Reading presentation. **Project #24**

Evaluation of Virtual Remote Center of Motion for Minimally Invasive Surgery

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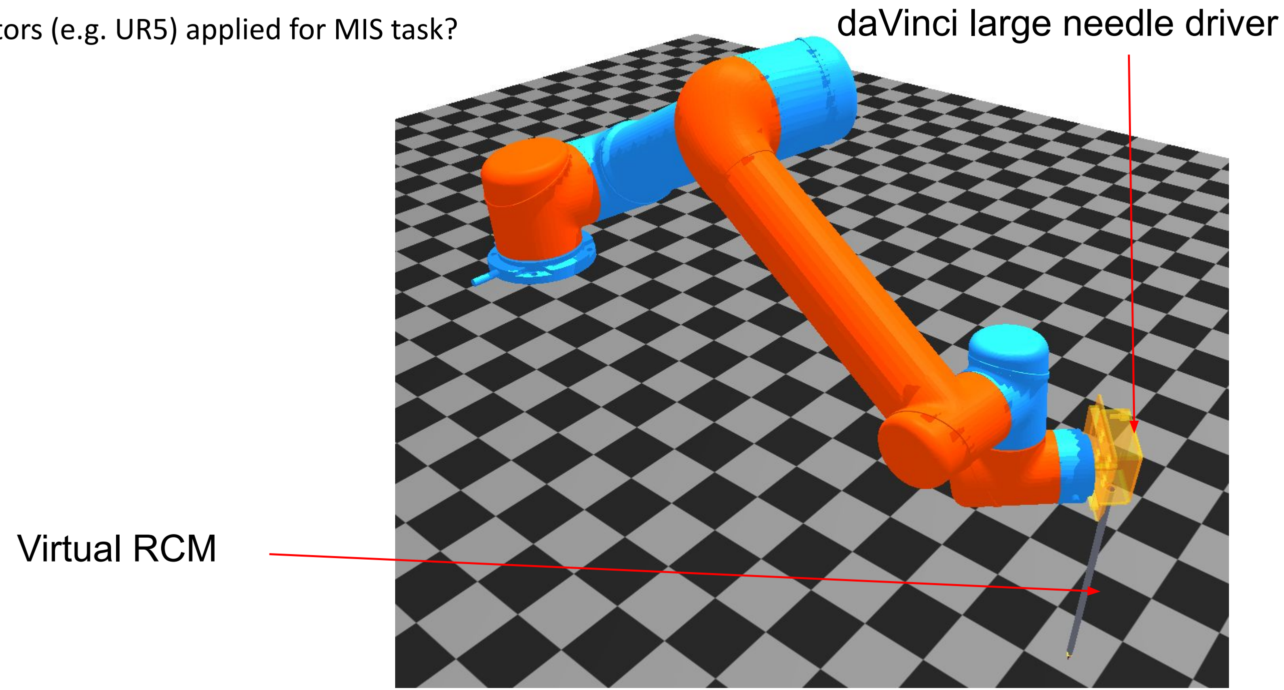
Project background

- Minimally invasive surgery (**MIS**) requires Remote Center of Motion (**RCM**)
- Not everyone has access to special MIS surgical systems
  - daVinci
- Feasibility of robot manipulators (e.g. UR5) applied for MIS task?
- Dynamic simulator **AMBF**



Objectives

1. Implement virtual RCM for MIS in AMBF simulator
2. Evaluate it (collision during bimanual tasks, accuracy, joint limitations)

Importance:

- The project would help to evaluate capabilities and constraints of manipulator arms applied in (bimanual) MIS tasks
- Would open the door for MIS related simulations using manipulator arms

Paper selection

B. Mitchell et al. "Development and application of a new steady-hand manipulator for retinal surgery" Proc. IEEE Int. Conf. Robot. Autom. pp. 623-629 2007.

- **Implements vRCM on real robot**
- **Gives general overview of RCM, pros and cons between mechanical RCM**

Introduction

- Retinal surgery specific -> Tremor-free, precise, safe
- **Task:** Retinal vein cannulation - insertion of a needle into a vein
- **Importance:** Helping surgeons: accurate manipulation + helps maintaining the position long
- One of the first eye-surgery robots to cooperatively share the tool control with a surgeon.

