Design of a compact robotic assisted ophthalmic system

6125

Design of a compact robotic-assisted ophthalmic surgical system

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The Goal of this project is to realize a Master-Slave system for robotically assisted vitreoretinal surgery.

Abstract

Purpose

Robotics have enhanced and refined microinvasive surgery in several disciplines. Its applicability in eye surgery has been limited by ergonomic and scaling issues. Our aim was to design and build a microrobotic system adapted to the needs of vitreoretinal surgeons.

Methods

Constraints regarding head positioning and size, ocular access, surgical execution, and procedural requirements were defined by observations at live surgeries, discussions with surgeons, operation room teams, and computer simulations. Additional design parameters for the robotic slave (RS) included a low weight, high stiffness, low friction and play-free design. For the control module (CM), intuitiveness of the controller, body posture of the operator and patient proximity were considered.

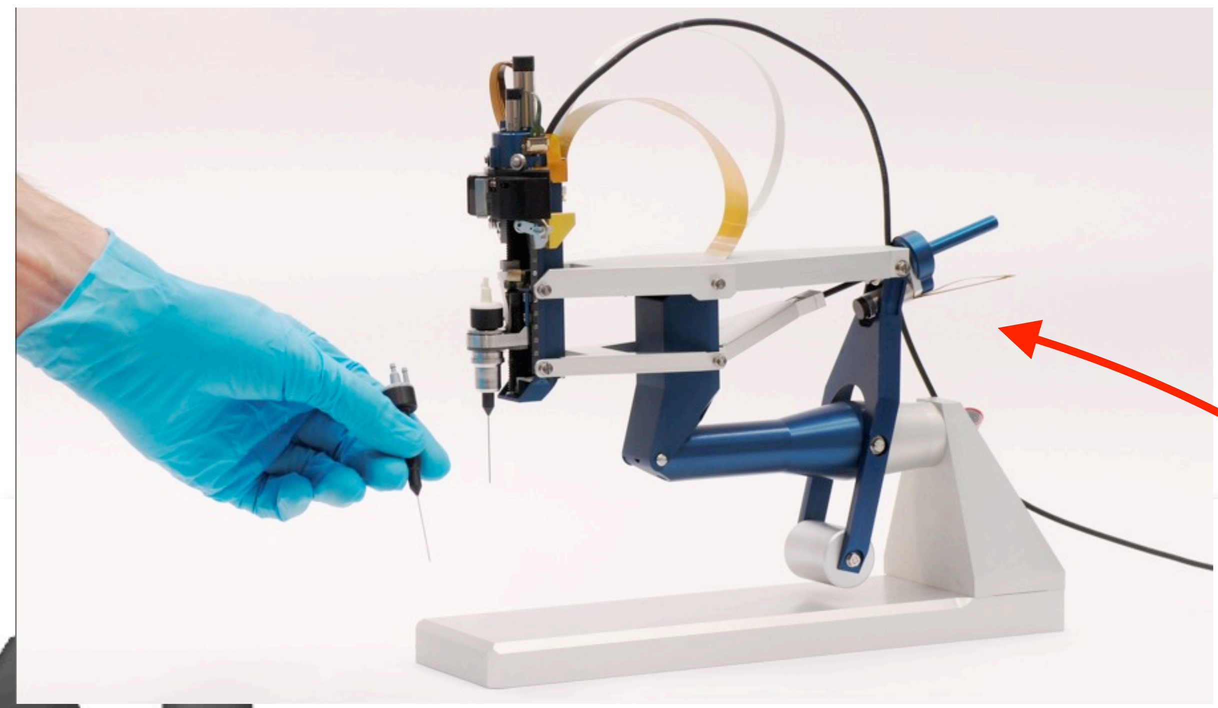
Results

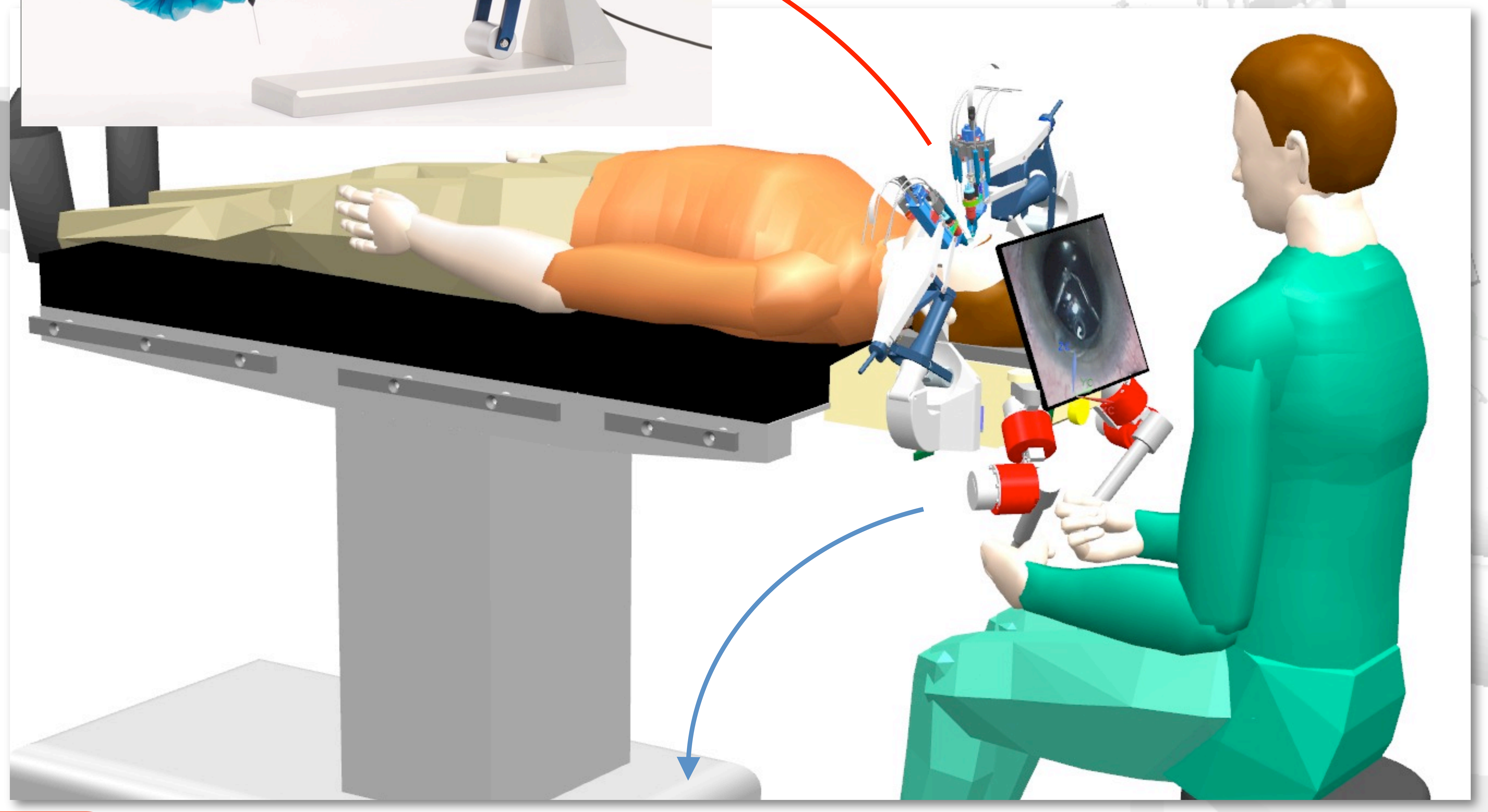
The RS consists of at least two instrument manipulators (IMs).The IM's design allows 5 degrees of freedom through a kinematically defined rotation point at the entry site into the sclera. Force measurement down to 10mN is possible and manipulation with an accuracy of <10µm. The design allows the back 180° of the eye to be reached.

The CM portion consists of two haptic interfaces (HI) with encoders for position input and motors to provide force feedback. A comfortable and intuitive working environment was created by manipulating the HIs to simulate the instrument tip inside the eye.

Conclusion

A microrobotic assisted system can be designed for vitreo-retinal surgery that meets the requirements and constraints imposed by this type of specialized surgery.





