

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

**Citation for published version (APA):**

Meenink, H. C. M., Naus, G. J. L., Beelen, M. J., Steinbuch, M., Rosielle, P. C. J. N., & Smet, de, M. D. (2012). *Ex-vivo experiments with a microrobotic surgical system for vitreo-retinal surgery*. E-Abstract 3789-. Poster session presented at conference; Annual meeting: Association for Research in Vision and Ophthalmology; 2012-05-05; 2012-05-11.

**Document status and date:**

Published: 01/01/2012

**Document Version:**

Accepted manuscript including changes made at the peer-review stage

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

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

Thijs MEENINK<sup>1,\*</sup>, Gerrit NAUS<sup>1</sup>, Maarten Beelen<sup>1</sup>, Maarten STEINBUCH<sup>1</sup>, Nick ROSIELLE<sup>1</sup> and Marc DE SMET<sup>2-3</sup>

1. Mechanical Engineering, Technische Universiteit Eindhoven, Eindhoven, The Netherlands; 2. Retina & Inflammation Unit, Montchoisi Clinique, Lausanne, Switzerland; 3. University of Amsterdam, The Netherlands

\*Thijs Meenink MSc PhD  
 Department of Mechanical Engineering  
 Control Systems Technology group  
 PO Box 513, Gem-N -1.62  
 5600 MB Eindhoven  
 The Netherlands  
 Tel. +31 40 247 4789  
 Fax. +31 40 246 1418  
 h.c.m.meenink@tue.nl

## 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 ( $<10\mu\text{m}$ ) 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.