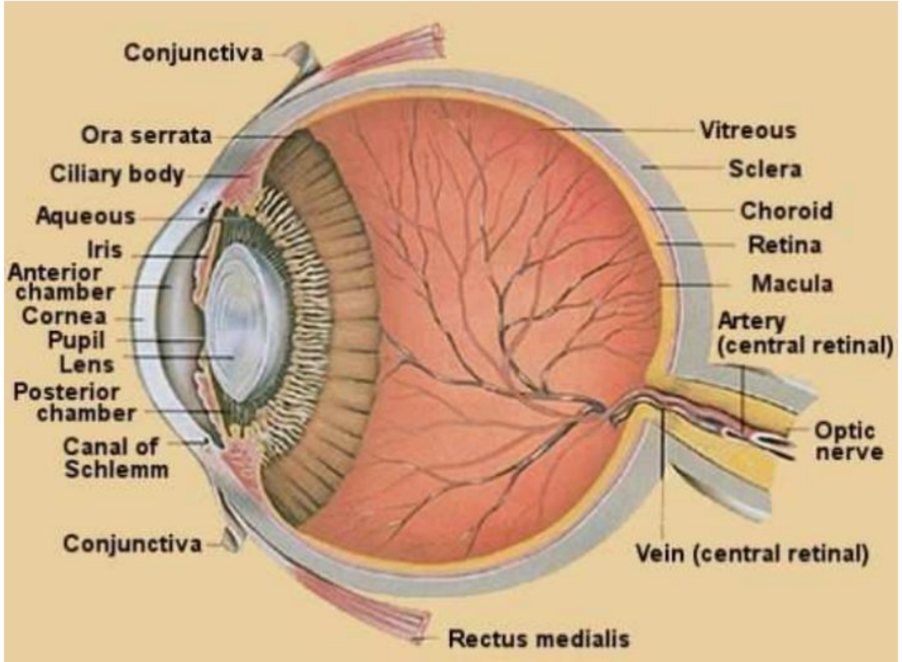


Fig. Eye anatomy

Technical approach - Mechanical Design (1)

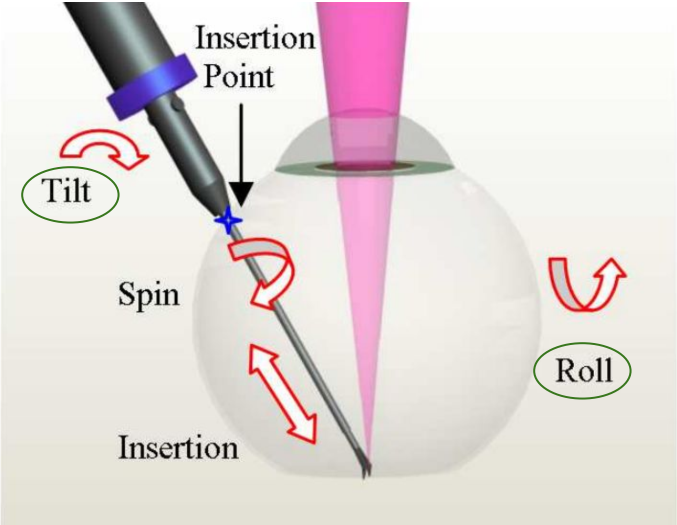
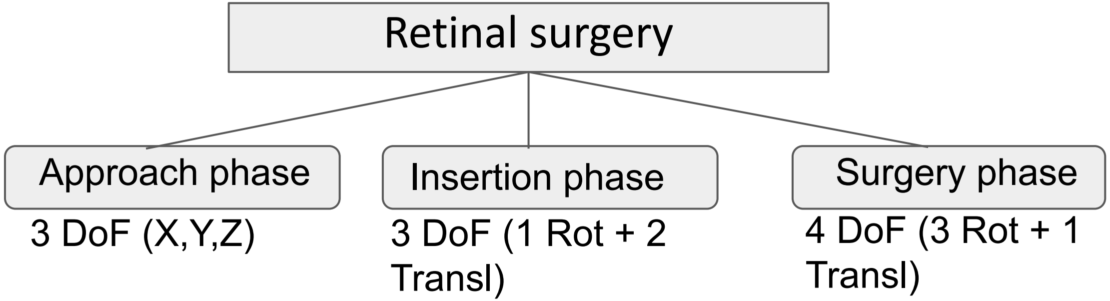


Fig. Setup for retinal surgery



- New robot has 5 DoF: 3 translations (general) + 2 rotations (local)
- 2 local DoF (tool insertion and spin) are eliminated -> thin tool holder, increased ergonomics

Technical approach - Mechanical Design (2)

