Abstracts

An Automated Pipeline for sEEG Electrode Localization

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Rationale:
Stereoelectroencephalography (sEEG) presents almost unprecedented opportunities to study in vivo brain function with a high signal-to-noise ratio. However, group analysis and correlation with anatomical and functional atlases requires localization of the implanted electrodes in common template space, such as Montreal Neurological Institute (MNI) space, which is highly labor intensive and may be subject to human error. In this context, we present a novel automated pipeline for rapid and precise sEEG localization.

Methods:
In our pipeline, electrode contacts are automatically marked in CT space and grouped into electrodes through an iterative algorithm as follows. The CT scan is thresholded at 2500 HU. Contiguous objects in 3D space are detected using the skimage Python package, and objects outside the skull or exceeding size and sphericity criteria are removed to exclude bolts and wires. Centroid coordinates are measured for each contact and clustered into trajectories. Our novel algorithm iteratively selects the remaining contact nearest to the brain's center, tentatively clusters all ungrouped contacts within 3 mm of a test line drawn from the selected contact, and establishes the trajectory with the most consistently spaced electrodes as a final electrode trajectory, repeating the process until no electrodes remain ungrouped. The patient-specific CT is coregistered with the preoperative MRI using FMRIB's Linear Image Registration Tool (FLIRT). The patient's MRI is then nonlinearly coregistered with the template MRI using FNIRT. Subsequently, electrode coordinates from CT space are warped into MNI template space using these transforms. To facilitate quality control, the subject CT scan is rendered superimposed on the template MRI (Figure 1) and 3D renders of the location of each identified electrode contact in CT space (Figure 2a) and MNI space (Figure 2b) are saved for review.

Results: Across a total of 2,020 intracranial contacts in a consecutive series of 17 patients, the pipeline correctly and automatically localized all electrodes to MNI template space. Six electrode trajectories were not directly identified due to metal artifacts. For these electrodes, locations were interpolated based on the first and last contact location and the number of contacts in that electrode as listed in the surgical record. The accuracy of final localizations was manually verified based on patient imaging review by two neurosurgeons.

Conclusions: We offer an automated pipeline for sEEG electrode localization in stereo that is efficient, interpretable, and highly accurate. The pipeline further provides electrode localizations in both CT space and MNI space for quality control review. This novel approach expedites the process of electrode localization, enhances precision, and streamlines integration of the resulting data for group analysis and functional network correlation, marking a significant contribution to the study of brain function through sEEG.

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