or difficult to use. A recent software SimNIBS (Windhoff et al., 2011) becomes popular for its ease of use, but it's based on the surface approach to represent the head anatomy, which has its own limitations (e.g., cannot capture the detailed structures of the skull, leading to un-realistic skull segmentation) . Here we propose a new software, ROAST, to provide an end-to-end solution that aims to address all these problems in the modeling process.

Methods:

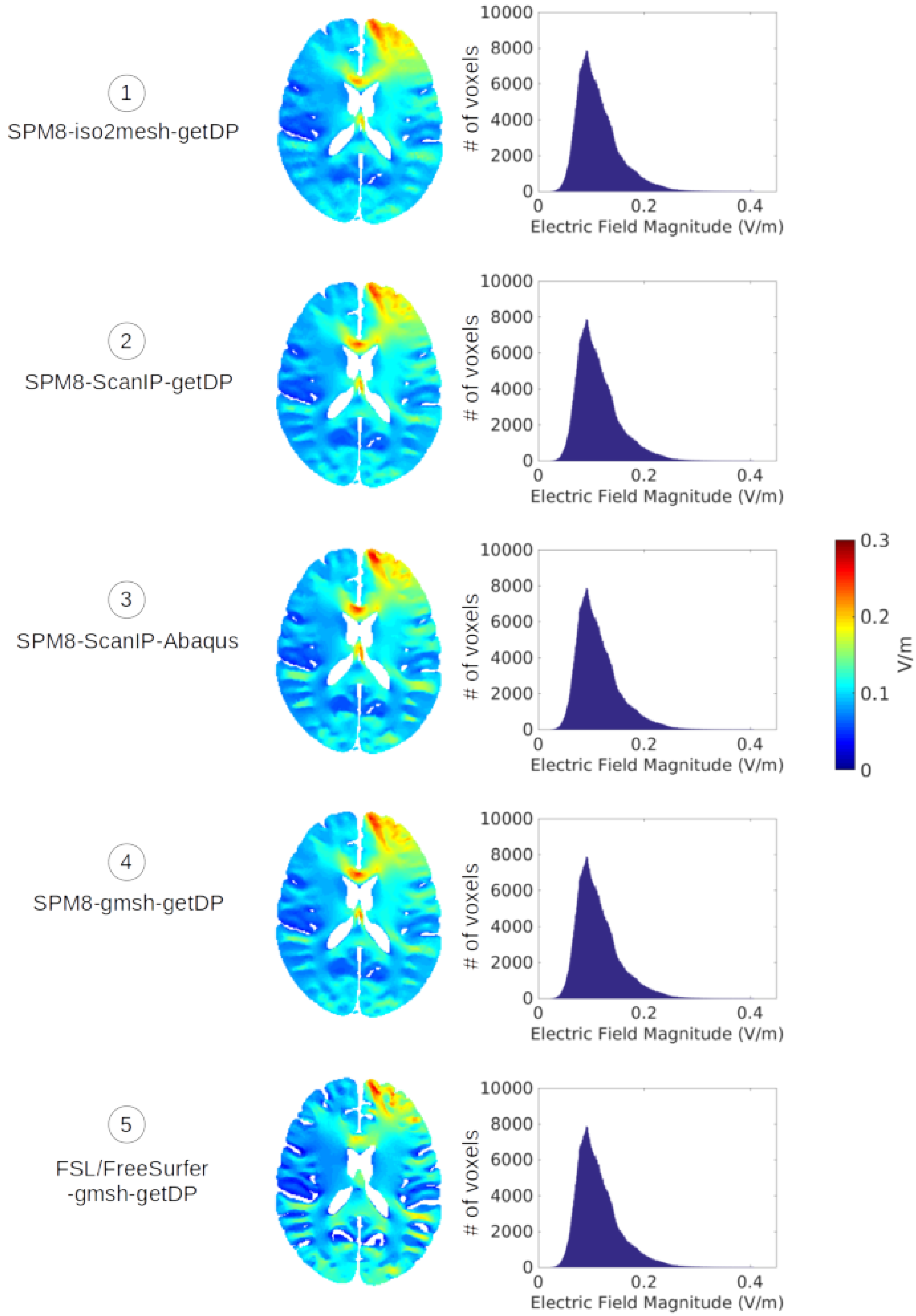
We put together the segmentation algorithm in SPM8 (Ashburner and Friston, 2005), our in-house Matlab script for segmentation touch-up and automatic electrode placement (Huang et al., 2013), the open-source finite element mesh generator iso2mesh (Fang and Boas, 2009) and solver getDP (Dular et al., 1998). The complete pipeline is a Realistic vOlumetric Approach to Simulate Transcranial electric stimulation and has therefore been named ROAST. We tested it on the MNI-152 standard head (Grabner et al., 2006) and compared the results with those obtained with a commercial mesher and solver (ScanIP and Abaqus), and with SimNIBS.