Mechanical RCM vs Virtual RCM

+ Increased safety
- Bulk design

+ Ergonomic design
- Decreased accuracy

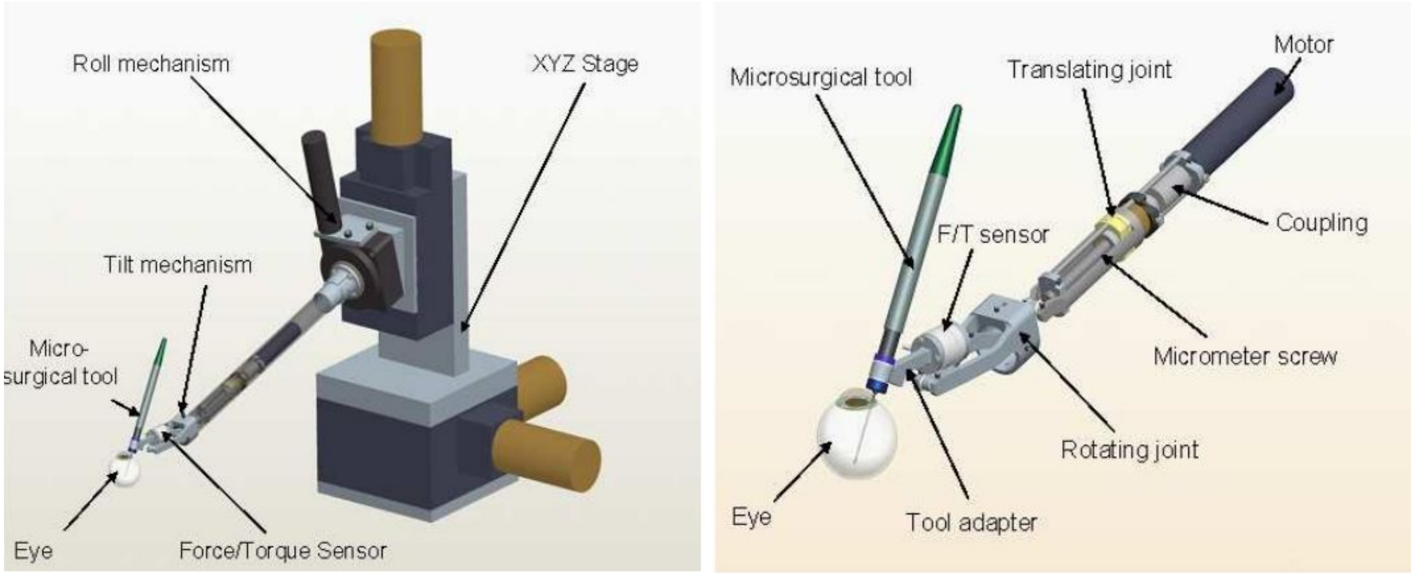


Fig. 3. Robot mechanical system (rendering of CAD model): general view (left) and tilt mechanism (right).

Technical approach - Implementation (1)

4 modular subassemblies:

1) An off-the-shelf XYZ translation assembly;
2) A roll mechanism;
3) A tilt mechanism;
4) Specialized instruments held in the tool holder.

The tool holder :
-forceps
-needle holder
-scissors

Fig. Tilt mechanism

Technical approach - Implementation (2)

