CS 446 Computer Integrated Surgery II

Critical Review

Group 8

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Project Background

Vitreoretinal microsurgery is one of the most challenging and demanding procedures. The eye is small, severely limiting the available workspace for the surgeon, and is very delicate, and cannot withstand large amount of force without sustaining permanent damage. When inserting a surgical tool into the eye, there are two points of contact: the inner eye, where the surgery is being performed, and the sclera, where the shaft of the tool makes contact with the entry point. It becomes essential to not only accurately measure the amount of force at those locations, but also to develop an optimal method of alerting the operator when the force is near or above the acceptable level. It is the goal of our project to test the various methods of alert system (vibrotactile, auditory, motion scaling) on a dual force sensing instrument attached to a cooperative control surgical robot, and to analyze which method serves the purpose the best.

Paper Selection

**“Microsurgical robotic system for vitreoretinal surgery”**

Y. Ida, N. Sugita, T. Ueta, Y. Tamaki, K. Tanimoto, and M. Mitsuishi, *International Journal of Computer Assisted Radiology and Surgery*, vol. 7, no. 1, pp. 27–34, Jan. 2012.

Reasons for selecting paper

While the paper discusses the use of a master-slave surgical system for vitreoretinal surgery, it briefly discusses the advantages and disadvantages of other types of surgical systems, including the cooperative control robot that we are using for our experiments. In addition, many feature ideas for this slave-master robotic system could apply to a cooperative control robot, such as easily swappable parts that could be easily sterilized. The paper lists specific requirements a robotic system for vitreoretinal surgery must meet in terms of workspace, robotic degrees of freedom, accuracy, remote center of motion, sterilization and compatibility with the surgical environment. These specifications also apply to cooperative control robot.

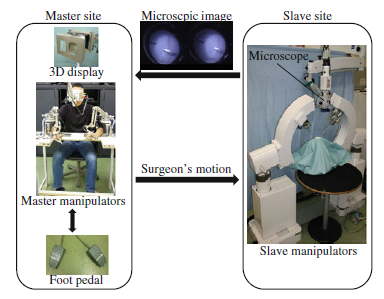
Problem Statement and Goal

Microsurgery of the eye is a daunting task because high precision is required. Some factors that make this process difficult is the limited workspace due to the small size of the eye, limited visual feedback from microscope, small surgical instruments and hand tremor. These difficulties allow only the most experienced surgeons to achieve good outcomes with traditional method of surgery. In a particular drug delivery procedure that involves holding a micropipette inserted to a retinal vein while all of the drug is emptied out into the vein, the required accuracy is within 10 micrometers. The average hand tremor amplitude, however, is 10 times that amount or about 100 micrometers. Surgical procedures on the eye including the one just mentioned could largely benefit from a well manufactured surgical robot that could deliver the movement accuracy and stability, while maintaining strict safety.

Introduction and Background

There are three types of robotic system that could serve the purpose: handheld, cooperative and master-slave console. The advantages of handheld and cooperative control device is the small dimensions and portability. While master-slave console is bulky, it is pursued by the authors of the paper because handheld and cooperative systems are based on applied force which may become unstable and may require recalibration from user to user. In addition, master slave console can take advantage of motion scaling which means large movement on the master console would translate to smaller movements on the slave console.

Equipment Overview

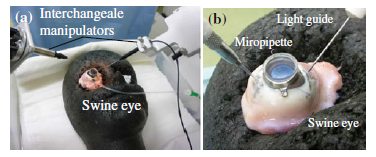
Credit: Ida et al

The slave unit dimension is 390 x 408 x 1058.5 mm, and has 5 degrees of freedom. The tip instrument can be easily swapped out and typical examples include light tool, forceps and vitriol cutter. Three translational DOF (X,Y and Z axis) are only used to set the tip in place and will not be allowed to move during the operation (to solve the RCM problem). The remaining two remaining DOFs are rotational and are used during the procedure.

The master unit includes a workstation that has two joysticks and the user gets visual feedback from a 3D display fed from two microscopic cameras. The control will only be allowed to move only if the foot pedal is engaged.

Results

To test out the effectiveness of the system, retinal vessel microcannulation was carried out ex vivo on swine eyes as in the figure below.



Retinal vessel microcannulation is a procedure in which a micropipette of diameter 20-50 micrometers is inserted into a blood vessel 50-150 micrometers in diameter and is held there for 1-2 minutes until the drug delivery is complete.

For this particular experiment, an eye surgeon with 10 years of field experience operated the slave console with 20 micrometer tip micropipette attached to perform the procedure. The initial positioning, however, was done by an engineer receiving instructions from the doctor. After the initial position was done, the surgeon used two rotational DOF and 1 translational DOF to position the tip into the vessel. As soon as the tip entered the vessel, he let go of the foot pedal, allowing the drug to flow without any disturbance from hand tremor. The surgeon was able to complete this process 3 times successfully with average operating time of 5 minutes.

Critique

While the paper focuses mostly on the ability of the robot to complete an operation quickly and accurately, it does not raise any potential safety issues that may arise from using the system. In the concluding remarks, the author speaks of using this machine in clinical settings and suggests that in vivo experimentation with flowing blood vessels is the last step before doing so. To me, this comes off as a bit hasty thing to suggest since safety issues have not been resolved. In addition, while it lists many disadvantages of traditional hand surgery such as hand tremor, the author neglects to list an important advantage: natural haptic feedback. One question that I had why as to the engineer had to make the initial entry under the guidance of the doctor. While I am sure there was a good reason, the paper did not make that reason clear.

Conclusion and Future work

All in all, the paper shows a good demonstration of how a master-slave console robotic system could be used to perform one of the most difficult microsurgery procedures in shorter period of time while maintaining high accuracy. While the paper advocates the use of master-slave console as system of choice for vitreoretinal surgery, it gives good insight into how the current project with the dual force sensing tool can be improved in the future. Firstly, the dual force sensing instrument should be easily removed, swapped and sterilized. We should come up with a way to expedite the process of having a force sensing instrument that can be swapped from the FBG interrogator. Secondly, the paper suggests that the forceps tip is a standard tool for eye surgery. The current force sensing tool is just a prong, and differently shaped force sensing tools can be developed. Lastly, retinal vessel microcannulation seems to be a good procedure to gauge the performance of a surgical system. This could be performed using the cooperative control robot for analysis of the effectiveness of the system and potential readiness for clinical use.