Shared Control for Telemanipulation in Minimally Invasive Surgery

PhD location : ICUBE, Strasbourg & LIRMM, Montpellier, FRANCE

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1. CAMI context

Medical interventions can still significantly be improved in terms of patient-specific planning and optimal realization. For improving quality of care, senior physicians need to see beyond the immediately visible, to be assisted in real-time in safety-related decision making and access to augmented dexterity. Junior physicians need to train and learn skills efficiently before operating alone. Public health authorities and medical companies require the demonstration of the usefulness of innovations before commitment.

The strategic vision of the Computer Assisted Medical Interventions (CAMI) LABEX is that an integrated approach of medical interventions can allow breakthroughs in terms of quality of procedures, that will be observed by practical service provided to users and patients and by the use of CAMI technologies in clinical practice. The CAMI Labex aims especially at tackling two challenges in the next 5 years: the development of endoluminal interventions and the enhancement of the level of autonomy of robot-assisted medical interventions. This PhD proposal subscribes simultaneously to both challenges.

2. Context and Objectives

Robotics brings many advantages to minimally invasive surgery. Telemanipulation improves notably comfort of use and precision of positioning and displacement of miniature surgical instruments. It is also possible to augment the gestures of the users by providing automatic or semi-automatic modes for specific tasks or parts of tasks. Automatic procedures are largely used in orthopedic surgery or neuro-surgery, where the medical task can be completely defined and planned from pre-operative images.

For surgery in the abdomen and in the digestive tract such automatic modes are however not used for different reasons: a) Generally the medical task is only partly defined from pre-operative images (for instance, for a dissection the trajectory of the electrosurgical tool is only coarsely known beforehand), b) the task implies interactions with deformable tissues, which are difficult to model, and c) the registration with respect to pre-operative images is difficult (deformations, large changes of positons, etc.).

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However, parts of tasks can be realized automatically when they can be defined geometrically directly from intra-operative images (endoscopic camera). Many works have been carried out towards this direction [Nageotte09], [Liu16], [Osa18], [Shademan16], but many practical difficulties remain: registration between robot and intra-operative sensor are subject to errors, interactions with tissues are difficult to predict, models of robots are imperfect (in particular for continuum robots).

In this PhD project, we want to study the possibility to realize semi-automatic tasks by combining autonomous modes with telemanipulation motions through shared control. We will especially consider control schemes where motions are automatically generated and where the user complement or correct the positioning of the robot.

3. Detailed project

The objective of the PhD project is to explore new shared control modes between a robotic system and a user in the case of teleoperated medical robots, in order to perform partly pre-defined tasks.

A direct application concerns endoluminal surgery. The ICube laboratory in Strasbourg is an excellence center for robotic in endoluminal surgery in France. It has developed a telemanipulated robotic platform called STRAS [Zorn18] (see fig. 1), successfully tested in in vivo conditions and currently under transfer to an industrial partner.

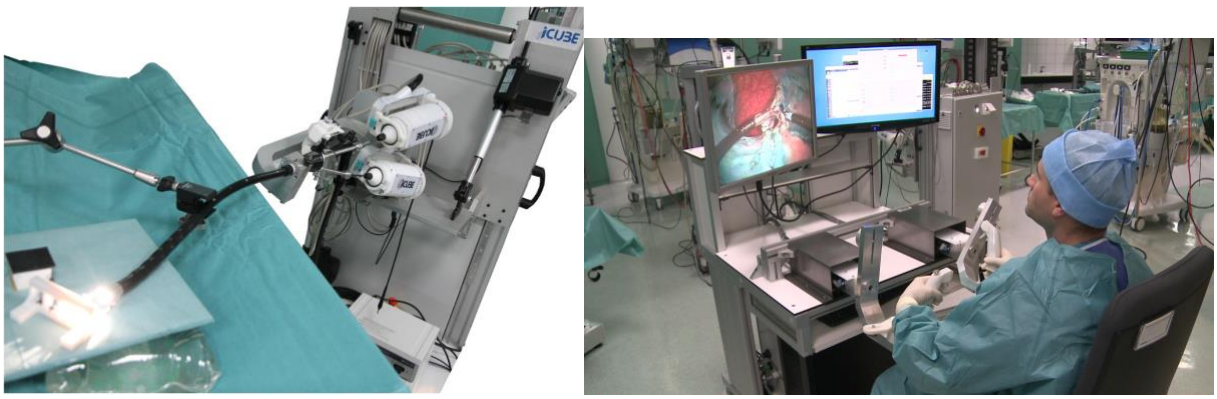

Fig. 1. left: Slave part of the STRAS platform. Right: Telemanipulation during in vivo trials.

