Bimanual teleoperation of Steady Hand Eye Robot with dVRK

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CIS 2 Presentation

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- Mentors:

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Background – Retinal Surgery

- In retinal microsurgery, surgeons are required to perform micron scale maneuvers
  - Vein cannulation: 60 micron needles in 100 micron veins
  - Surgeons need to feel force 7.5 mN in magnitude [2]
- Surgical performance is further challenged by [1]
  - thin and long surgical tools
  - physiological hand tremor
  - fatigue from prolonged operations

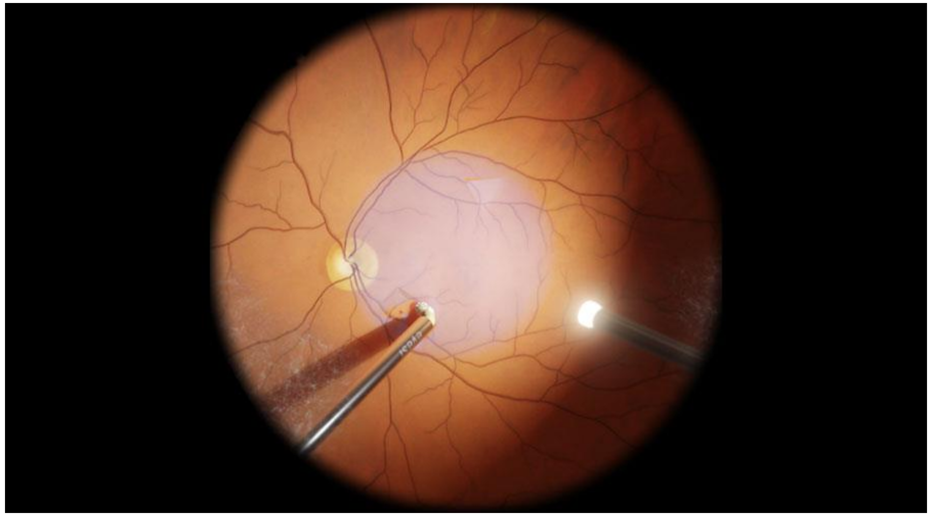
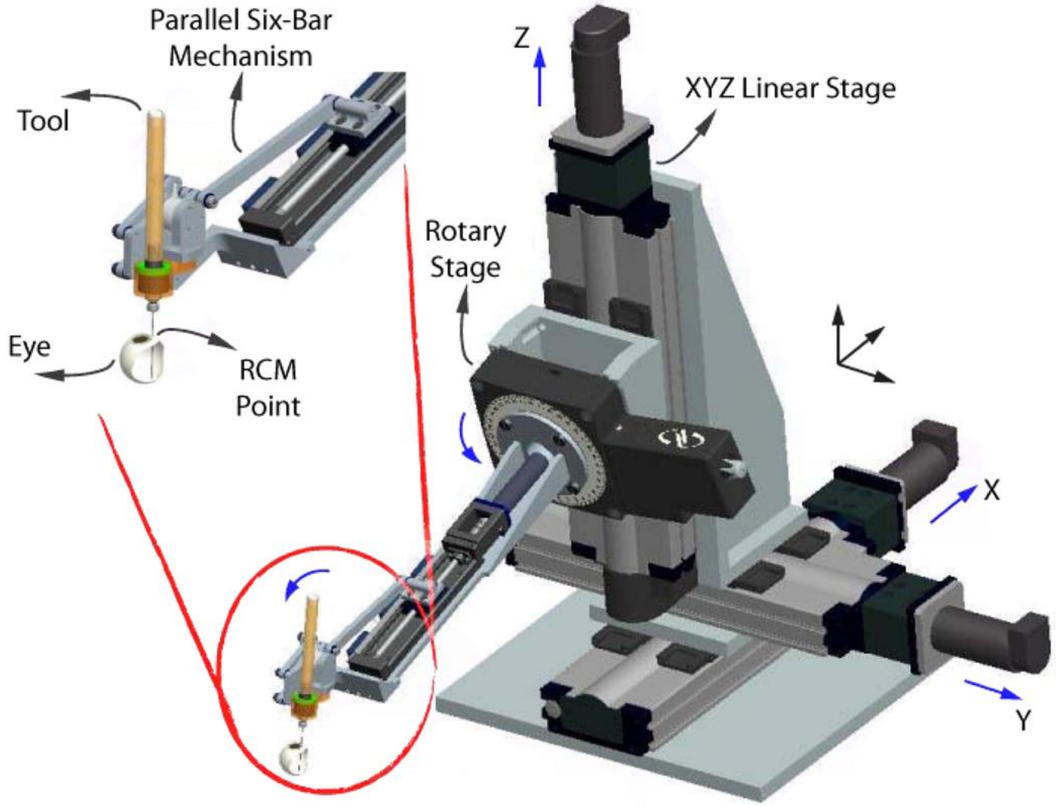


