Optimising Transcranial Focused Ultrasound Stimulation
An Open-Source tool for Precise Targeting

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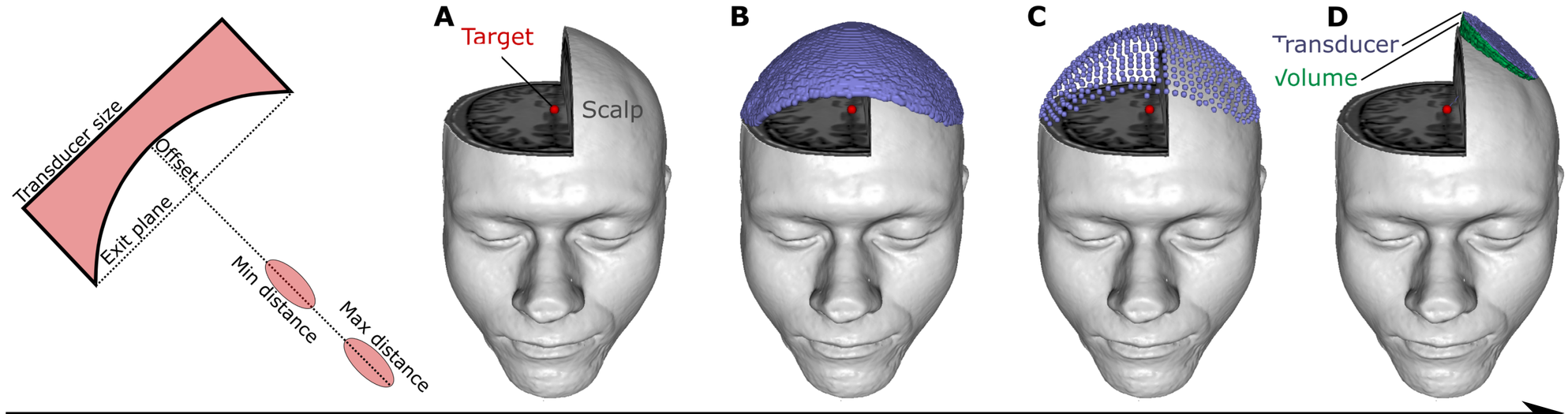
BACKGROUND

Low-Intensity transcranial focused ultrasound stimulation (TUS) is a recent and under-development non-invasive neuromodulation technique. Its unique capability to safely penetrate deep targets with notable spatial accuracy underscores its significance.
However, this spatial accuracy also implies careful preparation to deliver the right energy to the selected target. Two aspects have to be considered to successfully perform TUS:

1. The skull density, which absorbs a large part of the acoustic power and requires therefore to adapt the TUS parameters. This aspect is already considered through the development of acoustic simulation software.
2. The angle between the scalp and the TUS transducer, since it could deviate the acoustic field. But no tool is available to address this point.

To consider the scalp-transducer requirement, we introduce here a novel open-source tool specifically designed for TUS studies. Its main objective is to determine, at an individual-level basis, the optimal transducer position over subjects' scalps.

PRINCIPLE



Step 1: Provide ultrasound transducer characteristics to fit with the different available devices.

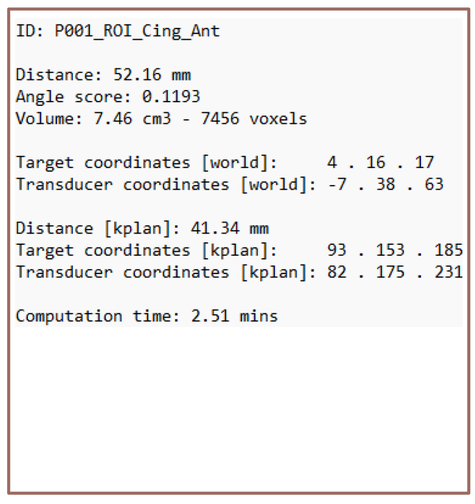
Step 2: Provide binary maps of the target and the participant's head.

Step 3: Selection based on the distance.

Step 4: Decrease resolution to save time.

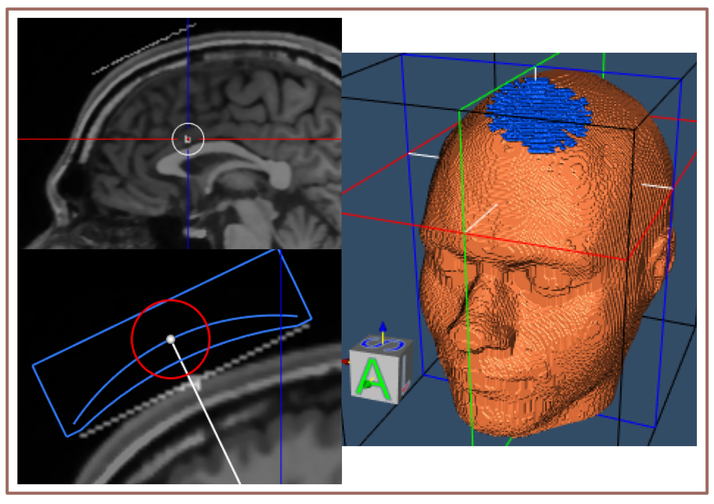
Step 5: Transducer-Head angle estimation.

