Chapter 22
From Concept to Market:
Surgical Robot Development

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ABSTRACT

Surgical robotics and supporting technologies have really become a prime example of modern applied information technology infiltrating our everyday lives. The development of these systems spans across four decades, and only the last few years brought the market value and saw the rising customer base imagined already by the early developers. This chapter guides the reader through the historical development of the most important systems and provides references and lessons learnt for current engineers facing similar challenges. A special emphasis is put on system validation, assessment, and clearance, as the most commonly cited barrier hindering the wider deployment of a system.

INTRODUCTION

Traditionally, robotics is a combination of mechatronics, electronics and software. The recent development in robot structures and components gradually enabled the rise of smaller scale and fine mechatronic structures that can be used in various applications beyond the industry (Habib, 2006). These trends can also be tracked in standardization activities, the newly released ISO 13482:2014 is the first representative of a new family of standards aimed at service robotics. It applies to personal care robots designed to the quality of life of humans, excluding medical applications. Service robots are to support their users and humanity in various tasks, from elderly care to demining (Habib, 2007).

A rapidly growing field within service robotics is medical robotics, including rehabilitation robotics and surgical systems. In the past decades, numerous different robotic surgery devices have been created, and only a few reached the market. The Medical Robotic Database (Pott, 2014) lists over 450 international surgical robotic projects, of which several dozen are with the potential to become commercially available. Parallel, the

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number of surgical robotics related publications has been steadily rising in the past years (O'Toole et al., 2010), making Computer-Integrated Surgery (CIS) one of the leading areas within medical technology.

CIS refers to the entire field of technology-aided interventional medicine, from image processing and augmented reality applications to automated tissue ablation. CIS means the combination of innovative algorithms, robotic devices, imaging systems, sensors and human–machine interfaces. These systems should work cooperatively with physicians in the planning, execution and evaluation phases of surgical procedures (Taylor & Kazanzides, 2008). A subfield of CIS is called Image-Guided Surgery (IGS), where the digital system is not necessarily involved in the physical part of the operation, but improves the quality of surgery by better visualization or guidance. IGS means the accurate registration (correlation and mapping) of the operative field to a pre-operative (typically Magnetic Resonance Imaging–MRI, or Computer Tomography–CT) imaging or intra-operative (ultrasound–US, fluoroscopy) data set of the patient, providing free-hand navigation, positioning accuracy of equipment, or guidance for a mechatronic system. IGS systems have been successfully prototyped and commercialized, and now being used in neurosurgery, radiotherapy, pediatrics, orthopedics and various other fields.

This chapter introduces the aims and means of surgical robot development, giving a better understanding of the difficulties the field is challenged with through examples taken from existing robots. Medical robots are mostly employed for the accuracy and reliability of their mechanics; however, it may still be hard to fully exploit their features, as surgical tasks are typically unique, involving the semi-autonomous manipulation of deformable objects in an organic, limited environment.

Medical imaging gives the capability to navigate and position a surgical tool at the target point. Furthermore, there is the option to introduce advanced digital signal processing to control or record the spatial point-of-interests and motions (Kazanzides et al., 2010). This can be useful for surgical simulation and risk-free training. Finally, robotized equipment can greatly add to the ergonomics of the procedures. The main advantages of robotic surgery systems–based on (Karas & Chiocca, 2007) and (Lirici et al., 1997)– are the following:

- Superior 3D spatial accuracy provided by the robot,
- Specific design for maximum performance (including miniature robots),
- Stabilization of the instruments within the surgical field,
- Advanced ergonomics supporting long procedures,
- Stable performance,
- High fidelity information integration,
- Invulnerability to environmental hazards,
- Patient advantages (reduced blood loss, less trauma, shorter recovery time),
- Decreased costs (per treatment) due to shorter hospitalization and recovery,
- Possibility to provide better and more realistic training to physicians.

Further optional benefits:

- Improvement of manual dexterity, motion scaling,
- Physiological tremor filtering,
- Integrated 3D vision system with high definition (HD) resolution.

Robots have been introduced to the operating room primarily to provide higher accuracy and dexterity. They can support surgeons with advanced targeting, steady positioning and task execution with a precision beyond human capabilities. Therefore, the treatment delivery accuracy and objective evaluation of interventional systems