INTERACTIVE MESHING AND SIMULATION OF DEEP BRAIN STIMULATION WITH PATIENT SPECIFIC MODELS

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INTRODUCTION

Deep brain stimulation (DBS) is an effective therapy for movement disorders such as Essential Tremor and Parkinson's disease and is a potential therapy for several other disorders. DBS is becoming more complex: novel lead designs are being introduced with directional electrode contacts, and in some cases multiple leads are being implanted in close proximity in a single subject[1]. Finite element bioelectric field models have been used successfully to predict the effects of DBS[2], but until now these have been time-consuming and computationally costly to generate. We have developed Virtual DBS: an interactive system to simulate and visualize the effects of DBS in patient specific models for arbitrary electrode geometries and configurations of anodes and cathodes.

OBJECTIVES

1. Develop an efficient processing pipeline combining multiple imaging modalities to build interactive patient-specific models.
2. Simulation of DBS in near real-time with one or multiple leads to explore the effect of stimulation in the patient's brain.

METHODS

Patient Specific Model: Virtual DBS uses an image processing pipeline that has been developed to incorporate structural T1 MRI and diffusion weighted imaging (DWI). The T1 MRI is first processed by FreeSurfer which provided segmentations of the brain surface, ventricles, and thalamus. The DWI data is used to reconstruct diffusion tensors (DTI) and is used as an estimate of anisotropic brain tissue conductivity. White matter nulled MRI sequences are used to gain increased contrast in grey matter nuclei such as the thalamus for patient-specific segmentations.

