

Chapter 42

Advances in Robot Surgery

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ABSTRACT

Mini-invasive surgery deserves increasing attention to lower the post-operative stay in hospital and lessen falls-off complications. This leads to the trends in robots, as innovative integrated computer-aided implementations. Out of front-end haptic effectors, the background support is turning to inclusive on-duty functions, e.g., surgical planners, operation assistants, etc., making possible the rethinking of protocols to progressively embed the innovations offered by the micro- and nano-technologies. The chapter brings in surgical robotics, with focus on technology and design issues of the remote-mode operation assistants. The investigation leads to define the technical characteristics of a CRHA, Co-Robotic Handling Appliance, to be purposely developed, to support the duty-split approach surgical planner. The expected features are outlined, including analysis of operation potential of special-purpose contrivances (i.e., automatic changing device of the surgical tools) and of scope-driven enhancers (i.e., exploration of the intervention theatre, IT).

INTRODUCTION

The robotics is multidisciplinary technology, developed to perform tasks in co-operation with, or without direct human intervention. Anthropomorphism is a reduced issue when:

- The tasks to be performed are coherently defined, so that their programming and

control are fully described by protocols and reliably implemented in the intervention theatre;

- The expected duties are out of standard human abilities because of performance complexity and accuracy requirements, hostile surroundings and safety risks, etc. and require sound and rescaled solutions.

The robotics follows, with the typical features of: functionally driven presets; task programming

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and up-dating; oversight of surroundings and intelligence; as well as autonomous management within the given specifications. Surgical robots, similarly, follow this evolution, moving from mainly anthropomorphic configurations, to progressively more duty-driven geometry.

The switch from man-like to duty-driven devices is deemed to occur in parallel with the development of minimally invasive robot surgery, *MIRS* (Lum et al., 2006; Konietzschke et al., 2004; Seibold et al., 2005). Radical advances are expected to have an impact on micro-surgery in deep, narrow body sites; these provide the most difficult challenges for minimally invasive surgery; examples are: neurosurgery with poor visibility due to blood or cerebrospinal fluid; microsurgery in the outer wall for oesophageal, an area not accessible with the traditional endoscope through the mouth; and the like. Similarly, changes are expected with the micro- and nano-technologies, when end-effectors, scaled for very localised interventions, are offered, with accuracy and handling capabilities beyond standard human range.

The robotic achievements are technology-driven with results connected to:

- **Information Infrastructure:** Data acquisition, processing, transmission, validation, vaulting, etc. are continuously expanding options supported by the ICT, and effective computer tools ceaselessly appear to support remote supervision and control. Tele-medicine is acknowledged technology (Reintsema et al., 2004; Guthart & Salisbury, 2000; Intuitive Surgical, 2005), while remote-surgery has chiefly experienced noteworthy accomplishments (Rosen & Hannaford, 2006);
- **Execution Effectors:** Specialised tools and fixtures are most challenging research opportunity today, closely tied to human scale (Cepolina & Michelini, 2004). In the future, surgeons will continue to deal with standard size devices; inner-body equip-

ment will evolve in timely fashion toward micro- and nano-apparatuses, as soon as effective new solutions are conceived and made available (Farokhzad & Langer, 2006; Silva, 2007).

This twofold fall-out, basically, leads to the supplementary developments of <computer integration> and of <functionally-driven instrumentation>, together leading to <computer-aided surgery>.

The biggest research challenge is the simultaneous need for micromanipulation in local interventions, and gross motions at the handling level. This conflict is solved by the master/slave option, to perform micro-manipulation by miniature slaves, scaled from natural size motion by the master controller. This format, however, needs especially implemented information infrastructures, with due focus on the direct and indirect potential of the effectors, but, also, enhanced attention to the opportunities for computer integrated aids.

These aids are the enablers, expanding robotics in planning and inserting surgical interventions more accurately and less invasively, each time confining the effectors to narrow spaces. We expect to see the emergence of four complementary roles:

1. **Surgical Planning:** To integrate accurate patient specific models, surgical process optimisation and a variety of execution protocols, permitting the plans to be fulfilled accurately, safely and with minimal invasiveness;
2. **Surgical Effectors:** To in-progress develop new operating tools, conceived as special-purpose task-driven devices (chiefly, out of anthropomorphic scale), based on the emerging micro- and nano-technologies;
3. **Surgical Ambient-Intelligence:** To expand the special purpose man/robot interface, assuring transfer of the surgeon's expertise, know-how and proficiency, towards the

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