Applications of Task-Level Augmentation for Cooperative Fine Manipulation Tasks in Surgery[1]

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Abstract. We report on applications of an augmentation system for cooperative fine manipulation using the steady hand manipulation paradigm. Using the "steady hand" robot as the experimental platform we investigate using such a system for creating composite retinal images using a GRIN lens endoscope and for puncturing small blood vessels in the retina.

1 Introduction

Performance of fine and dexterous tasks such as microsurgery is seriously affected due to limitations imposed by physical attributes of the sensory motor, muscular and skeletal systems on manual dexterity, precision and perception. These limitations provide a clear opportunity for augmentation. Using the "steady-hand" approach, we explore applications of a supervisory framework for human augmentation.

The "steady hand" robot used for these experiments was first reported in [1]. The task-level system used here is described in [2]. An explicit task representation is provided by the user for each task that includes planning inputs, safety considerations, and performance parameters. The task-level system generates a representation for the corresponding finite state machine (FSM). Each state of this FSM represents a step in the task, and each transition a termination predicate. The System maintains a basic set of states, and transitions. A detailed description of the task-level system appears in [2].

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2 Experiments

We are experimenting with simple microsurgical tasks such as tool guidance and positioning, constrained and guarded tool motions.

Retinal Mosaics: For these experiments, a porcine eye was positioned naturally in a phantom head, and a port was created in the eye for positioning the GRIN lens endoscope (Insight IE 3000, Insight Instruments Inc.) such that the RCM point is at the port. A task strategy for collecting the images was then executed. The images and the robot position at which they are taken were then used to construct the composite image. An example of a line of 5 images and the corresponding composite image appear in figure 1.

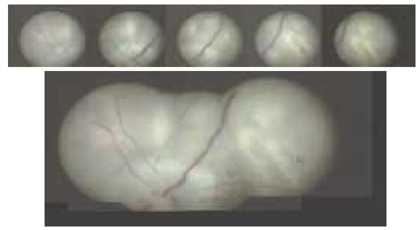

Figure 1: GRIN lens endoscope images and the composite image.

Retinal Vein Cannulation: In these experiments directed at positioning a tool in the occluded vessel, a porcine eye was mounted naturally in a face phantom and a MEMS micro-needle (XACTIX Inc.) was mounted on a 2mm shaft to be used as the probe. The micro-needle mimics a micro-pipette used in experimental vein cannulation treatment. Although they can not deliver anti-coagulants, micro-needles allow us to prototype experiments for evaluating augmentation strategies. The lens of the porcine eye was removed to improve access to the retina. The GRIN lens endoscope was positioned to image the target blood vessel for visual verification.

Lack of blood flow often caused the vessels to be partially collapsed. As a result, our first attempts to cannulate the vessels by approaching them in a perpendicular direction were unsuccessful. We modified our approach to be at a small angle to the vessel, and this allowed us to successfully cannulate sub-millimeter vessels. Figure 2(right) shows the micro-needle positioned in a small retinal vessel. Since not all vessels can be reached by approaches with small angles, we are exploring the alternative of mounting the micro-needles at an angle to the shaft. Further experiments are ongoing.

Figure 2: Experimental Setup for retinal cannulation (left), micro-needle positioned in a vessel (right).

References

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