AIRA: A Patient-Specific, Risk-Weighted Surgical Path Planning and Preclinical Robotic Execution Framework for Maximal Safe Glioma Resection

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Gliomas remain the deadliest form of brain cancer, with patients surviving one year post-diagnosis on average, 5-year survival rates as low as 5%, and no major treatment advances in the past 50 years. While resection remains the gold standard, it relies on complex multimodal MRI integration and intensive pre-operative planning, making it difficult to fully account for patient-specific anatomy and intraoperative brain shift. Thus, balancing maximal tumor resection while preserving critical regions remains a significant challenge, leading to high recurrence rates and neurological deficits. This project aims to improve resection outcomes through an objective, patient-specific, brain shift-aware neurosurgical execution platform: Automated Intelligent Resection Assistant (AIRA). AIRA processes 6 MRI modalities through a self-developed deep learning architecture, producing maps of tumor, eloquent cortex, vasculature, and white matter tracts. These maps are processed through a custom cost function, assigning surgical risk values across the brain. Dijkstra's algorithm computes the safest resection route, optimizing tumor removal while preserving healthy tissue. To account for brain shift, a cost function utilizing the fence-post technique was developed, using catheter movement to update surgical routes intraoperatively. Evaluating 100 autonomously generated resection paths across 25 patients, the mean per-voxel risk was 0.21 ± 0.07 (vs. 0.74 from random paths; risk range = [0 1]), demonstrating consistent avoidance of high-risk tissue. For further validation, a 6-DOF robotic arm was developed and tested on these paths, with minimal path deviation. By quantifying surgical risk and accounting for brain shift, AIRA has the potential to automate the maximal resection of gliomas.

Awards Won:
Second Award of $2,400