DEPARTMENT OF BIOENGINEERING
PH.D. DISSERTATION DEFENSE

Trishia El Chemaly

Towards Perception-Aware Augmented Reality for Microsurgical Guidance

ADVISORS: BRIAN HARGREAVES & NIKOLAS BLEVINS | APRIL 10, 2026 - 4:00 PM | ALLENX 101X

Microsurgical procedures in the temporal bone and lateral skull base are performed within highly confined anatomical spaces under limited visual and haptic feedback. Surgical guidance often relies on preoperative CT scans, requiring surgeons to mentally register 2D multiplanar images with the live microscopic view to localize target structures. Augmented reality (AR) has the potential to improve surgical guidance by overlaying preoperative imaging directly onto the operative field. However, achieving perceptually meaningful visualization under a surgical microscope remains challenging. Limitations in calibration accuracy, interaction modalities, occlusion handling, and depth perception can reduce the effectiveness and usability of AR systems, creating barriers to clinical translation.

In this thesis, I develop a set of methods and systems to enable perception-aware AR guidance for microsurgery. First, I present techniques for high-precision calibration and tracking workflows utilizing both electromagnetic and optical systems to establish accurate spatial alignment between the physical anatomy and virtual models. Second, I explore hand-tracking methods that allow surgeons to control AR systems without disrupting surgical workflow, supporting both sterile and intuitive interaction. Third, I introduce a perception-first digital twin framework that continuously integrates a tracked surgical state with virtual anatomical models to drive depth-, occlusion-, and proximity-aware AR visualization. Finally, I evaluate how different AR visualization strategies influence depth perception in microscope-based tasks. Collectively, this work establishes computational and interaction frameworks that enable more accurate and perceptually grounded AR systems for microsurgical guidance.