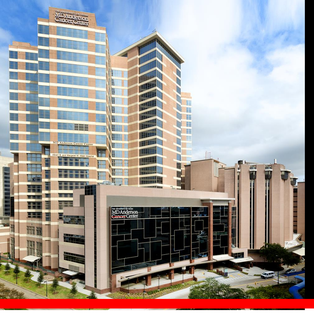

MRI-Based Therapy Guidance for Ultrasound Neuromodulation

Marie Gerges[1], Wayne Goodman[2], Junqian Xu[3], Xuefeng Zhang[2], Joo-won Kim[3], Richard Bouchard[1]

[1]Dept. of Imaging Physics, The University of Texas MD Anderson Cancer Center, Houston, TX

[2]Dept. of Psychiatry and Behavioral Sciences, Baylor College of Medicine, Houston, TX

[3]Dept. of Radiology, Baylor College of Medicine, Houston, TX

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Background

- Focused ultrasound (FUS) refers to ultrasound that is focused via a transducer, lens, or phased array.
- The pressure induced by FUS is highest at the focus and minimal elsewhere, so tissue outside the focus is not damaged during treatment.
- FUS offers a non-invasive way to treat small targets (mm in size) deep inside the body and brain.
- For example, the thalamus of the brain is targeted for FUS-based treatment of essential tremor and Parkinson's tremors.

Figure 1. Picture of subject wearing the FUS transducer utilized in our study (BrainSonix Sherman Oaks, CA). Source: http://www.brainsonix.com/technology/

- MRI-guided FUS allows researchers to identify a specific target in the brain and monitor brain function during treatment.
- Recently, researchers have begun to investigate MRI-guided FUS as a tool for neuromodulation, the enhancement or suppression of neural activity.
- However, factors such as the variable thickness of the skull at different points on the head, as well as differences in skull thickness among different people, present a challenge in predicting the location of the ultrasound focus.
- Here, linear acoustic modeling was used to simulate the acoustic field distribution and ultrasound focus generated by the transducer.

Objectives

We aimed to calculate the position and orientation of an ultrasound focus for a given position and orientation of the transducer, as well as assess whether the transducer would be able to transmit ultrasound through the skull at a given point.

Methods

- Collect MRI data for the following:
  - Multiple subjects wearing transducer
  - Transducer alone
  - Subjects with fiducial (small object used as a reference point) on side of head

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- Import MRI data into MATLAB
- Fit surface to skull, calculate normal vectors at surface

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- Use linear static analysis to calculate location of ultrasound focus
- Translate and rotate focus for different positions of transducer
- Assess curvature of skull based on normal vectors

Results

MRI data was collected with the Siemens MAGNETOM Prisma MRI machine at 3T.

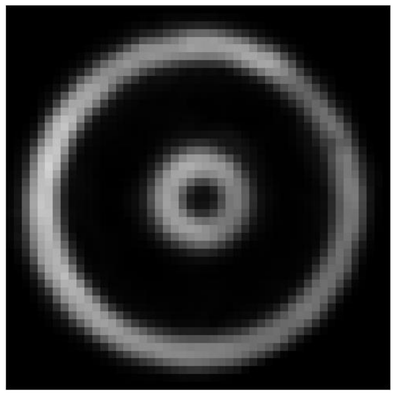

Figure 2. Cross section of transducer imaged with MRI.

- The MRI data were analyzed in MATLAB.
- The MRI image was processed to show only the surface of the subject's head.
- This full head surface was cropped to show only the part of the surface where the transducer would be placed.

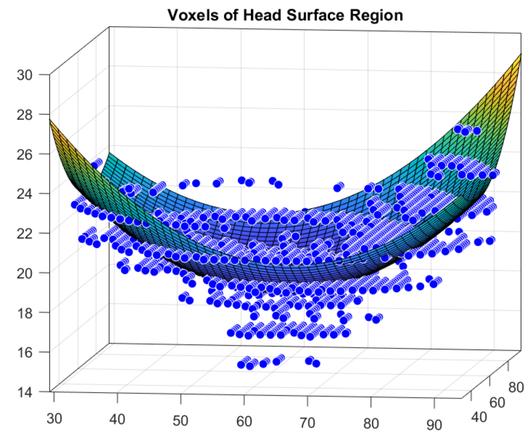

Figure 3. Polynomial fit of subsection of skull data. The blue points represent the voxels of the image. The continuous surface is the equation of best fit.

- The fit was calculated for a head surface with a fiducial (small vitamin pill) attached to the head as a placeholder for the transducer.
- Thus, it was necessary to remove the voxels representing the fiducial.

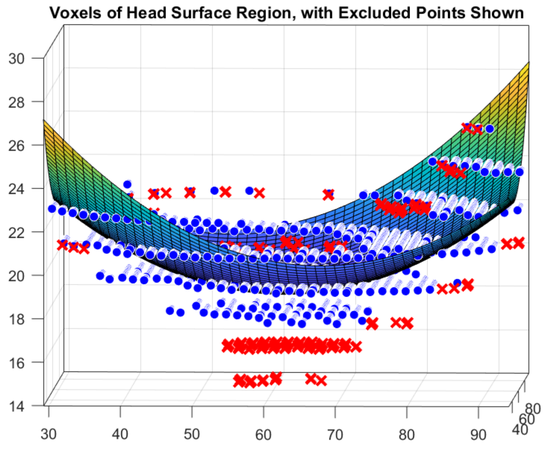

Figure 4. Points with a residual greater than 2 were excluded (indicated by red X's). The bottom two rows of points were excluded because they were part of the fiducial, rather than the head surface. Exclusion of these points confined the surface fit to only the voxels of the head surface.

Normal vectors of the surface were calculated using MATLAB's "surfnorm" function.

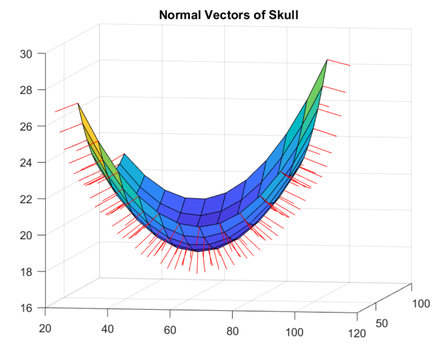

Figure 5. Normal vectors at different points on the surface fit.

Linear acoustic modeling was used to determine the distribution of the ultrasound beam.

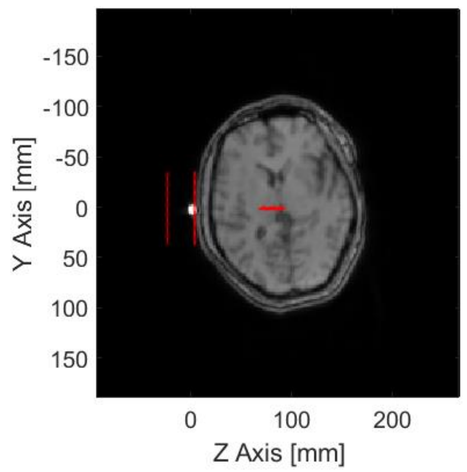

Figure 6. Simulated location and shape of ultrasound beam for the transducer aligned at a given position.

Conclusions

- Calculating the location of the ultrasound beam in the individual's brain is an important first step in using FUS for neuromodulation.
- Future work will determine the accuracy of our model in calculating the location of the ultrasound focus through comparison with experimental values.

Acknowledgments

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