3D imaging of brain blood flow using ultrasound

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Imaging blood flow in the brain is crucial to diagnose neurological disorders such as strokes and aneurysms, understand their root causes, and develop better treatments. No imaging method currently exists that can capture the dynamic, multi-scale nature of brain blood flow with sufficient detail, across all relevant patients, and in every possible setting. Using ultrasound waves, this project will create and validate a portable, 3D technology capable of imaging vessels as small as a few microns at a speed of thousands of frames per second. In doing so, the project will establish the first truly universal imaging modality for studying the human brain vasculature.

Neurological disorders are globally the most common cause of disability and second most common cause of death. These disorders are often associated with changes and impairments in brain blood flow, which makes imaging brain vessels crucial to both clinical diagnosis and scientific research. However, currently available tools, with magnetic resonance imaging (MRI) preeminent among them, are insufficient to universally interrogate the living brain: (1) the vasculature is inherently dynamic, but existing tools only capture static snapshots; (2) the brain vasculature spans scales ranging from centimetres to microns and velocities ranging from a few meters to less than one millimetre per second, but MRI lacks the resolution and sensitivity to capture this full spectrum; (3) MRI scanners are large, claustrophobic, and require that patients remain still, which prevents imaging patients continuously or while moving freely, as well as scanning people with movement disorders, claustrophobic, or obese.

Ultrasound is singularly positioned to address these issues, but the skull bone, a sound distorter, has prevented its transcranial application. This project will exploit advances that have already revolutionised imaging in geophysics, which we have recently used to prove that it is possible to image the brain structure through the skull, and will benefit from the recent construction in our lab of the first bespoke devices for 3D ultrasound brain imaging. At the same time, the project will incorporate recent advances in ultrasound contrast agents and super-resolution techniques inspired by Nobel-winning research in optical microscopy. Hinging on these disruptive advances, this project will combine signal processing, programming, and laboratory work to develop and validate, both experimentally and in human volunteers, a new ultrasound modality for brain blood flow imaging.

Goals of the project:

A) Develop methods for fabricating experimental models of the macro- and micro-vessels in the human brain using 3D-printing techniques.
B) Produce 3D images of experimental models of the brain vessels; this will include investigating the trade-offs of different acquisition sequences, designing experimental setups, acquiring and processing ultrasound data, and developing new imaging algorithms.
C) Generate the first ever 3D ultrasound image that maps blood flow across the whole brain in human volunteers.

The ideal candidate would have a degree in applied physics, engineering, or related fields, some experience in signal processing, and basic coding skills (Matlab, Python, etc.). It would be desirable for the candidate to have skills in computer-aided design and 3D printing, and previous laboratory experience.

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