Admittance control guidance methods

$$v = Gf$$

Constrained optimization technique for RCM

$$||J_h(q)\Delta q - Gf||$$

$$||P_{cl} + J_{cl}(q)\Delta q - P_o|| \leq \epsilon$$

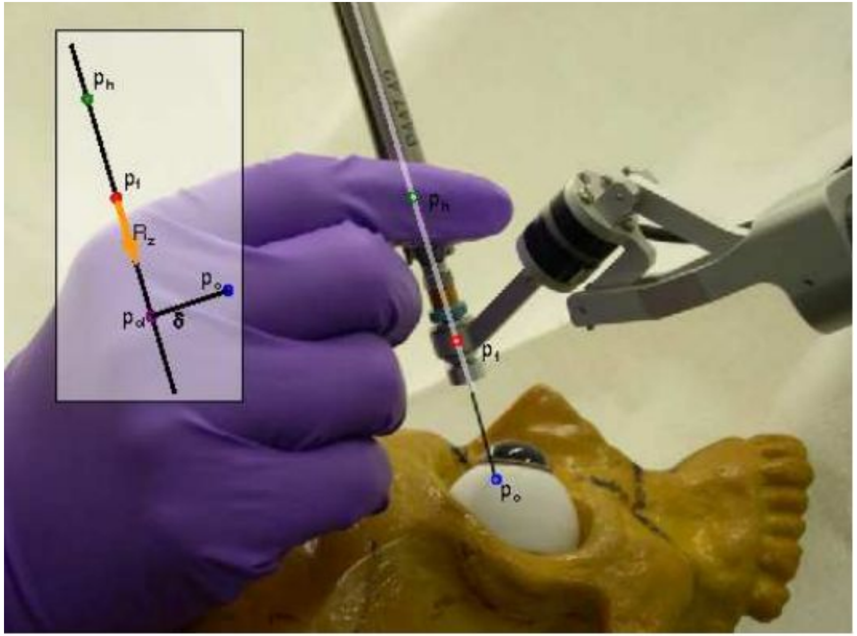
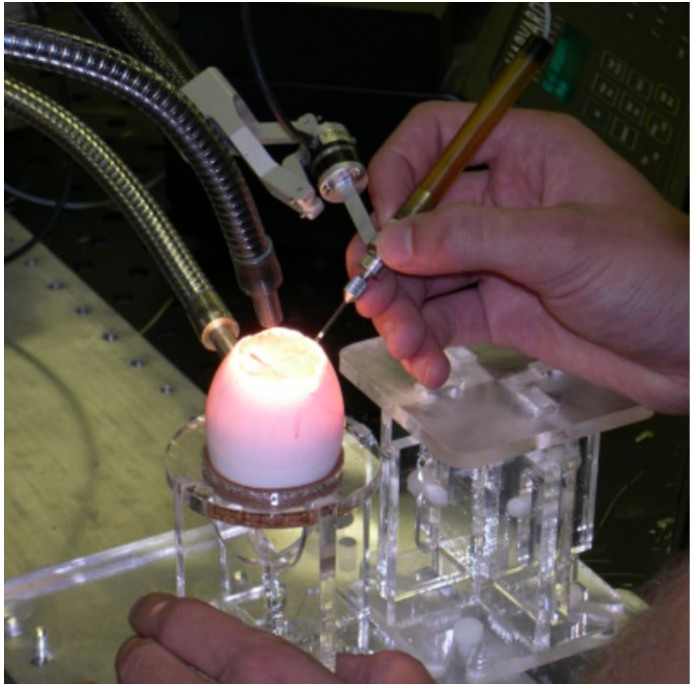
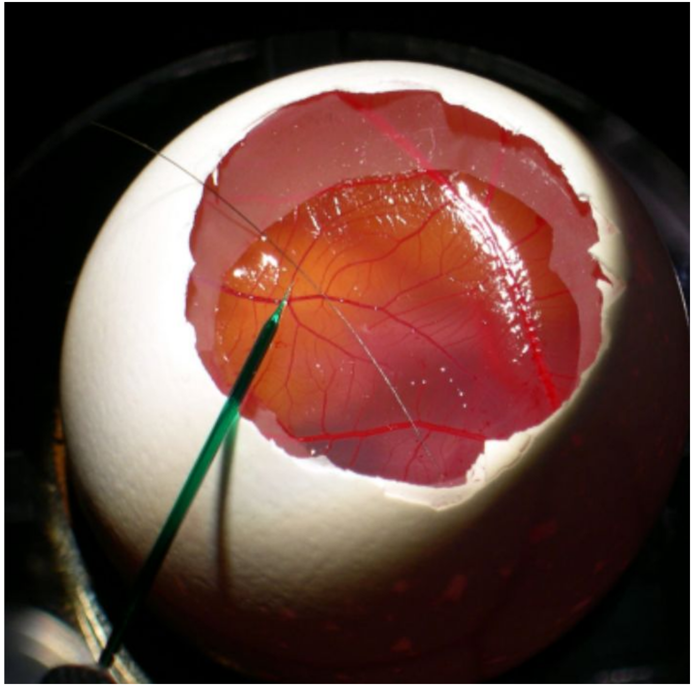