A second application is the robotic assistance to tumoral resection in tongue base surgery. The LIRMM laboratory in Montpellier works in collaboration with the ENT team of the Montpellier hospital for developing new tools and methods for force-based elastography for localizing tumoral margins using palpation. This work is realized with the telesurgery platform « Raven » (see fig. 2).

For these two applications, we wish to introduce intelligent modes in order to augment the capabilities of the robots. Several semi-automatic tasks can be envisioned, such as automatic scanning of a region of interest or suturing [Nageotte09].

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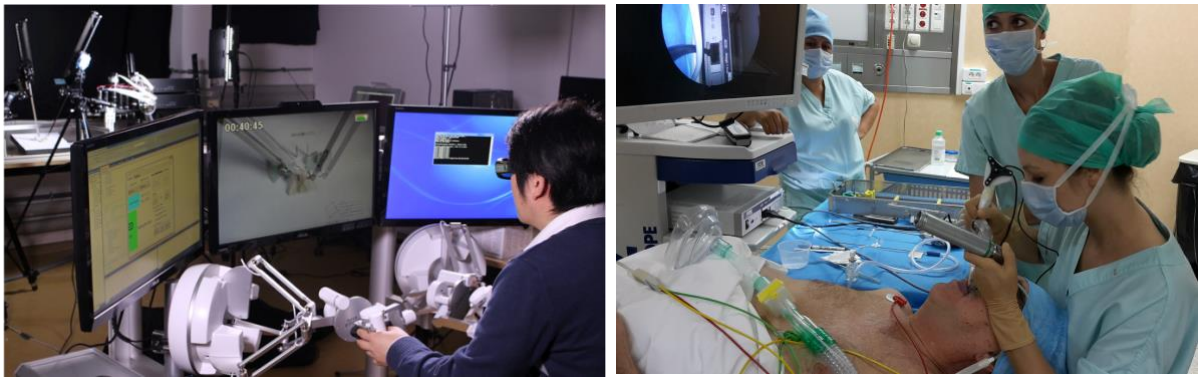

Fig. 2. Left: Telesurgery platform Raven. Right: Force-based elastrography at the Montpellier hospital

Corrective actions by the user seem useful for handling the following cases:

- Error of registration between the robot and the task defined from intra-operative images
- Modelling errors of the robotic system (kinematic model for instance)
- Deformations of tissues created by interactions with the robot
- New constraints appearing during the task realization

Many aspects could be analyzed during this PhD, namely and among others:

- Interaction between the user and the robotic system: Several shared control approaches have been proposed for tasks already performed beforehand [Zeestraten18]. They can be used as a basis for cases where the task has been partly defined but not realized yet. Several cases can be envisioned depending on whether the master interface provides haptic feedback or not.
- Taking uncertainties in the task definition into account: The task will be defined from one or two endoscopic camera(s). Definition errors along the depth will probably be of higher magnitude therefore requiring larger corrections along this direction.
- Adaptation of the control algorithms: Further than immediately correcting the task, the corrections provided by the user could be used to identify modeling errors. An objective will be to allow improvement of the system behavior along time in order to reduce the need for corrections

4. Collaboration

ICUBE brings its expertise in the use and control of flexible robotic system and more generally in robotic system control. The STRAS robotic system will be used during the PhD project.

LIRMM brings its expertise in the domain of surgical robotics and telemanipulation.

5. Required profile

We are looking for candidates who have graduated or will shortly graduate (master level) **with majors in robotics, mechatronics or applied automatic control**. Knowledge in computer vision will be useful for setting up the experimental work. The work will require a significant part of practical experiments, therefore liking of practical work is required. Proficiency in programming languages such as C or C++ is also required.

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6. Application

For applying, the candidates shall send a resume, a cover letter and master grades to: Nageotte@unistra.fr and nabil.zemiti@lirmm.fr

7. References

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