# Ex-vivo experiments with a microrobotic surgical system for vitreo-retinal surgery

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# Ex-vivo Experiments With A Microrobotic Surgical System For Vitreo-retinal Surgery

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## Abstract

### Purpose

Developments in vitreoretinal eye surgery are limited by human capabilities. To improve current vitreoretinal surgical procedures and to enable new procedures, a robotic system has been developed called PRECEYES, extending human capabilities.

### Methods

A compact, lightweight, easy to setup robotic master-slave system has been realized to perform vitreo-retinal eye surgery (see Figure 1-3). The system's reach covers the major part of the vitreous cavity (up to the peripheral region). A combination of advanced mechanical and control design facilitates high accuracy (<10μm) extending human capabilities and significant time saving. The accuracy and reproducibility of the system are validated via bench experiments, including pointing and pick-and-place movements. Vitreo-retinal surgical procedures were simulated in an eye model, eggs and porcine eyes via ex-vivo experiments. The experiments include cannula placement, vitrectomy and membrane peeling.

### Results

A fully functional master-slave robotic system for vitreo-retinal eye surgery has been realized. First functional tests show a short setup time, an intuitive usage in combination with good ergonomics and satisfactory instrument reach and accuracy. Simulation of vitreo-retinal surgical procedures indicates improved accuracy and time efficient surgery compared to manual surgery.

### Conclusion

A microrobotic surgical system for vitreo-retinal surgery is realized that meets the requirements and constraints imposed by this type of specialized surgery. First functional tests validate the realization of these requirements and constraints, improving current vitreo-retinal surgical procedures in time efficiency and accuracy, and enabling new, high-precision procedures.

