A master-slave robot for vitreo-retinal eye surgery

A master-slave robot for vitreo-retinal eye surgery

Thijs Meenink
Department of Mechanical Engineering
Control Systems Technology
PO Box 513, WL 1.59
5600 MB Eindhoven
The Netherlands
Tel. +31 40 247 4580
Fax. +31 40 246 1418
h.c.m.meenink@tue.nl

Introduction

Vitreo-retinal eye surgery relates to surgery at the inner side at the back of the eye, e.g. the vitreous humor or the retina. Nowadays it is performed manually via a trocar, not unlike minimally invasive surgery (MIS). Steady hand movements are required to operate ocular tissue with high accuracy. During eye surgery forces are below the detection limit (60 mN). Robotically assisted surgery with force feedback can extend existing surgical skills, using a master-slave system (fig. 1).

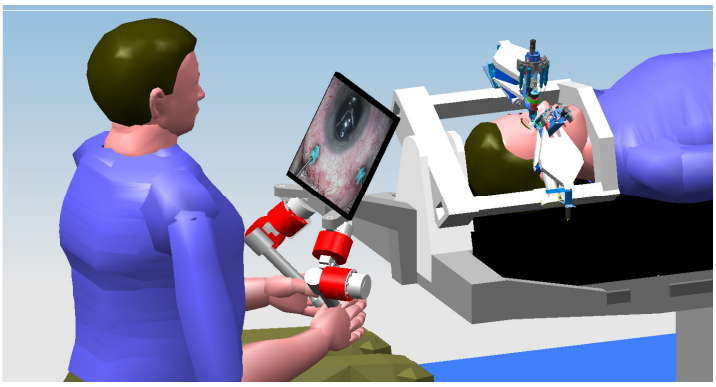

Figure 1. Concept design of the master-slave system.

The slave robot, performing the actual surgery, is controlled by the surgeon via a master. Key properties of the master-slave system are: (1) easy to place, (2) compact and light weight design, (3) direct view on the patient, (4) intuitive operation, (5) suitable for a complete intervention and (6) an ergonomic operating posture.

Master device

Both master and slave parts are supported by a frame, which is mounted to the surgical table. The main components of the master are haptic interfaces and a 3D-display. An intuitive working environment is created by virtually placing the hands of the surgeon on the instrument inside the eye, therefore the geometry of the degrees of freedom (DoFs) are placed as such (fig.2).

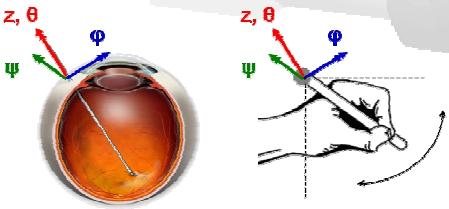

Figure 2. The 4 DoFs of the instrument and the haptic interface

All DoFs in the master are equipped with a force feedback motor and are backdrivable. Position is measured by encoders.

Slave

The slave is provided with multiple instrument manipulators (IMs, fig. 3) and is adjustable to position the IMs over either the left or right eye. 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 DoFs about the entry point are desired (fig. 2, left). The range of motion is indicated below.

Φ-Ψ	Z	Θ
+/- 45º	>30 mm	360º

A fifth DoF is used to actuate the instrument, e.g. forceps. 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.

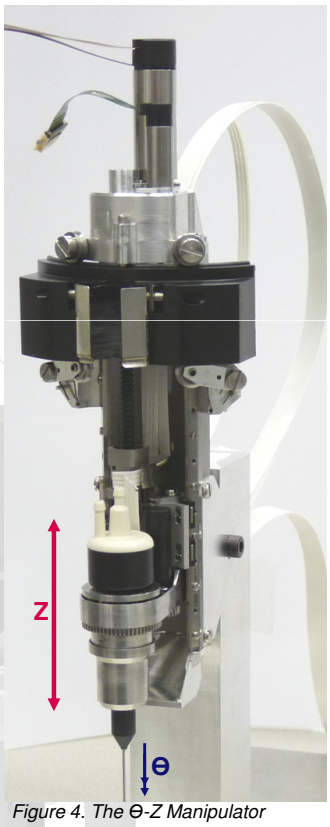

Figure 4. The Θ-Z Manipulator

Different instruments are used during surgery, therefore each IM is equipped with an onboard instrument changing system. It consists of a rack holding instruments and an actuator to select the desired instrument. The manipulator Z-Drive and a bistable instrument clamp are used to effect the change automatically in a fast and secure way.

Currently the first IM is realized (fig. 4) at the TU/e GTD for a test program.

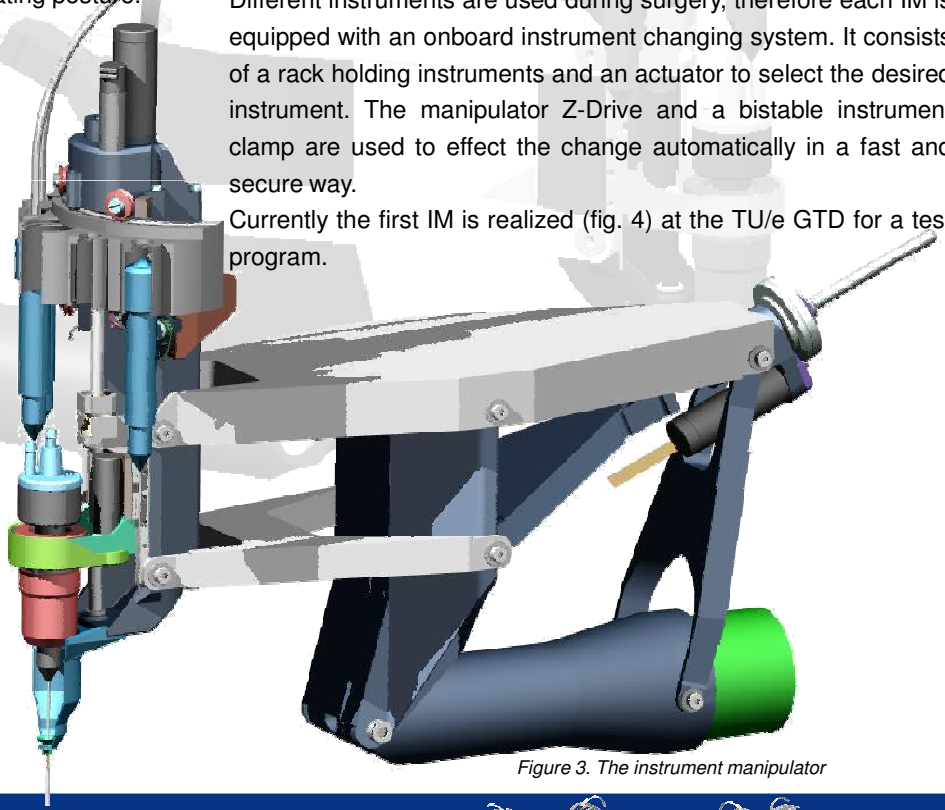

Figure 3. The instrument manipulator

* M.D. de Smet, Amsterdam Medisch centrum, The Netherlands