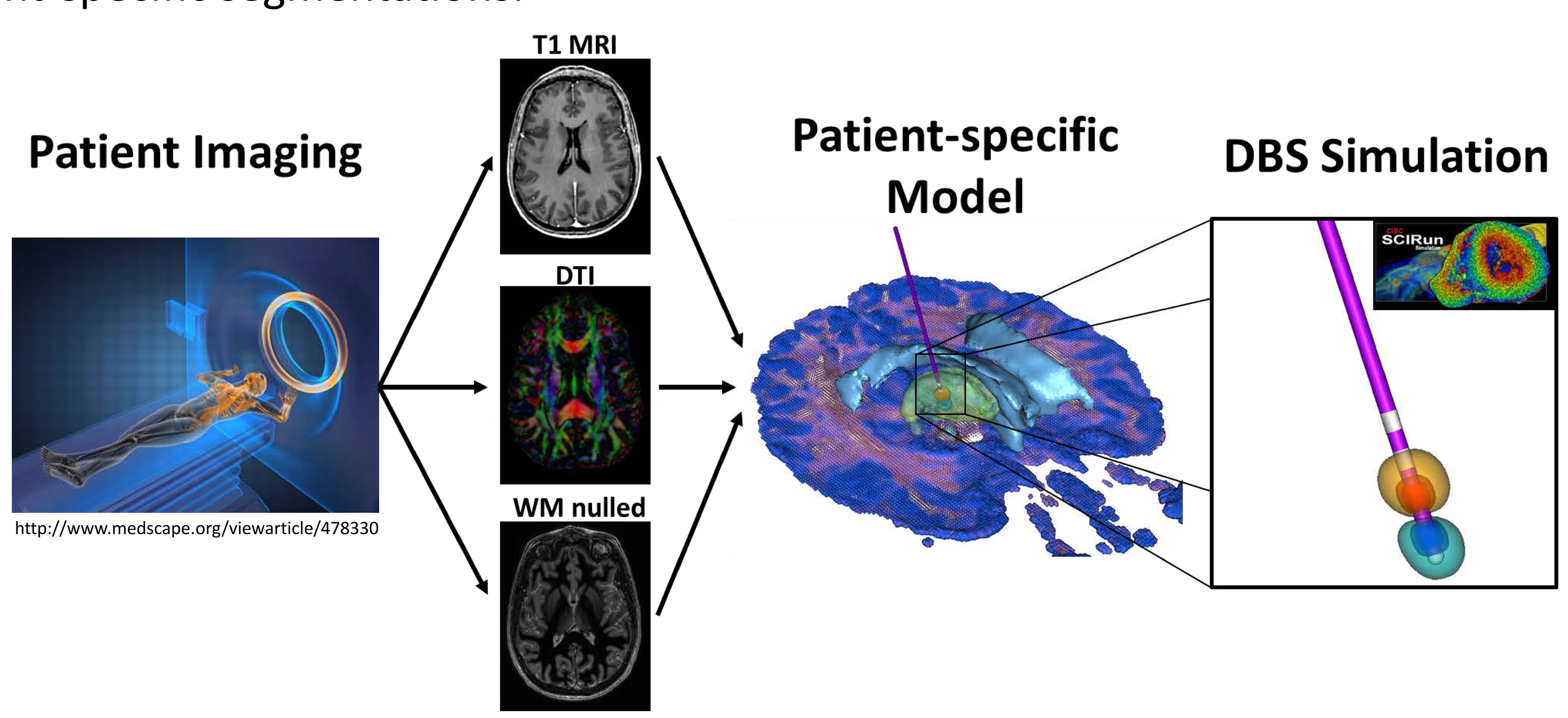


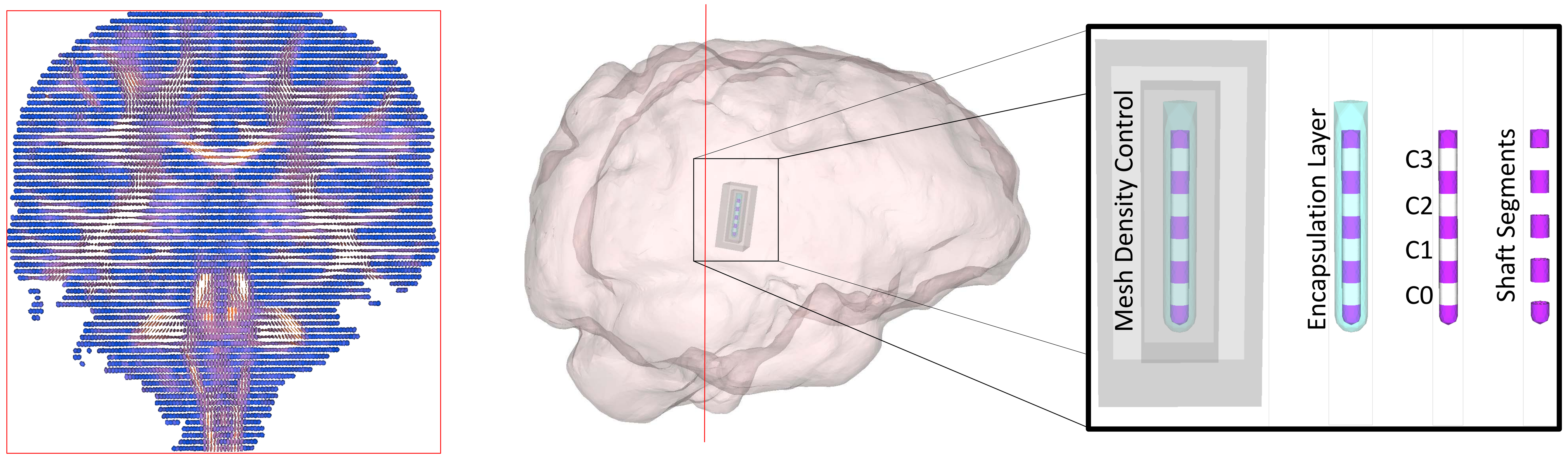
Figure 1. An outline of the image processing pipeline and integration with bioelectric field simulations of DBS.

Interactive DBS Simulation: The segmentation of the brain surface and Medtronic 3387 DBS lead geometry are used to create a finite element model (FEM) used to solve the bioelectric field induced by stimulation from any of the DBS contacts. The lead geometry consists of a surface mesh representation for each of the individual components: the contacts, the shaft, and the encapsulation layer. The interactive, 3-D environment allows the user to move and rotate the DBS lead anywhere in patient space. Multiple DBS leads can be placed inside of the patient model and boundary conditions are applied to simulate anodes and cathodes at any contact. Changing the lead position or trajectory triggers the generation of a new finite element mesh and solution of the bioelectric field problem. Active contacts and stimulation strength can also be adjusted, increasing the parameter space that can be explored with this tool.

