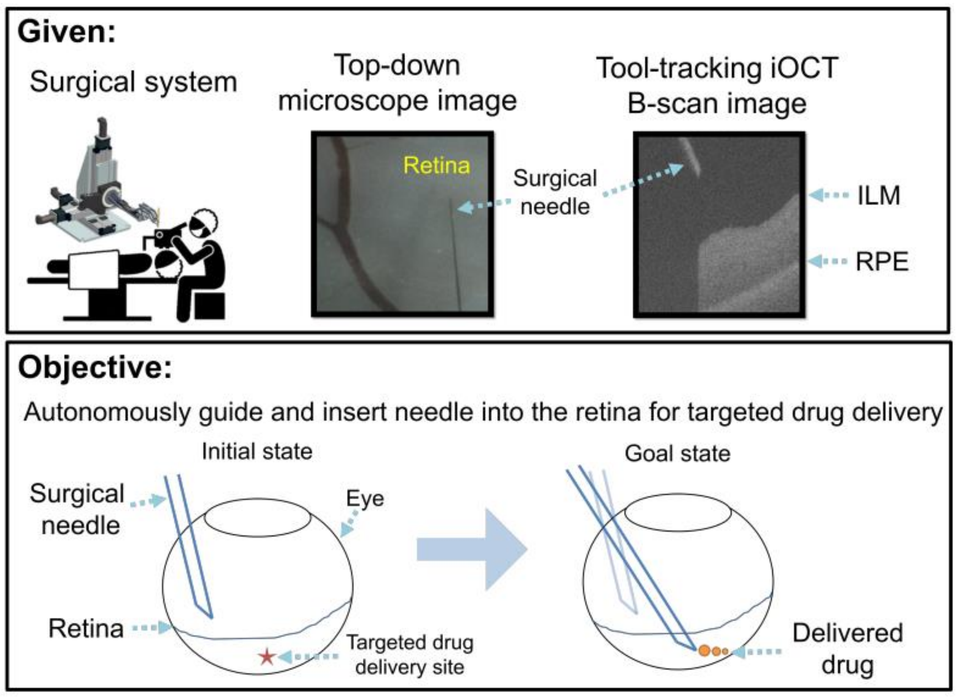
Towards Task Autonomy in Robotic Retinal Surgery using RGB-D images

Ji Woong Kim*, Shuwen Wei*, Peiyao Zhang*,
Peter Gehlbach, Jin U. Kang, Iulian Iordachita, Marin Kobilarov
* Denotes equal contribution

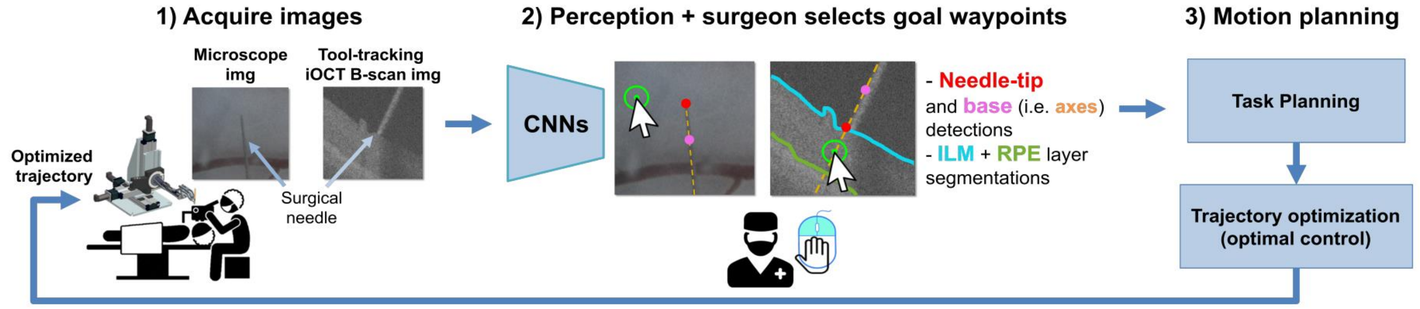
Johns Hopkins Whiting School of Engineering
Wilmer Eye Institute, Johns Hopkins Medicine

Problem Statement

- How can we utilize RGB-D images (microscope & OCT) to enable task autonomy in robotic retinal surgery?
- We answer this question by developing an autonomous needle navigation procedure with precise insertion depth control