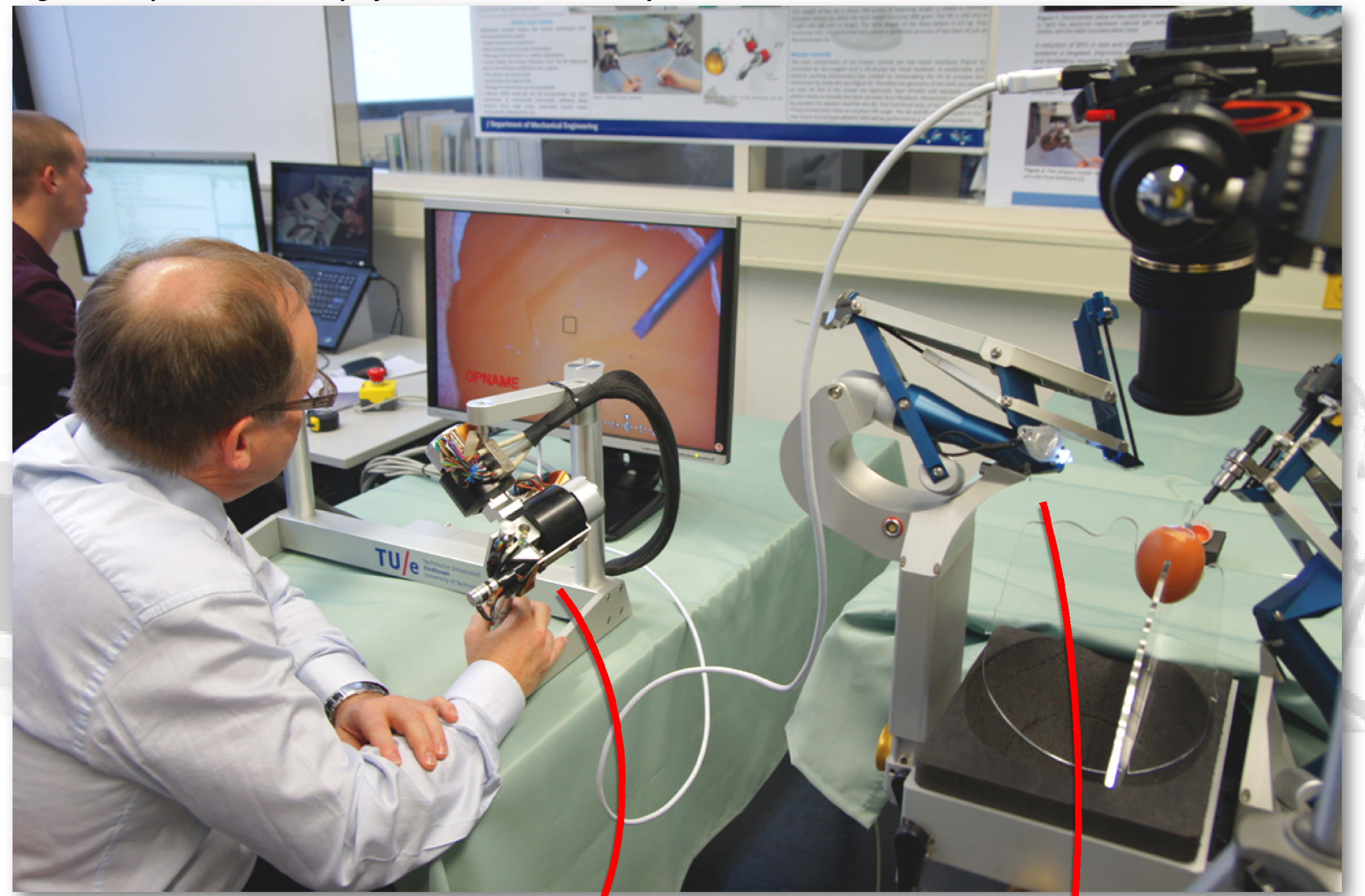
## References

Hendrix, R. (2011), *Robotic assisted eye surgery. A haptic master console*, PhD thesis (supervisors: Nijmeijer, H., Steinbuch, M.), Eindhoven University of Technology, Eindhoven, the Netherlands

Meenink, H.C.M. (2011), *Vitreo-retinal eye surgery robot: sustainable precision*, PhD thesis (supervisors: Steinbuch, M., De Smet, M.D.), Eindhoven University of Technology, Eindhoven, the Netherlands.

Leng, T., Miller, J.M., Bilbao, K.V., Palanker, D.V., Huie, P. and Blumenkranz, M.S. (2004), *The chick chorioallantoic membrane as a model tissue for surgical retinal research and simulation*, 24(3): 427-434

*Figure 1. Experimental setup of the PRECEYES robotic system.*



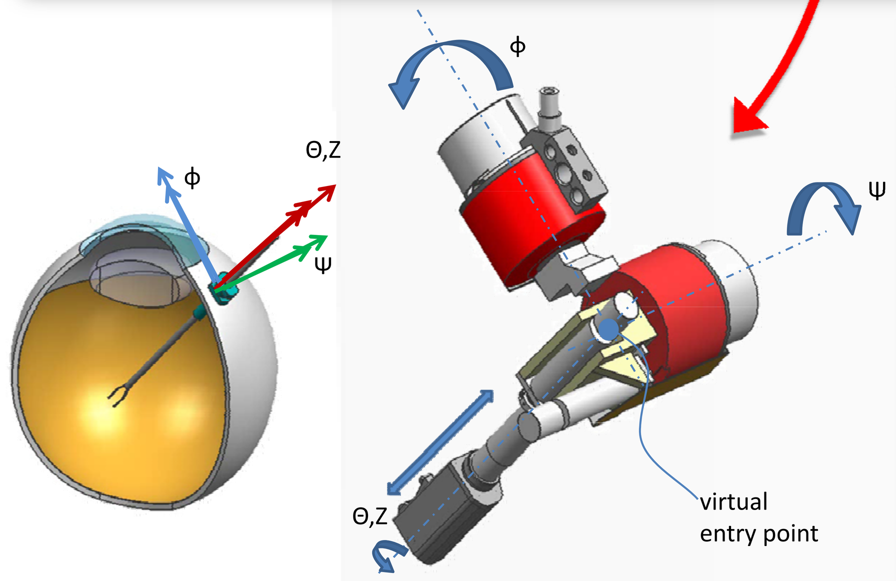



*Figure 2. Similar movements of the haptic interface and the instrument contribute to an intuitive usage.*