Illustration of retinal surgery
http://www.vrmagic.com/fileadmin/featuresite/eyesi30/ilm_peeling.jpg

Background – Steady-hand Eye Robot

- Technical Specifications
  - 5 DOF
  - admittance control
  - 0.25 mN resolution
  - repeatability of 3 µm, resolution of 1 µm
  - repeatability of 0.0001°, resolution of 0.0005°
- Disadvantages of SHER:
  - Inverted hand-eye coordination due to incision points
  - One-to-one motion scale
  - Non-transparent motion

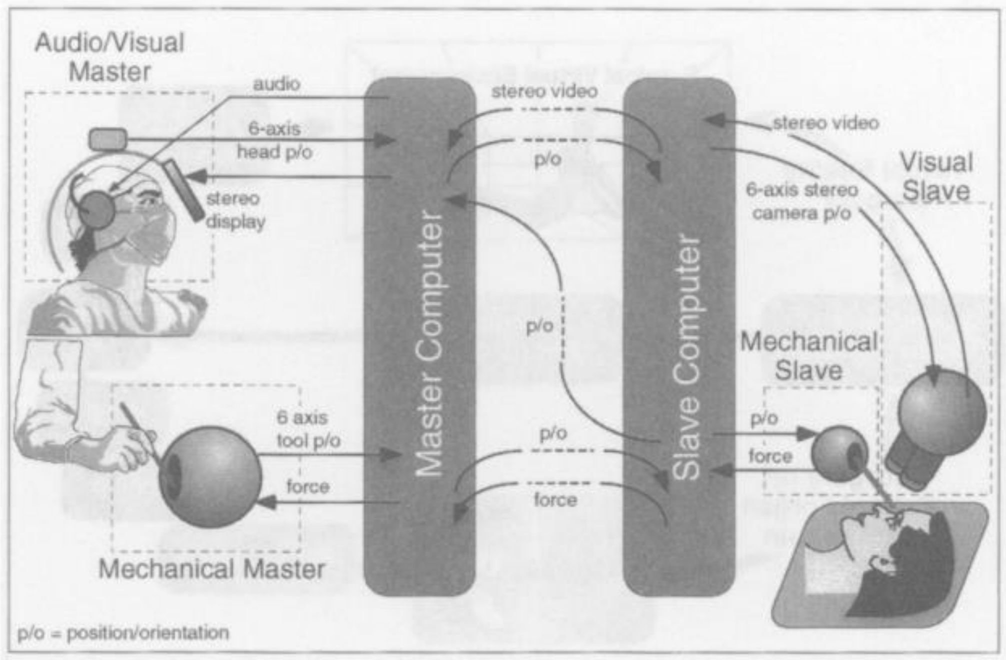


Background – da Vinci Research Kit

- An “open-source mechatronics” system, based on the first-generation da Vinci system.
  - 7 DOF
  - Master-slave teleoperation
  - Stereo display
  - Surgeon console to improve ergonomics
  - Two controllers

Background – Teleoperated Retinal Surgery

- First reported system design for teleoperated eye surgery [3]
- Other teleoperated eye surgeries have been reported [4][5]
- However, no bimanual teleoperation has been reported



Reported teleoperated eye surgery in 1993 [3]

Bimanual Teleoperated Retinal Surgery

- Advantages:
  - Improved ergonomics
  - Arbitrary motion scale
  - Surgeon can reorient the workspace as needed
  - Less disturbance to the delicate movement due to surgeon-patient separation
- Challenges of teleoperation:
  - two tools to manipulate eye ball
  - sensory feedback

Project Goal

- Implement a bimanually teleoperated system for retinal surgeries with dVRK, which improves the safety, precision and ergonomics of surgical procedures.