RESULTS

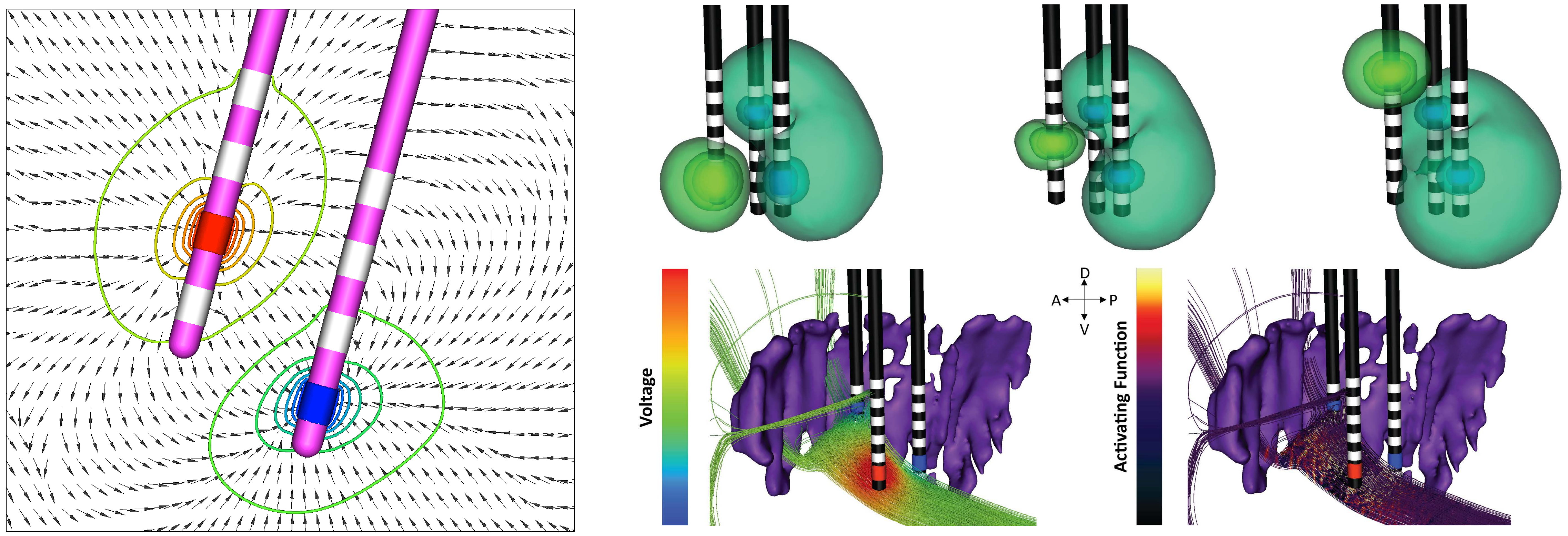
Finite Element Model

Diffusion Tensor (DTI) Slice | **DTI Slice** | **Surface Mesh Electrode**



Segmentation and anisotropic conductivity of the patient's brain provide accurate modeling of DBS. Use of surface mesh representations of the electrodes allow flexibility in rapid testing of different geometries and allow addition of multiple electrodes.

Multiple Electrodes and Current Steering/Electric Field Shaping Abilities



Use of multiple electrodes with independent anodes and cathodes allows for new configurations of bipolar and tripolar electric fields. Adjusting active contact locations and stimulation amplitudes is used to shape the electric field induced by DBS in ways that are not possible with a single electrode.

CONCLUSIONS

We anticipate that this simulation tool will enable interactive exploration of DBS effects within and among subjects. Further, we anticipate that a combination of modeling and postoperative clinical analysis will elucidate the mechanisms of DBS in ways that were not previously possible.

REFERENCES

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