Chapter 17
Autonomous Surgical Robotics at Task and Subtask Levels

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ABSTRACT

The revolution of minimally invasive procedures had a significant influence on surgical practice, opening the way to laparoscopic surgery, then evolving into robotics surgery. Teleoperated master-slave robots, such as the da Vinci Surgical System, has become a standard of care during the last few decades, performing over a million procedures per year worldwide. Many believe that the next big step in the evolution of surgery is partial automation, which would ease the cognitive load on the surgeon, making them possible to pay more attention on the critical parts of the intervention. Partial and sequential introduction and increase of autonomous capabilities could provide a safe way towards Surgery 4.0. Unfortunately, autonomy in the given environment, consisting mostly of soft organs, suffers from grave difficulties. In this chapter, the current research directions of subtask automation in surgery are to be presented, introducing the recent advances in motion planning, perception, and human-machine interaction, along with the limitations of the task-level autonomy.

INTRODUCTION

Minimally Invasive Surgery (MIS) reshaped surgical practice significantly during the last decades. Contrary to the traditional technique operating through large incisions, MIS is performed through few-centimeter wide ports—so-called keyholes—using laparoscopic instruments, the area of operation is observed on endoscopic camera stream. Smaller incisions offers benefits both for the patient and the hospital, like lower risk of complications, rapid recovery and thus shorter hospital stay. On the other

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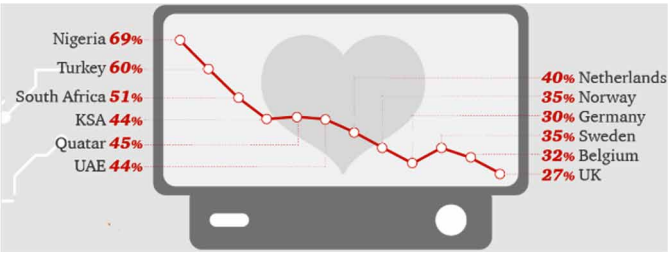
hand, MIS presents new challenges to the surgeons, such as the limited range of motion, different forms of motion, with less Degrees of Freedom (DoF) and also fatigue from weary postures.

Robot-Assisted Minimally Invasive Surgery (RAMIS) was introduced to ease these difficulties. The idea of teleoperated master–slave surgical systems originates from space research: the intervention was to be performed on the patient—in this case an astronaut—by a slave device, controlled by a human surgeon through a master device on Earth (Márton, Szántó, Haidegger, Galambos & Kövecses, 2017; Takács, Nagy, Rudas & Haidegger, 2016). The slave side robot arms are equipped by laparoscopic instruments and an endoscopic camera, and copy the movement of the surgeon next to the remote master console, who is able to observe the operation on the endoscopic camera stream.

In the past years, there has been a strong uptake of Computer-Integrated Surgery (CIS) systems, and their current global annual market potential is estimated at $11.4 bn, with an expected annual growth of 7%, according to a recent study by LG Electronics. Also, more and more people accept the advancement of surgical robotics, although, the willingness was measured lower in the developed countries

Figure 1. International acceptance of robotic surgery. A 2017 study by PwC found that there is growing number of people who would embrace these technologies
(PricewaterhouseCoopers, 2017) Image credit: PwC



in a recent survey conducted by PricewaterhouseCoopers (PwC) (Fig. 1). A recent Eurobarometer poll found that 26% of responders would be comfortable with a robot surgeon operating on them (2% up from 2014)[1], while IEEE found that 62% of people would be willing to allow an AI driven robot to operate on their children if need be[2].

However, real remote teleoperation has not become a daily practice, and stalled at the state of research mainly due to the issues caused by time delay, it turned out that teleoperation itself can present a number of benefits. The communication latency—being the biggest issue—can be reduced to a level that is insignificant for the surgeon by placing the master and the slave devices close to each other; in the case of commercial RAMIS, the master and the slave side devices are in the same room. This technique can reduce the fatigue of the surgeon, being able to operate in a more ergonomic, seated position. Furthermore, the movement of the surgeon can be scaled on the slave side—the most delicate movements can be controlled by relatively large hand movements, and hand tremors can also be filtered.

There is no doubt, that the most successful RAMIS device on the market is the da Vinci Surgical System (Intuitive Surgical Inc., Sunnyvale, CA). The 1st generation da Vinci was cleared by the U. S. Food and Drug Administration (FDA) in 2000, and soon became widely used. In 2019, its 4th generation is available (Fig. 2.), with more than 5300 units installed worldwide, which performed over 1 million procedures last year (Takács et al., 2016).