3D Acoustic Simulation and Optimization Algorithms for Transcranial Focused Ultrasound Delivered With Robotic Systems

SOFT026

Systems Software

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Neurodegenerative diseases, such as Alzheimer's disease, are one of the leading causes of disability and death worldwide. Current pharmaceutical treatments are hindered by inefficient drug delivery methods to transport medication across the blood-brain barrier (BBB). Fortunately, focused ultrasound (FUS), a rapidly emerging noninvasive therapeutic device, can open the BBB by concentrating ultrasonic energy at a centralized location point in the brain. This increases the bioavailability of therapeutics for improved medical treatment and likelihood of patient survival. Although beneficial in clinical settings, FUS suffers from attenuation and distortion caused by the heterogeneous human skull, yielding a deviation between the focal point of FUS and its target. Finding the optimal FUS transducer for each patient and desired target for treatment is very challenging. In this project, I define this problem as constrained optimization and develop a novel iterative search algorithm to optimize a FUS transducer based on accurate 3D acoustic simulations of transcranial FUS propagation. From digital medical images, I present an automatic, universal framework to reconstruct high-fidelity acoustic and geometric properties of the skull and accurate 3D FUS simulations. Then, I design and develop a novel, graphics-processing-unit-accelerated iterative search algorithm to optimize a FUS transducer that outperforms the state-of-the-art, achieving a high accuracy and minimal error of 3.85 ± 1.37 mm and 3.56 ± 2.12 degrees. The novel modeling, simulation, and search algorithm are integrated into a surgical robot to establish an end-to-end framework for patient-specific FUS treatment, such as BBB opening for drug delivery and thermal ablation of cancerous tumors.

1. In this research project, the student directly handled, manipulated, or interacted with (check ALL that apply):

human participants	potentially hazardous biological agents		
vertebrate animals	microorganisms	rDNA	tissue

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3. This project is a continuation of previous research (Form 7):	YES	✘ NO
4. My display board includes non-published photographs/visual depictions of humans (other than myself):	YES	✘ NO
5. This abstract describes only procedures performed by me/us, reflects my/our own independent research, and represents one year's work only:	✘ YES	NO
6. I/we hereby certify that the abstract and responses to the above statements are correct and properly reflect my/our own work.	✘ YES	NO

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