Results:

Figure 1 shows an axial brain slice of the electric field distribution from different modeling pipelines. Pipeline 1 is ROAST and Pipeline 5 is SimNIBS. It is evident that the relative distributions of electric fields are visually quite similar across different pipelines. The overall magnitude distribution of fields is also remarkably similar (histograms on the right column). The quantitative differences for the electric field distributions between these methods are shown in Figure 2. The title at each column indicates which two pipelines were compared. Relative differences in electric fields from using open source versus commercial meshers and solvers are an average of 20% (Figure 2A–D), with differences in the CSF shooting up over 100% when getDP is used instead of Abaqus (Figure 2B). This is expected as the CSF is a very thin layer with a high jump of conductivity from its neighboring tissues. Different solvers handle this discontinuity differently when computing the electric field from the solved voltages (Engwer et al., 2017). SimNIBS-generated segmentation gives higher deviations (average 67%, Figure 2E) in electric field compared to those from SPM8-generated segmentation.



·Figure 2: Difference in electric field distributions between the pipelines in Figure 1. GM: gray matter; WM: white matter; CSF: cerebrospinal fluid; BRAIN: gray and white matter; ALL: all the tissues.



·Figure 1: Example brain slices from the MNI152 head showing electric field distributions output by different modeling pipelines. Histograms of the electric field magnitude in the brain are also shown.

Conclusions:

This paper proposes a new pipeline for TES modeling, which we have termed ROAST. It is a fully automated simulator based on free software (except Matlab). Using the volumetric segmentation from SPM, it allows for a more realistic modeling of the anatomy and runs faster (15–30 minutes) compared to SimNIBS (10 hours). Also, as the dependent libraries are included in a single package (for Linux, Windows, and Mac), it is easy and straightforward to use (compared to other tools, e.g. SCIRun), without the need to install software (other than Matlab). It only gives a 9% difference in predicted electric field distribution in the brain when compared to commercial FEM software. The difference is higher (47%) in the brain when comparing with SimNIBS, mainly because SimNIBS builds the model based on the surface segmentation of the MRI, as opposed to the volumetric segmentation generated by SPM. Further work is needed to validate which pipeline gives more accurate models using direct measurement of *in vivo* electric fields in the brain (Huang et al., 2017). Nonetheless, we release ROAST now at https://www.parralab.org/roast/

Brain Stimulation Methods:

Non-invasive Electrical/tDCS/tACS/tRNS [2]

TDCS

Imaging Methods:

Anatomical MRI

Informatics:

Workflows [1]

Modeling and Analysis Methods:

Other Methods

Keywords:

Computing
Data analysis
Modeling
Segmentation
STRUCTURAL MRI
Workflows

[1|2]Indicates the priority used for review

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Please indicate which methods were used in your research:

Structural MRI
Computational modeling

For human MRI, what field strength scanner do you use?

1.5T

Which processing packages did you use for your study?

SPM
FSL
Free Surfer
Other, Please list - iso2mesh, getDP, gmsh

Provide references using author date format

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