# Telesurgical Robotics

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## INTRODUCTION

Telesurgical robotic systems allow surgeons to perform surgical operations from remote locations which may be the same room where operation is being performed or somewhere outside. It may be across the 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 first appearance 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 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 of the distinguishing features of this technology are;

- More degrees of freedom (referred sometimes as dexterity) in the surgical tool manipulation 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 the surgeon, who is now seated and working with an ergonomic console rather than the uncomfortable standing posture in conventional surgical procedures.
- Enhanced safety, and thus, increased patient trust in surgery by making use of comprehensive and robust safety techniques.

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 these down to a minimum possible level.

Moreover, telesurgical robotics is a multidisciplinary field and requires shared understanding and communication 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 great challenge. A number of telesurgical robots have been developed so far with the objective of optimizing certain metrics and thus each one of telesurgical robots has its own advantages as well as shortcomings. The main scope of this article is to identify key design metrics for telesurgical robots and compare the existing telesurgical robotic systems accordingly. This information is expected to play a vital role while designing the next generation of telesurgical robots.

## FOCUS OF THIS ARTICLE

The main focus of this article is to provide a comprehensive survey about telesurgical robotics which can be equally beneficent to engineering and as well as medical

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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 can be used as a foundation for the development of the next generation telesurgical systems. A separate section is dedicated for the future research directions in the field 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 these were generally modified to cater the needs of surgery. The Unimation PUMA 200 was also an industrial robot selected with meticulous care for the subject purpose. Since then, many specialized robots have been designed to match the needs of a surgical environment. According to figures at MeRoDa (Laboratory for Biomechanics and Experimental Orthopaedics, Institute for Computational Medicine, n.d.), an online database related to medical robotics, at present, around 41 medical robotic systems are in commercial use and a few hundred systems are under the development stage in academia and research institutes worldwide. Only 03 out of these 41 commercially available systems, i.e., Zeus, Laprotek and Da Vinci, fall under the category of telesurgical robotic systems, and have been able to make success in the surgical market as well.

The reason for such a fewer numbers mainly pertains to the multidisciplinary nature of the field. A successful system requires concerted effort of engineers, medical practitioners, scientists and, to some extent, business professionals. To put all this in a nutshell, the medical professionals are the one who generally raise the need or a problem and engineers are to provide a doable solution. Surgeons act as its evaluators as they happen to be the directed customer-community as well. The business people provide a feasible way to commercialize the technology to make it meaningful. This scheme of things assigns the role and determines the dynamics of interaction amongst the contributing communities.

## STATE-OF-THE-ART

The recent advancements in surgical robotics have led to its enormous usage in practice, making surgical robotics industry worth of more than $0.5 billion per annum. For example, till 2009, da Vinci surgical system of Intuitive Surgical Inc., for laparoscopy, was reported to be installed worldwide at more than 1,000 locations (Alterovitz & Desai, 2009). Moreover, it has been successfully used for thousands of surgical procedures globally. This success has increased the interest of researchers and investors, and therefore, a number of other systems have been built since then. According to one study, the worth of surgical robotic industry has been estimated to reach $1.5 billion till 2018 (Global Industry Analysts, 2012).

Here, we describe some of the successful and widely researched telesurgical robots while highlighting their key features and capabilities.

### Zeus Surgical System

The Automated Endoscopic System for Optimal Positioning (AESOP), a four DOF endoscopic manipulator, was developed by the Computer Motion Inc. AESOP was not a telesurgical system itself but it had been utilized as a building block for many other systems, including Zeus (Holt, 2004), developed by the merger of Computer Motion Inc. and Intuitive Surgical Inc. in 1995. It received the US Food and Drug Administration (FDA) approval in 2001.

Zeus comprised of three robotic arms attached to the OT bed. One robotic arm used the AESOP technology with a 3D high quality digital camera, while the other two were used for the surgical procedures. Zeus was the first telesurgical robot based on master-slave topology. The surgeons used a small master manipulator of 6 DOF to move the robotic arms (Holt, 2004). Zeus system is no more in production (Jyotsna Dwivedi, 2012) and has been superseded by the da Vinci surgical system.

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