# Control of meso-robots for endoluminal Surgery

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***Abstract*— This work deals with the design, the implementation and the experimental validation of a force-reflecting teleoperation architecture for robotic assisted endoluminal surgery. On that account, a meso-scale surgical robot was used as target device to be teleoperated. This meso-robot was developed during the ARAKNES (Array of Robots Augmenting the Kinematics of Endoluminal Surgery) FP7 project, in which the key idea consisted on transferring the robotic degrees of freedom that are required for surgery inside the peritoneal cavity.**

***Keywords—safety; design framework; adaptive control; dual-quaternion; bilateral teleoperation; surgical robotics; endoluminal surgery***

## I. INTRODUCTION

In order to build the desired teleoperation architecture, several works were carried out:

1. First, the specifics of designing surgical robots were investigated in order to propose a systematic design framework for surgical robotic components that could facilitate the technology transfer from research centers to the operating room.
2. Second, by applying the proposed framework, a generic real-time software architecture for surgical robots was proposed and implemented. This software architecture serves as support for the global teleoperation architecture.
3. Third, the latter teleoperation architecture was developed. This architecture uses adaptive control techniques in which:

   A) An active state observer (AOB) is employed. Moreover, the original Kalman equations (proper of the AOB) were revised and reformulated in order to approximate a Markov chain Monte-Carlo method that allows to better consider, in real-time, nonlinear uncertainties and disturbances that affect the meso-robotic system.

   B) A realistic viscoelastic Kelvin-Boltzmann soft-tissue environment model is also used.

   C) All fundamental (robot) control equations are formulated and performed in the dual-quaternion domain. To that end, one of the first dual quaternion based control toolboxes was implemented.

Such combination of tools and techniques, allowed to demonstrate improved performance of the system with respect to previous works in the field. In this context, two teleoperation schemes of types ``position--position'' and ``position--force'' were proposed in order to fulfill the specific hardware requirements of ARAKNES. Both schemes were analysed in terms of their transparency and stability, i.e. the two parameters that allow quantifying the performance of teleoperated systems.

In addition, having implemented a stable real-time teleoperation control system (and the associated control toolboxes) allowed in turn to study the effects of scaling the positions and the forces, which are respectively commanded and felt by the surgeon. These effects were examined from the point of view of the surgeon's performance and also of the teleopoeration system's performance. In both cases, improvements were observed and it was additionally shown that the availability of online estimated environment's parameters could be exploited to offer surgeons new assistance capabilities that facilitate tasks such as detection of contact and/or discrimination of tissues.

Finally, the possibility of performing wireless control of surgical robots was also explored and experimentally demonstrated. The purpose of this latter study was to increase the mobility of the meso-robot and, possibly, to improve its mechanical performance and/or degree of miniaturization.

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