Simulation and Visualization Tool for Subject-specific Transcranial Focused Ultrasound Neuronavigation

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To provide an open-source, user-friendly MATLAB-based application for simulation and planning of transcranial Focused Ultrasound (tFUS) human studies as well as real-time tFUS neuronavigation.

We use mSOUND, a fast angular spectrum method that models nonlinear ultrasound propagation in heterogeneous media (e.g., skull). The pipeline consists of 1) generation of a pseudo-CT image from a T1w-MRI image; 2) computation of tFUS acoustic beams of the transducer at hundreds of locations on the scalp; 3) a tool for visualization of the beams at the modeled transducer locations, and 4) real-time neuronavigation for visualization of the tFUS beam when moving the transducer.

Pre-processing steps 1) and 2) take ~12 hours for simulation of a 650kHz focused transducer at ~1000 locations on the subject' scalp with mSOUND. For each beam solution, 3D rendered surfaces of the intensity distribution are saved, along with the average acoustic energy deposition for various deep brain nuclei, evaluated using FreeSurfer. These data are accessed for rapid visualization of different beam solutions for tFUS planning (step 3) and real-time neuronavigation (step 4). Using a navigation system with optical tracking, TMS Navigator (Localite, Germany), an overall frame rate of 2 Hz for MATLAB-based beam calculations and visualization was achieved.

The proposed tool allows subject-specific, simulation-based planning and real-time visualization of the acoustic beam created by curved ultrasound transducers at hundreds of locations on the scalp. We are currently evaluating the impact of skull-induced beam deformations on tFUS navigation compared to line of sight targeting approach.

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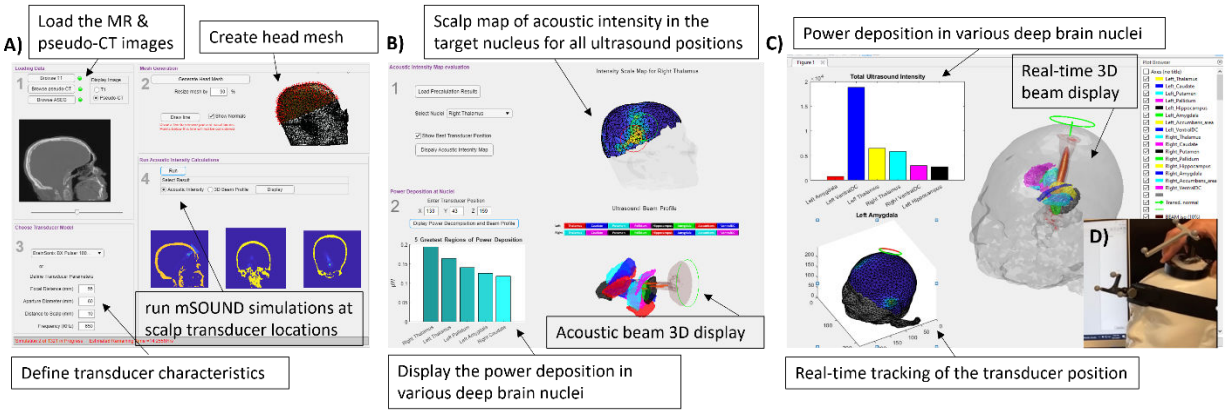

Figure1. A) Pre-processing GUI (step 2). B) tFUS visit planning GUI (step 3). C) real-time acoustic beam display engine integrated with the Localite navigation system (D, step 4).