Deliverable

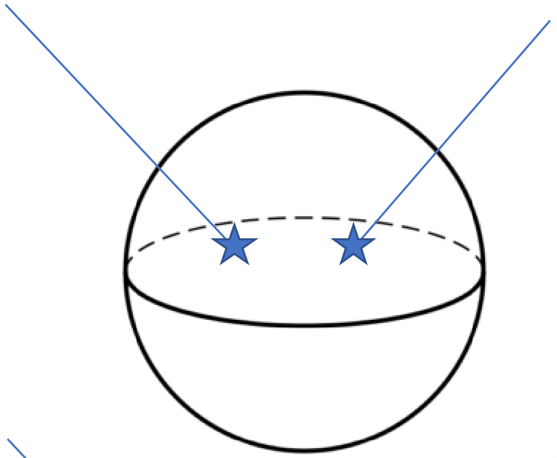
- Minimum:
  - Framework to bimanually teleoperate two SHERs with dVRK with stationary eye ball
- Expected:
  - Framework to bimanually teleoperate two SHERs with dVRK with complex motions allowed such as rotating and tilting eye ball motion
- Maximum:
  - User study result of comparison of bimanually teleoperated, hand-over-hand and manual operation modes with complex motions allowed such as rotating and tilting eye ball motion

Design Approach

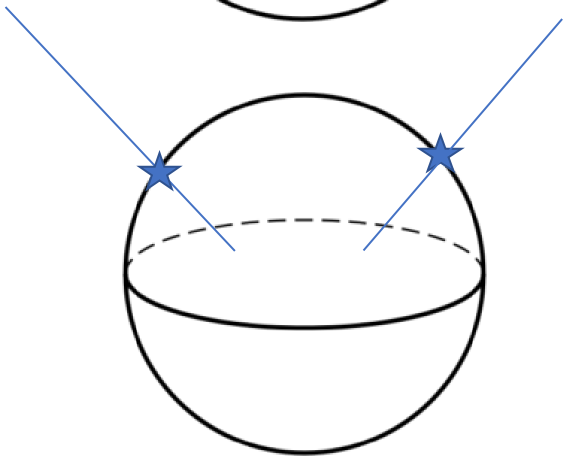
- Create ROS interfaces for the robots
- Prototype teleoperation logic, master/slave mid-level controller
- Implement other necessary components, including visual, audio feedback
- Test within the team and evaluate
- Iterate and improve
- Test with different users, potentially surgeons

System Design (Preliminary Concept)