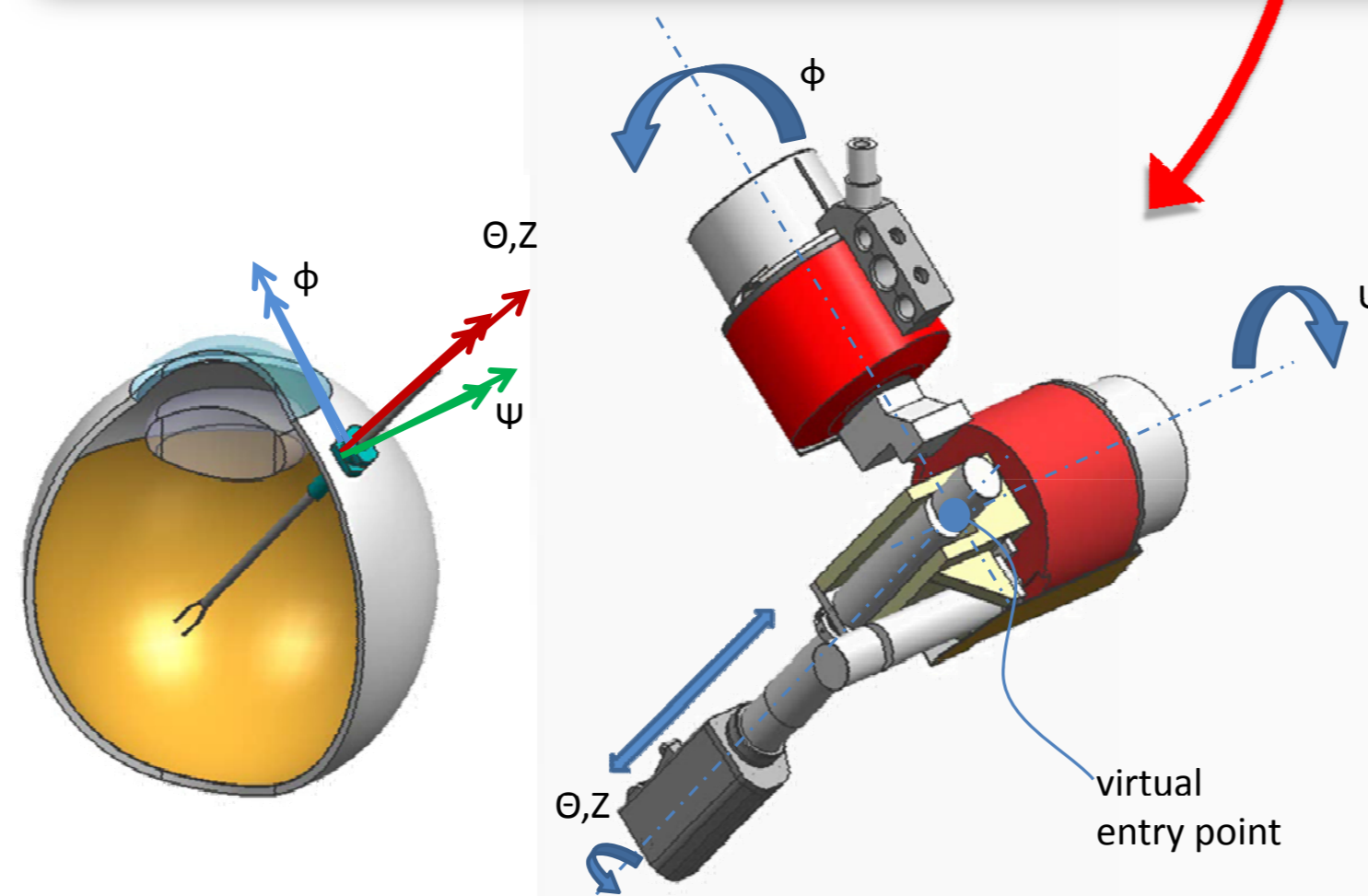
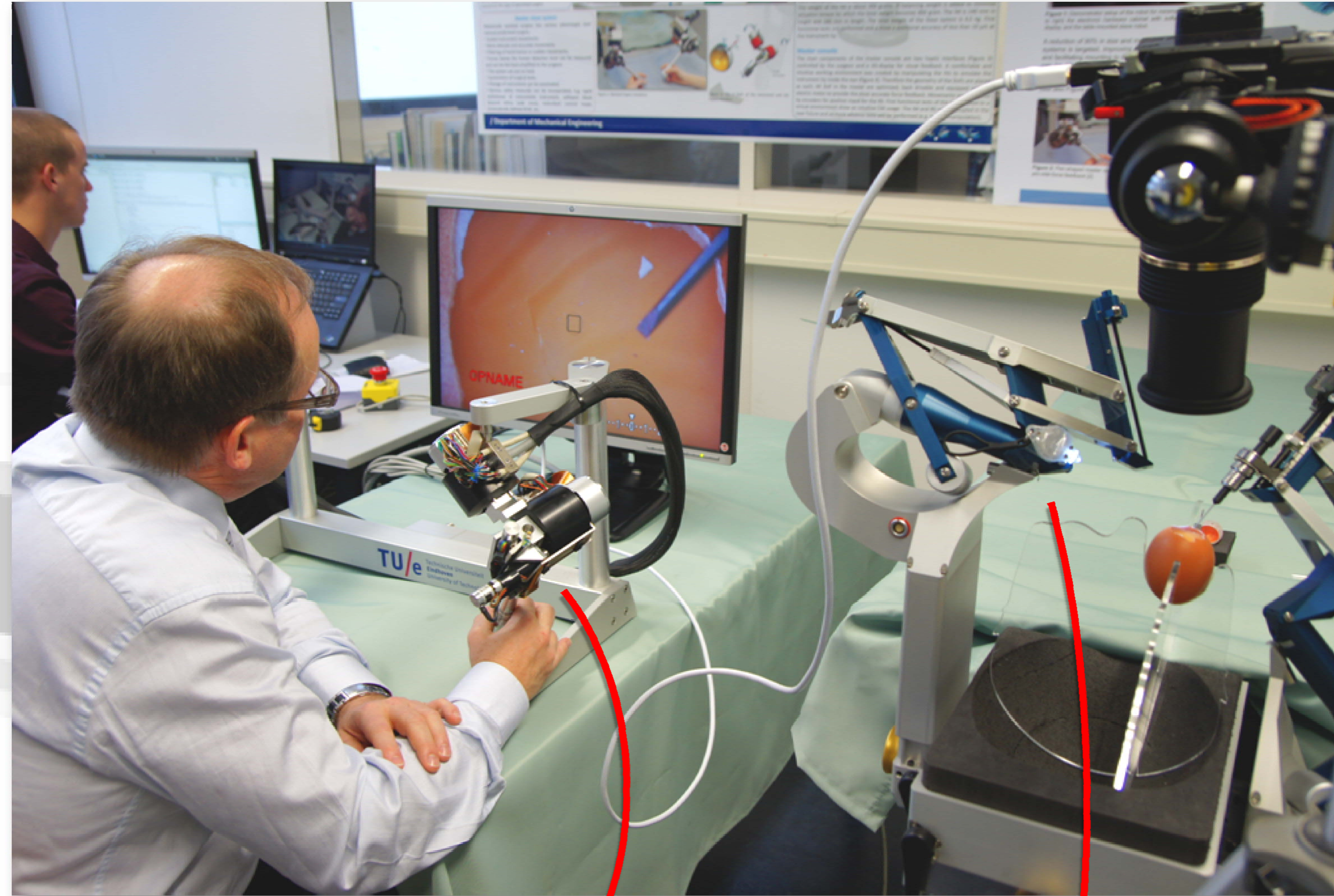


Figure 2. Similar movements of the haptic interface and the instrument contribute to an intuitive usage.

