Chapter 30
Medical Manipulators for Surgical Applications

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ABSTRACT

Great advances have been made over the last decade with respect to medical manipulators for surgical robots. Although they cannot replace surgeons, they can increase surgeons' abilities to perform surgeries with greater therapeutic effectiveness. These advanced surgical tools have been implemented in complex, precise, repetitive, and difficult surgeries. This chapter reviews medical manipulators used in surgical applications. At present, several kinds of medical manipulators have been developed to perform a variety of surgical procedures and can be classified into different categories. Here, the authors discuss general design principles and summarize and classify medical manipulators based on joint category and level of autonomy, with illustrations of applications. Finally, a brief synopsis is provided.

INTRODUCTION

In the last decade, great progress has been made in medical robot-assisted surgery. Compared with conventional manual surgery, medical robots can perform precise movements with high levels of dexterity and accuracy without fatigue-related manual tremor (Yousef et al. 2010). Medical manipulators have been used to handle various kinds of surgical tools or instruments, assisting surgeons to perform repetitive, precise motions. For these reasons, medical manipulators are implemented during complex, precise, repetitive, and difficult surgeries (Hockstein et al. 2007; Taylor 2006; Taylor and Stoianovici 2003).

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GENERAL DESIGN PRINCIPLES

The first medical application using an industrial manipulator was implemented in the 1980s (Kwoh et al. 1988). However, applications in the medical environment are quite different from those in the industrial environment. It is important to consider design principles for medical manipulators in clinical applications (Taylor and Stoianovici 2003).

1. Safety is the most challenging issue for medical manipulators, which are in close contact with surgeons, patients, and the environment (Duchemin et al. 2004).
2. To date, medical manipulators have served as surgeon assistants; therefore, they should be accessible to clinical staff during operations. Medical manipulators should be lightweight and compact but have sufficient strength and dexterity, and high accuracy to be compatible with different operating theatres with respect to their intended use (Taylor and Stoianovici 2003).
3. The degrees of freedom (DOF) configuration should be reasonable so that the inverse kinematics of medical manipulator is simple with analytical solutions rather than arithmetic solutions. Analytical solutions of inverse kinematics are convenient for robot control, especially master-slave control, by virtue of their short processing time.
4. Medical manipulators must be easy to install and layout in clinical applications.

THE CLASSIFICATION OF MEDICAL MANIPULATORS BY JOINT CATEGORY

According to the automatic degree of each joint, medical manipulators can be divided into three types: all-active joints articulated, all-passive joints articulated, and active-passive-combined joints articulated.

Active Joint Articulated Medical Manipulator

Medical manipulators with all-active joints are used in most surgical robotic systems. The advantage is that the robot can perform automatic surgery with high accuracy and stability. However, the disadvantage is that the motors and transmission structures are complex or cumbersome. Furthermore, all-active joints articulated medical manipulators are associated with greater risk for unexpected system errors.

The Robodoc system (Figure 1) is a five-active-joint SCARA robot that is used to core the femoral head for hip-replacement prostheses. The active joint articulated manipulator can automatically orient the rotary cutting tool in any direction within the workspace (Hockstein et al. 2007; Kazanzides et al. 1992).

Another example is the MicroHand medical manipulator (Figure 2), which was designed for microsurgery. The slave manipulators (left and right hands) of Microhand have cable-driven structures (Wang et al. 2005).

An example of an all-active joints articulated medical manipulator, developed by the author's group, was designed for microwave ablation in liver cancer (Figure 3). It is used to accurately position the needle-guiding hole, by which the microwave ablation needle can be injected into

Figure 1. The Robodoc medical manipulator (Pransky 1997)

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