OUTPUTS



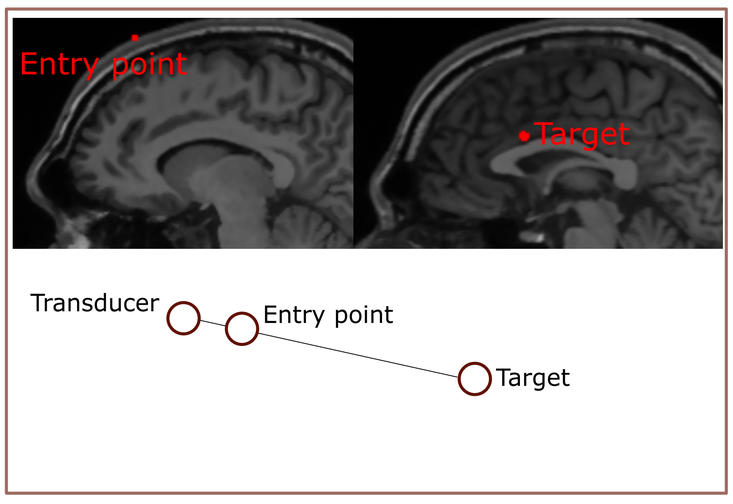
Report

Transducer-Target distance
Coordinates
Volume



K-plan

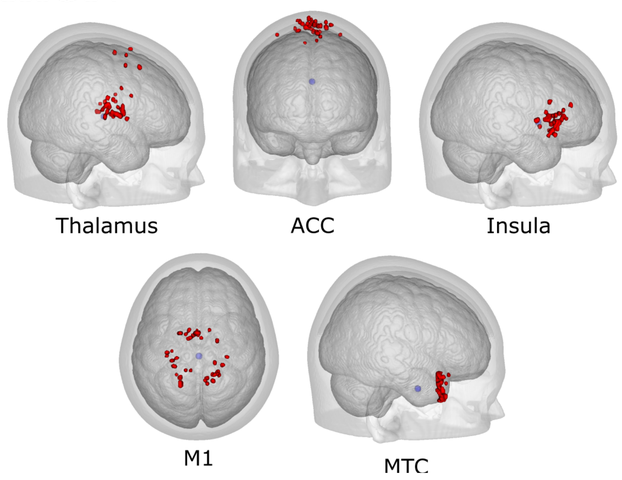
Nifti file with the target, entry point, trajectory and transducer.
Mostly to help in positionning all of them in K-plan

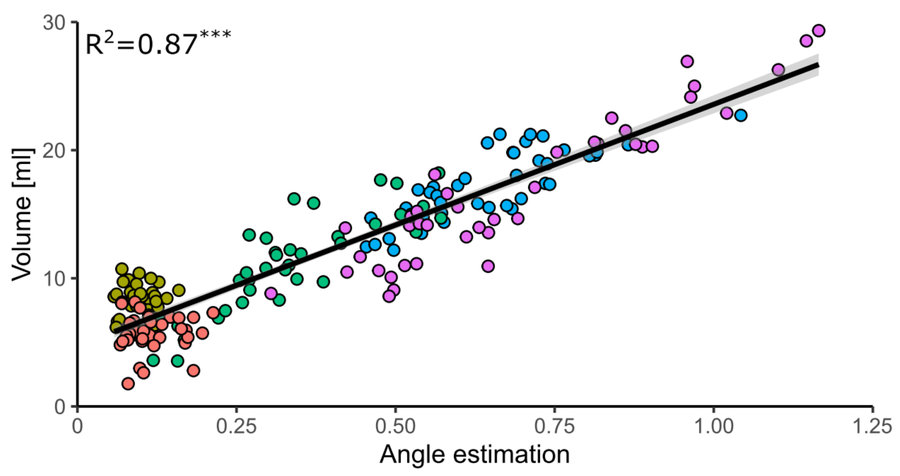


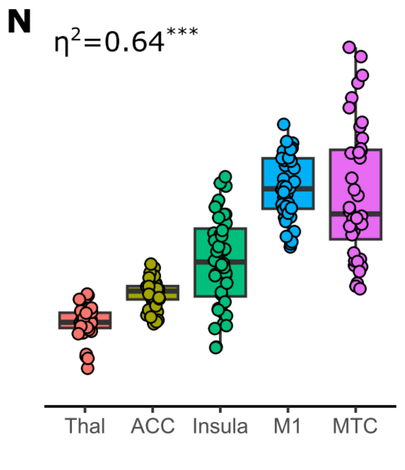
Neuronavigation

Nifti file with the target and entry point.
Mostly helpful for neuronavigation (requires to align the target and entry point)

VALIDATION







This code is commonly used for TUS research at the University of Nottingham, and showed its robustness on 40 healthy subjects, each for 5 different targets with different characteristics :

1. The right thalamus (deep); 2. The medial anterior cingulate cortex (ACC, in the optimal depth, medial and frequently targeted); 3. The right insula (on the side); 4. The medial primary motor cortex (M1, close to the surface); 5. The right middle temporal cortex (MTC, behind the ear).

The results showed:

1. A high inter-subject and inter-target spatial variability, highlighting the need to use an individual-based approach when selecting the best transducer position.
2. A high relation between the angle estimation (quick to estimate [<1sec/item]) and the real volume (longer to calculate [~7sec/item]) between the scalp and the transducer ($R2=0.869$, $p<0.0001$)

AVAILABILITY

Code: https://github.com/CyrilAtkinson/TUS_entry

Manuscript: Accepted in Neuromodulation: Technology at the Neural Interface