Chapter 80
State of the Art and Key Design Challenges of Telesurgical Robotics

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ABSTRACT

Telesurgical robotic systems allow surgeons to perform surgical operations from remote locations with enhanced comfort and dexterity. Introduction of robotic technology has revolutionized operation theaters but its multidisciplinary nature and high associated costs pose significant challenges. This chapter provides a comprehensive survey of the current progress in the field of surgical robotics with a detailed discussion on various state-of-the-art telesurgical robotic systems. The key design approaches and challenges are identified, and their solutions are recommended. A set of parameters that can be used to assess usefulness of a telesurgical robot are discussed. Finally, guidelines for selection of a suitable surgical system and the future research directions are described.

INTRODUCTION

Telesurgical robotic systems allow surgeons to perform surgical operations from remote locations. It could be the same room where a surgical operation is being performed or a place somewhere else outside. It could be across two different countries or even cross-continental as demonstrated in "Operation Lindbergh, (Jacques Marescaux, 2002)" where surgeons performed laparoscopic cholecystectomy form New York, USA while the patient was at Strasbourg, France. Similarly, a telesurgery service was established in Ontario, Canada, between a teaching hospital and a rural community hospital located over 400 km away in 2003. It has been nearly twenty years since the emergence of telesurgical robotics in the operating room, but it has been only the last five years or so, that the potential of surgical robotics is being recognized by the surgical community as a whole. Now, it can be said with considerable

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confidence that robotic surgery has demonstrated numerous advantages over conventional surgery and it has revolutionized the operation theater (OT) as well as the surgical techniques.

Some prominent features of this technology are;

- More degrees-of-freedom for the surgical tool manipulation are available than the conventional one.
- Greater precision (even up to <10 micrometers) than the conventional surgical techniques where it is highly dependent of the human hand resolution (100 micrometers typically).
- Less fatigue for surgeons, who now sit in an ergonomic console rather than being in an uncomfortable standing posture required by the conventional surgical procedures.
- Enhanced safety and increased patient trust in surgery by making use of comprehensive safety-critical features.

However, these advantages come at the expense of extremely high costs of these complex machines. It is yet to be determined when the benefits will outweigh the cost associated with these (Camarillo, 2004). Staggering capital and operational costs are a great challenge for the designers and engineers to bring down to a minimum possible level.

Moreover, telesurgical robotics is a multidisciplinary field and requires shared understanding among various professionals like medical doctors, engineers and computer scientists. Due to this diversity, there are various design objectives and meeting them altogether is a challenge in itself. A number of telesurgical robots have been developed so far with the objective of optimizing certain metrics and thus each one of these has its own advantages as well as shortcomings. The main scope of this chapter is to identify key design metrics for telesurgical robots and compare some of the notable existing telesurgical robotic systems accordingly. This information is expected to play a vital role while designing the next generation of telesurgical robots.

MAIN FOCUS OF THE ARTICLE

The main focus of this chapter is to provide a comprehensive survey about telesurgical robotics which can be equally beneficent to engineering and as well as medical professionals. After a brief background, a detailed discussion of various state-of-the-art telesurgical systems is provided. Key design approaches and challenges are identified and their solutions are recommended. A set of parameters that can be used to ascertain the usefulness of a telesurgical robot are discussed. These parameters not only allow one to choose the most suitable option among the existing systems but also could serve as guidelines for the development of next generation telesurgical systems. A separate section is dedicated for the future research directions followed by conclusions.

BACKGROUND

The stereotactic brain surgery by using Unimation PUMA 200 robot is considered the first robot assisted surgery (Kwoh, 1988). In the beginning, there was a dearth of specialized robots custom-designed for medical surgeries. However, industrial robots had developed fully at that time and they were modified to