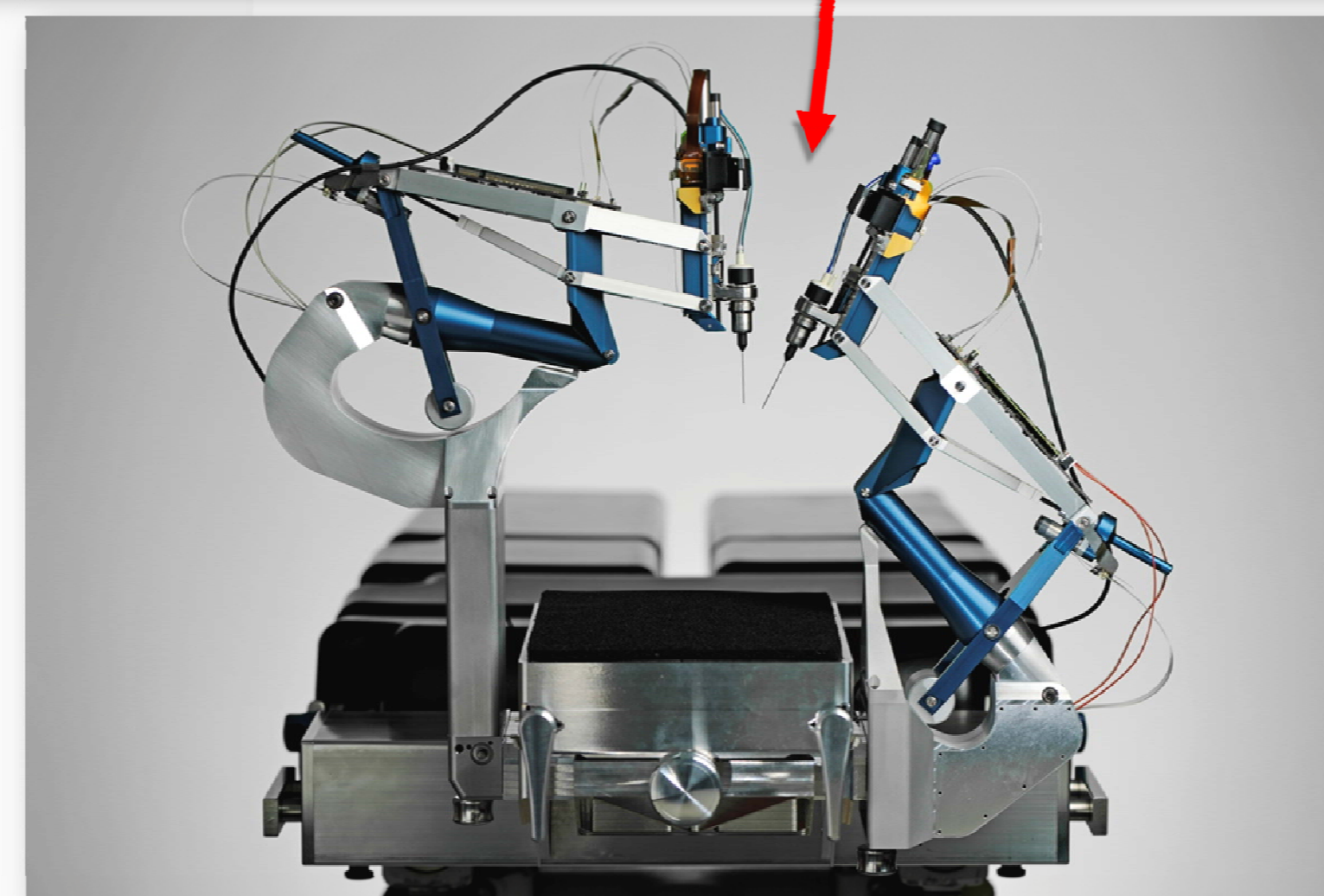


Figure 3. Realized robotic slave setup with two instrument manipulators

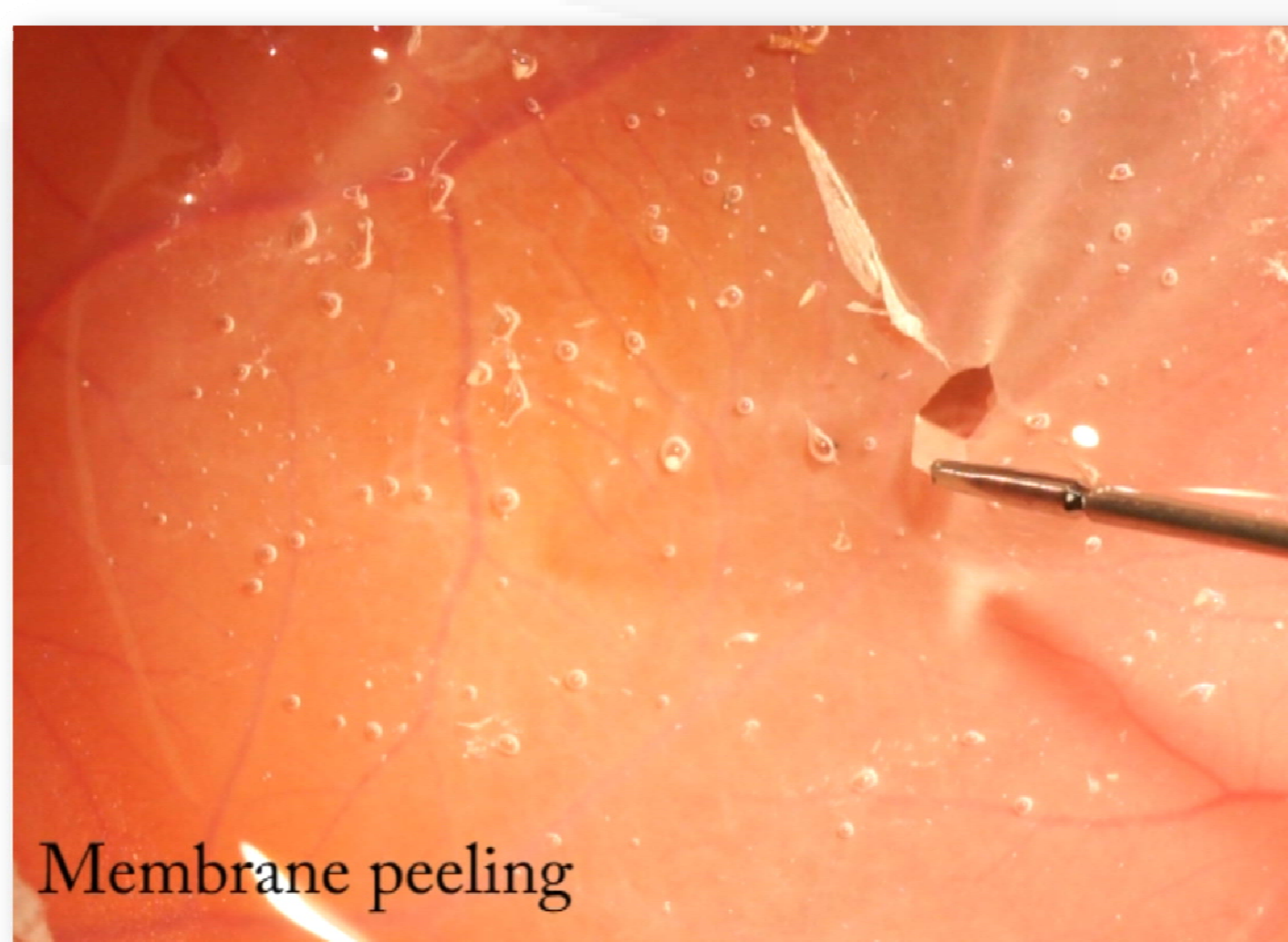


Figure 4. Peeling of the inner white shell membrane from a chicken CAM.



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  $\mu\text{m}$  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  $500\mu\text{m/V}$ ), the repeatability and smallest step accuracy was measured at the instrument tip at 25 mm insertion depth. The result was an intrinsic accuracy of  $<10\mu\text{m}$ , 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  $38\mu\text{m} \pm 28\mu\text{m}$ . 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  $35\mu\text{m}$  (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.

