A Novel End-to-End Deep Learning Pipeline for Stereotactic Cranial Surgery Planning

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Cancer and cranial diseases are the second leading cause of death worldwide. Early diagnosis and well-guided medical care as well as accurate analysis are essential to improve patient life expectancy and quality. We propose the first end-to-end deep learning pipeline for calculating cranial surgery risk factors to plan with minimal neurological damage. The proposed system is able to plan minimally invasive cranial surgeries using MRI scans of the patient and consists of a new scalable state-of-the-art (+3.2% mean dice score) UNet variant based on depthwise separable convolutions for brain tumor segmentation; a new state-of-the-art (+2.1% accuracy) transformer-based architecture for white matter tractography; a new state-of-the-art (+3.6% mean dice score) anatomical brain segmentation architecture orders of magnitude faster, smaller than the existing models which is trained with a new semi-supervised training approach based on contrastive learning; a state-of-the-art tumor classification model (+4.3% accuracy) trained with a new data augmentation pipeline designed specifically for medical imaging modalities, and a novel ML algorithm that learns the importance of each region in the brain for planning the surgery with the outputs of these models. The performance of the system is validated by a retrospective clinical study. It is shown to be able to detect the tracts to be damaged during surgery with 96.12% accuracy. The system can plan surgery for a case in less than a minute on modern accelerators. We have also developed compact desktop and augmented reality applications that can be used in well-equipped medical centers as well as rural hospitals.

Awards Won:

First Award of $5,000

Dudley R. Herschbach SIYSS Award