- Surgical mode
  - Control point at tip
  - RCM constraint at insertion

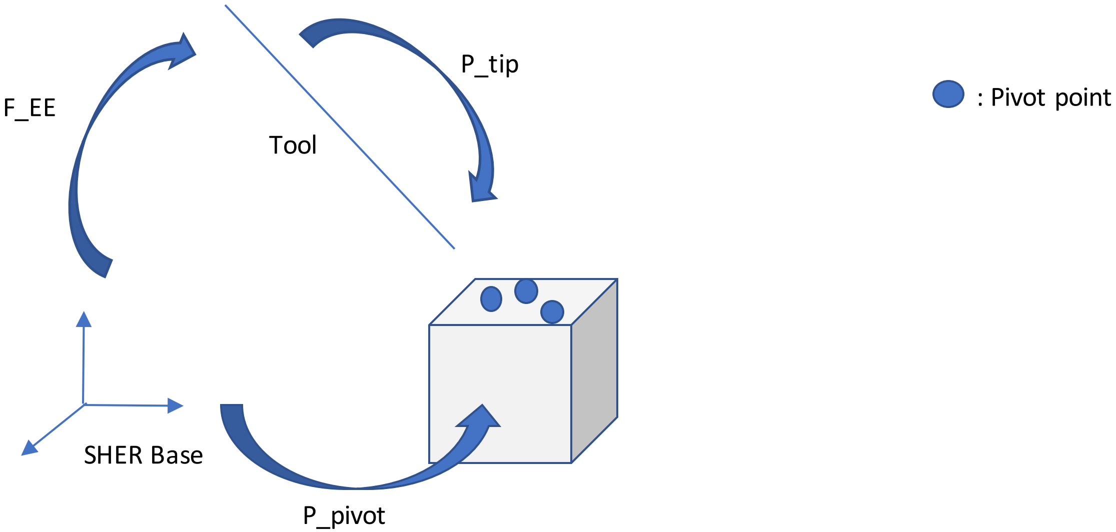


- Maneuver mode
  - Control point at insertion
  - Sphere constraint

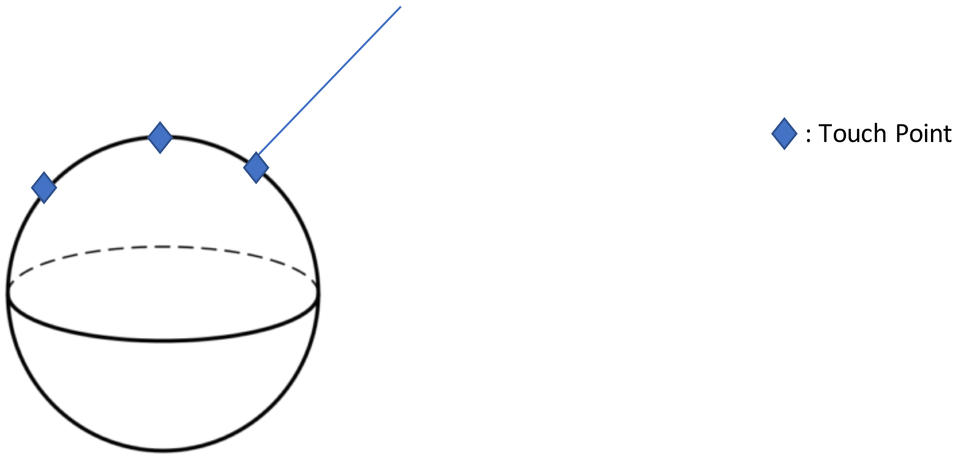


System Design (Preliminary Concept)