Conclusion

A microrobotic assisted system can be designed for vitreoretinal surgery that meets the requirements and constraints imposed by this type of specialized surgery. A master-slave system is designed, realized and functional tests are performed. More advanced tests e.g. in Vitro will be performed in the near future.

Master slave system

Robotically assisted surgery has various advantages over manual performed surgery.

- Scaled instrument movements
- More delicate and accurate movements
- Filtering of hand tremor or sudden movements
- Forces below the human detection level can be measured and can be fed back amplified to the surgeon.
- The system can put on hold.
- Automation of surgical tasks
- Change of instruments can be automated
- Various safety measures can be incorporated

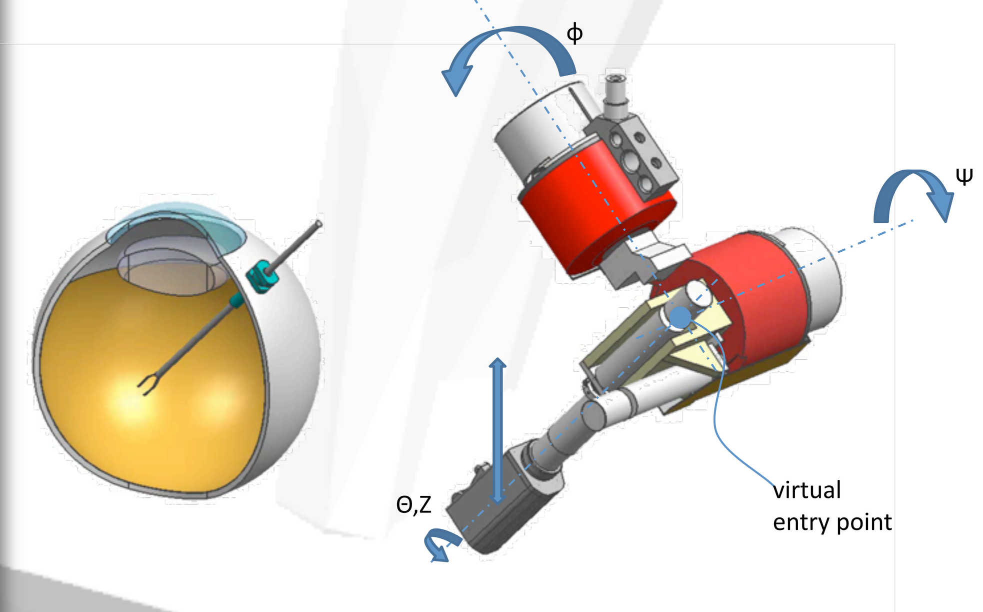


Figure 2. The 4 DoFs of the instrument and the haptic interface

Results

Designs of a CM and RS are made, realized and first functional tests are performed. Both CM and RS are supported by a pre-surgical adjustment system, integrated into the patient's headrest (figure 1). Adjustments are made to position the RS over the left or right eye. The CM is adjusted for surgical ergonomics.

Robotic Slave

The RS is provided with multiple instrument manipulators (IMs, fig. 3). The design of the IM is such that the point where the instrument enters the eye is kinematically defined. This results in an intrinsically safe design. Four degrees of freedom (DoFs) about the entry point are desired (fig. 2, left). A fifth DoF is used to actuate the instrument, e.g. forceps. The IMs range of motion is indicated below.

Φ-Ψ	Z	Θ
+/- 45°	>30 mm	360°

The instrument manipulator layout and reach, enables the surgeon to operate the vitreous humor and the complete back 180° of the retina. Key properties of the IM are: (1) force measurement with a resolution of 1 mN, (2) manipulation with an accuracy of <10 µm, (3) high stiffness, (4) backlash free and (5) it is equipped to perform a complete intervention.

For the use of different instrument, the IMs are equipped with an onboard changing system. Changing an instrument is performed in a fast and secure matter.

Master console

The main components of the master are haptic interfaces and a 3D-display for visual feedback. A comfortable and intuitive working environment was created by manipulating the HIs to simulate the instrument tip inside the eye. Therefore the geometry of the DoFs are placed as such (figure 2). All DoF in the master are optimized, backdrivable and equipped with an electric motor to provide the most accurate force feedback. Movements are measured by encoders for position input for the RS.