Fig. 5. Virtual RCM mechanism

Experiment and Methods

Experiment and Methods

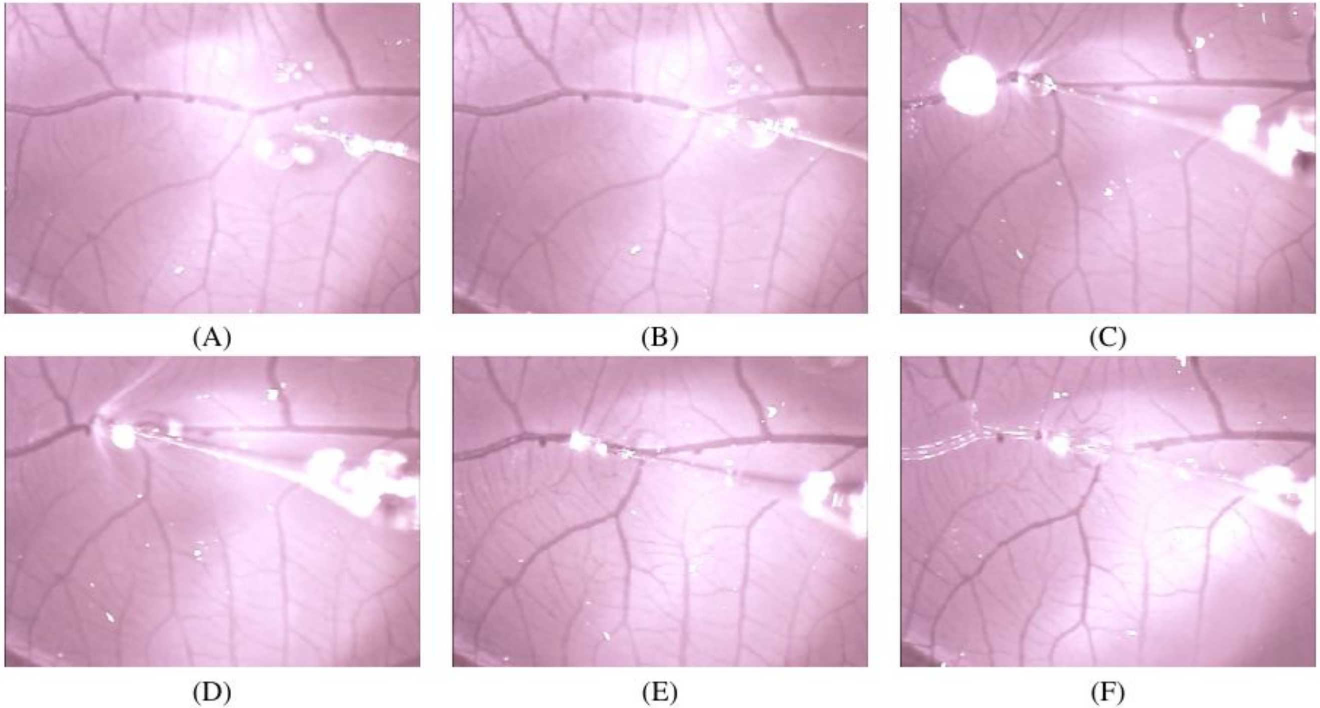


Fig. 8. Successive images of a cannulation taken through a microscope: (A) tip is positioned near target vein. (B) tip is touching target vein. (C) tip is pushed against target vein. (D) tip is pulled up using hooking motion. (E) tip is pulled back to allow vein to un-distort. (F) tip has not been moved; vein is filled with clear marker.

Analysis

- Input force priority control over RCM
- Values of G matrix and epsilon are not mentioned
- Paper relies on qualitative results more than quantitative
- No info on precision of the RCM following

Pros:

- Detailed description of the mechanical design, technical specification
- Provides real experiment focusing on vein cannulation of animal eye

Cons:

- Reliance on the knowledge of the previous work related to constrained optimization and admittance control
- Lack of mathematical proof of the robot stability and RCM satisfaction

References

[1] B. Mitchell et al. "Development and application of a new steady-hand manipulator for retinal surgery" Proc. IEEE Int. Conf. Robot. Autom. pp. 623-629 2007.

[2] A. Kapoor, M. Li, and R. H. Taylor, “Constrained control for surgical assistant robots,” in Proc. ICRA, 2006, pp. 231–236.

Appendix (1). Mechanical specifications

TABLE I

ROBOT PERFORMANCE SPECIFICATIONS FOR APPROACH PHASE (A), INSERTION PHASE (I), AND RETINAL SURGERY PHASE (R) MOTIONS.

Robot Specification	Units	Value
Roll/tilt motion	degrees	± 30
XYZ motion	mm	± 50
Roll/tilt precision	radians	0.00005
XYZ precision	μm	2
Net precision at retina	μm	5
Cartesian tip speed - phase A	mm/s	10
Cartesion tip speed - phase I	mm/s	5
Cartesian tip speed - phase R	mm/s	< 1