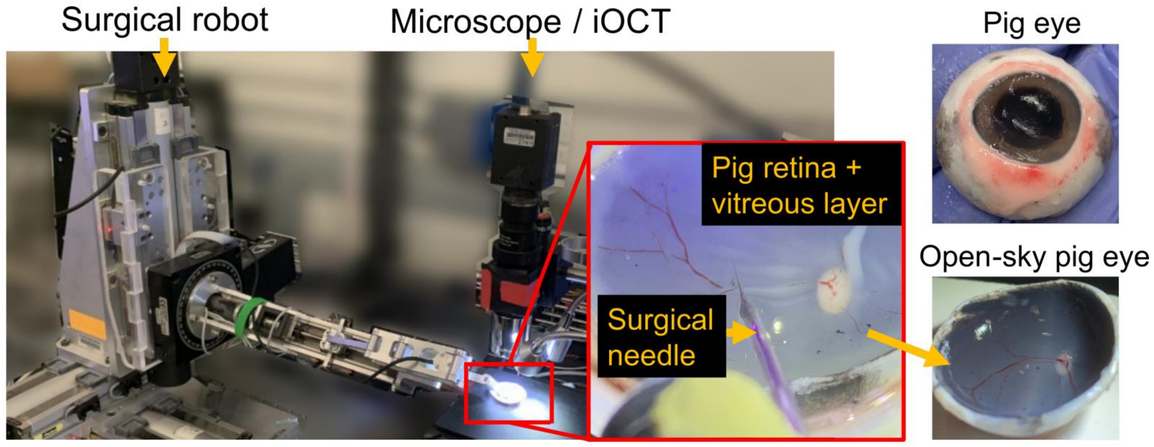


High-Level Approach



Our imaging system ensures that the depth scans are always aligned with the instrument axis, even during dynamic motion

Experimental Setup



Our 5-dof robot arm enables precise motion, while the custom OCT-integrated microscope provides real-time RGB-D view for global and local awareness of the surgical environment

Our Contributions

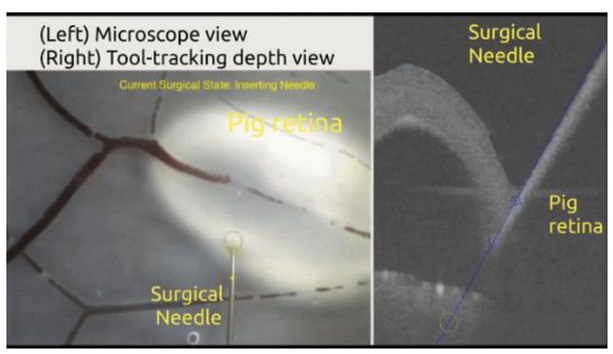
- We propose an intuitive workflow for real-time autonomous subretinal injection. The surgeon never touches the robot and simply commands waypoint goals via mouse-clicks in the RGB-D images.

- We combine RGB and depth images in real-time for dynamic applications. This is achieved by tracking the surgical instrument via a small OCT scanning region, enabling fast image acquisition. Otherwise OCT is too slow for real-time use.

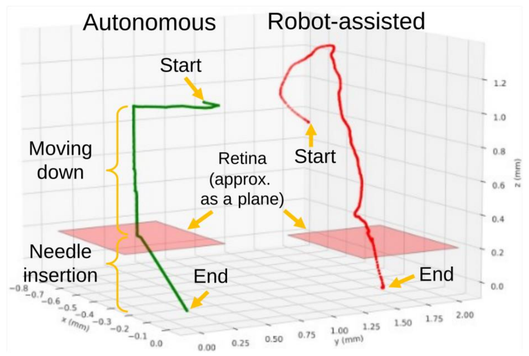
- Our system can be used in general applications for real-time RGB-D feedback in free-hand surgeries w/o the robot.

Results

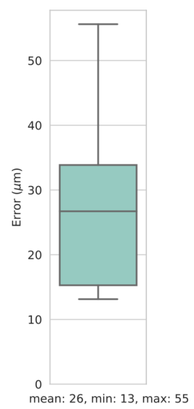
Successful injection example



Comparison to a human



Targeting accuracy



Total of 30 trials on pig eyes
Targeting accuracy: 26 ± 12μm
Total duration: 55 ± 10.8 s

Future work:
- closed pig eye experiments
- moving eye scenario
- challenging manipulation tasks