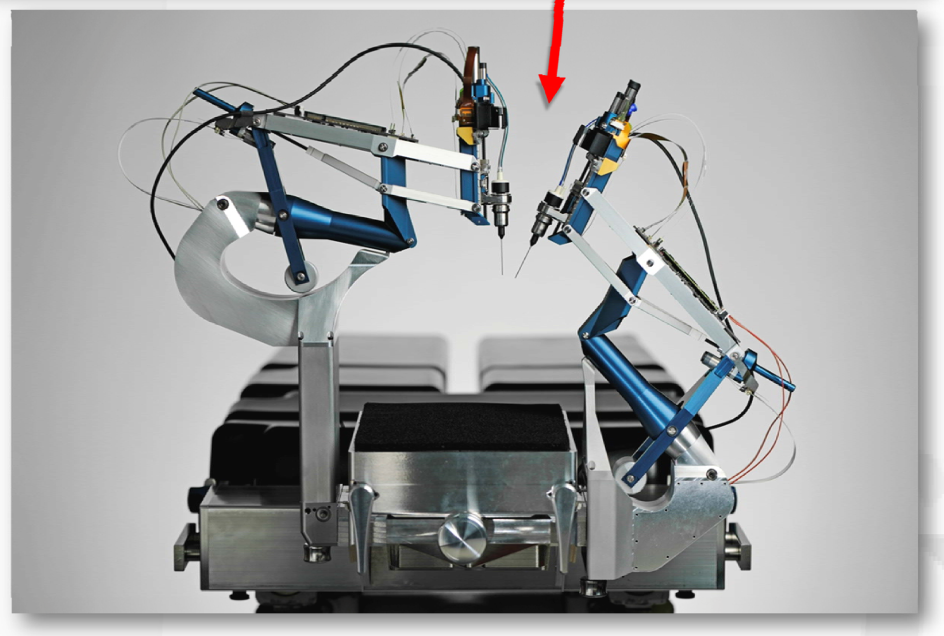


*Figure 3. Realized robotic slave setup with two instrument manipulators*


*Figure 4. Peeling of the inner white shell membrane from a chicken CAM.*


*Figure 5. Vein cannulation at a chicken CAM.*

## The PRECEYES robotic system for vitreoretinal surgery

### Introduction

The PRECEYES robotic system consists of a master console operated by the surgeon that controls two robotic arms (slave) which perform the actual surgery (Meenink, 2011; Hendrix, 2011, Figure 1). The haptic interfaces of the master console provide the motion reference for the instrument manipulators of the slave system (Figure 3). The slave system performs the actual surgery by controlling instrument manipulators that directly handle the instruments. A comfortable and intuitive working environment is created by manipulating the haptic interfaces to simulate the instrument tip inside the eye (figure 2). The PRECEYES robotic system is designed compact, lightweight and easy to setup to fit the current OR layout. With the PRECEYES robotic system instruments can be changed automatically, hand tremor can be filtered out, movements can be scaled, which allows μm precise movements. This could enable procedures as retinal vein cannulation for treating CRVO and BRVO.

### System evaluation

The compact, lightweight and easy to setup design contributes to a fast installation. The time to prepare a surgical table (Maquet 1120) with the PRECEYES and to activate it takes only a few minutes. Using a laserfibrometer (Polytec OVF-5000 with OVF-552, at 500 μm/V), the repeatability and smallest step accuracy was measured at the instrument tip at 25 mm insertion depth. The result was an intrinsic accuracy of < 10 μm, which corresponds to the requirements.

### User tests

The first user tests included a training program with simple tasks on paper and more advanced surgical tasks on a chicken egg chorioallantoic membrane (Leng, 2004). The tests show an intuitive usage combined with good ergonomics and satisfactory instrument reach and accuracy. User tremor is effectively filtered and a motion scaling of 10 to 40 times was considered adequate. The intuitive usage resulted in a short learning curve; users adapt in minutes and are able to perform surgical tasks successfully within an hour of first usage. Pointing tasks on squared mm-paper show an accuracy down to 38 μm ±28 μm. The accuracy of these tasks is limited by the magnification of the currently implemented visualization system (Sony A33 with 90mm macro lens, projected onto a 24"HD monitor).

### Ex-vivo experiments

The chorioallantoic membrane (CAM) of chicken eggs is used as a model to practice surgical tasks, see Figure 4 and 5; the transparent membrane in the right image. The CAM of chicken eggs is commonly used as a model for the retina as the membrane has similar characteristics as the retina (Leng, 2004). The first task involved peeling of the white inner shell membrane from the underlying CAM. With a knife and pick, the peel was successfully executed on the first attempt. It was performed within 2 minutes and without any complications such as bleeding. Similar results were realized using forceps to peel the membrane (Figure 4). After removing a piece of the inner shell membrane and exposing the CAM, retinal vein cannulation was simulated successfully to the veins on the CAM, having a diameter down to 35 μm (Figure 5). The outcome of these surgical tasks were consistent in subsequent experiments with various users. Ex-vivo experiments on porcine eyes showed a steady rotation point at the entry point through the pars-plana and a vitrectomy was performed.

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