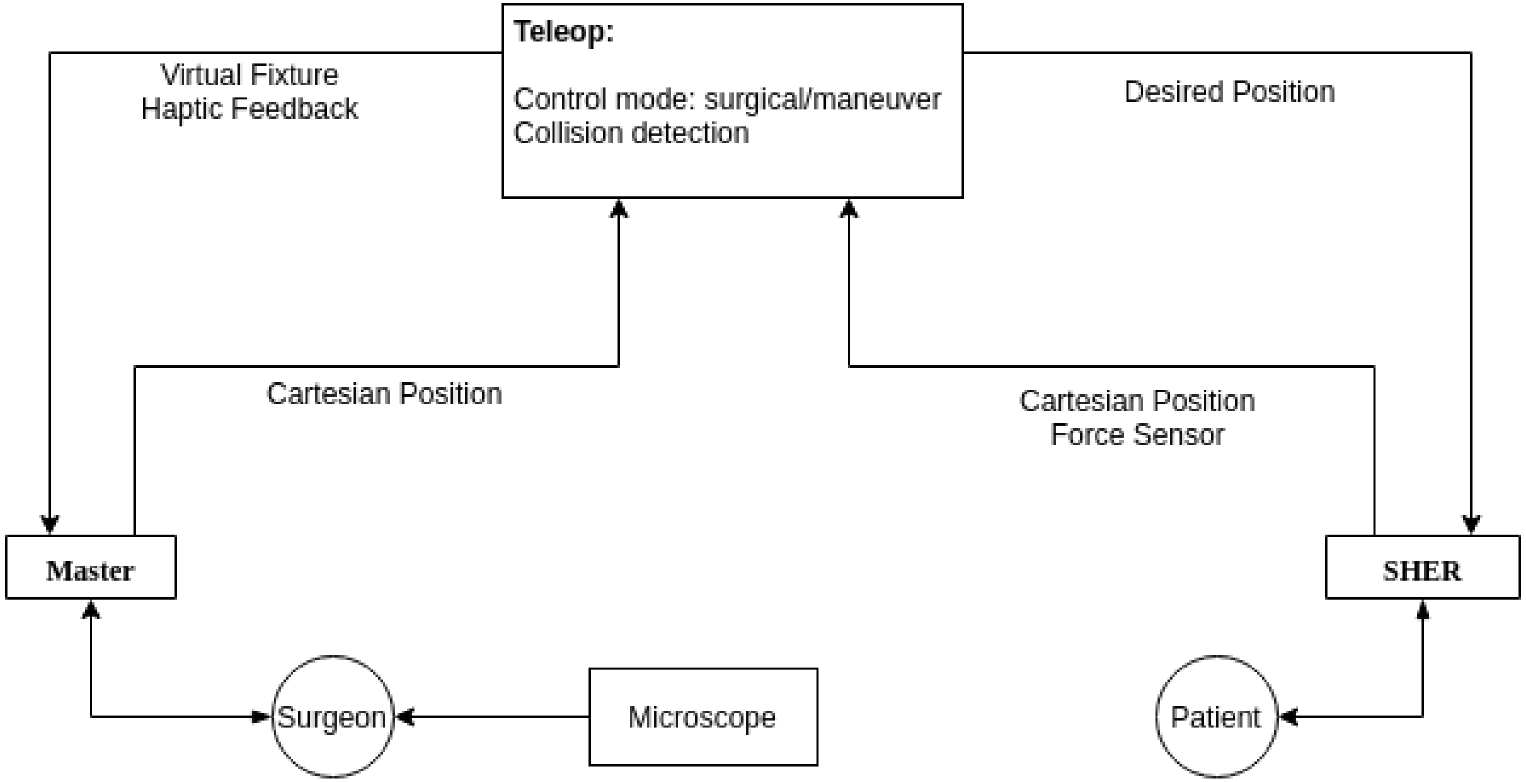
- SHER-SHER registration



- Eye-SHER registration



System Design (Preliminary Concept)



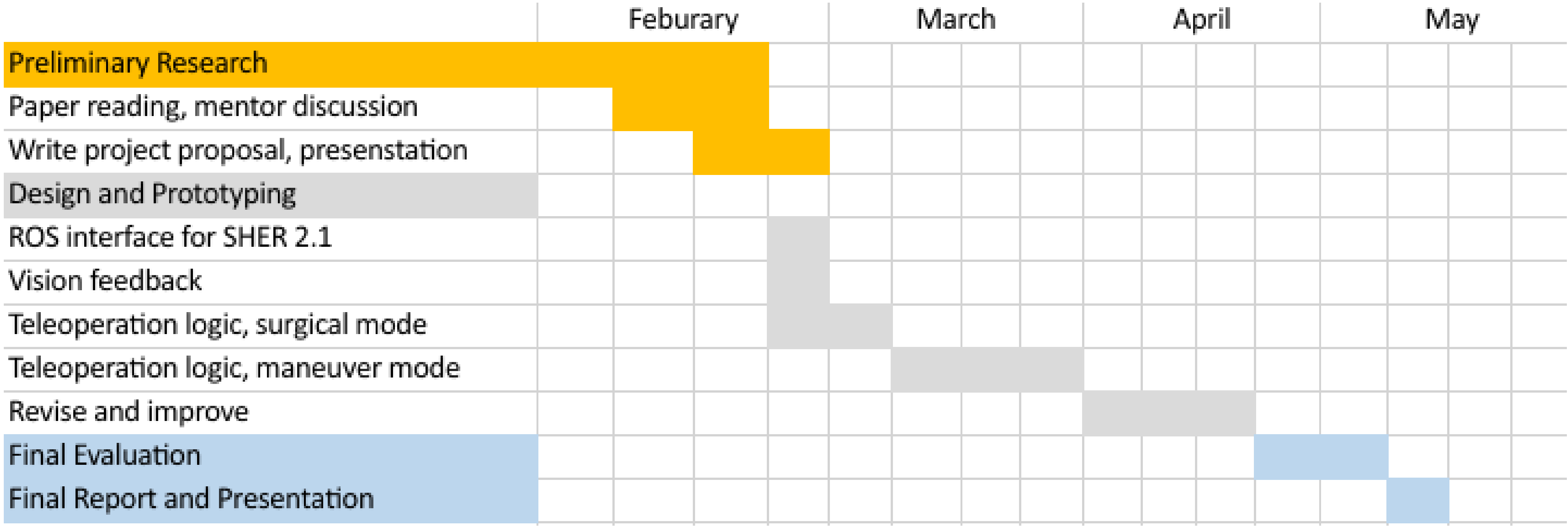
Management Plan

- Biweekly meetings with mentors
  - Time still needs to be worked out
- Meeting with Dr. Taylor and Dr. Iordachita as and when required
- Team meeting 1-2 times a week
  - Wednesday 6:30 pm onward
  - Saturday 5 pm if required

Responsibility distribution

- Since most of the project relies on coding, both team members can work together on different parts. But based on expertise and preference, the tasks were divided as follows.
- Max
  - ROS packages and dependencies for SHER robot, ensure compatibility with dVRK
  - Vision implementation
  - Sensor feedback
- Anurag
  - ROS packages for dVRK where needed, ensure compatibility with SHER robot.
  - Teleoperation logic
  - User study protocol

Timeline


Feburary
March
April
May
Preliminary Research
Paper reading, mentor discussion
Write project proposal, presenstation
Design and Prototyping
ROS interface for SHER 2.1
Vision feedback
Teleoperation logic, surgical mode
Teleoperation logic, maneuver mode
Revise and improve
Final Evaluation
Final Report and Presentation

Milestones

Accomplishment	Estimated Date	Status
Presentation	Feb 7th	We are presenting now!
Proposal	Feb 25th	Incomplete
ROS wrapper for SHER 2.1	Feb 28th	Incomplete
Bimanual teleoperation logic, surgery mode	March 13th	Incomplete
Bimanual teleoperation logic, maneuver mode	March 31st	Incomplete
Final Presentation	May	Incomplete

Dependencies

Dependency	Plan to resolve	Estimated resolution date
Access to SHER 2.1	Schedule with Dr. Patel	Resolved
Access to dVRK	Coordinate with dVRK users	Resolved
Shadowing an eye surgery	Coordinate with Dr. Patel	Feb
IRB protocol (potentially)	Coordinate with Dr. Taylor	March
Availability of students for evaluation	Coordinate with Dr. Patel and students in LCSR	April

References

[1] Üneri, Ali, et al. "New steady-hand eye robot with micro-force sensing for vitreoretinal surgery." *Biomedical Robotics and Biomechatronics (BioRob), 2010 3rd IEEE RAS and EMBS International Conference on*. IEEE, 2010.

[2] Gupta, Puneet K., Pahick S. Jensen, and Eugene de Juan. "Surgical forces and tactile perception during retinal microsurgery." *International Conference on Medical Image Computing and Computer-Assisted Intervention*. Springer, Berlin, Heidelberg, 1999.

[3] Hunter, Ian W., et al. "A teleoperated microsurgical robot and associated virtual environment for eye surgery." *Presence: Teleoperators & Virtual Environments* 2.4 (1993): 265-280.

[4] Gijbels, Andy, et al. "Design of a teleoperated robotic system for retinal surgery." *Robotics and Automation (ICRA), 2014 IEEE International Conference on*. IEEE, 2014.

[5] van den Bedem, Linda, et al. "Design of a minimally invasive surgical teleoperated master-slave system with haptic feedback." *Mechatronics and Automation, 2009. ICMA 2009. International Conference on*. IEEE, 2009.