RESEARCH ON ROBOTS USED IN SURGICAL APPLICATIONS

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Abstract: Nowadays robotic technology provides massive advantages over traditional procedures, including shorter hospitalization and rehabilitation time, and less pain and discomfort. This paper presents the fundamental requirements of a surgical robot, its applications, advantages and disadvantages of different topologies and concludes with a comparison between surgical robots and surgeons.
Keywords: medical robots, surgery

1. Introduction

Medical robots are a type of service robots that are used in hospitals in order to improve the level of patient care. They also reduce the medical personnel workload, therefore allowing them to spend more time for the patient care.

Today there is a high diversity of applications in which medical robots are being used, like surgical robots, telemedicine robots, disinfection robots, blood-drawing robots and exoskeletons, which provide external support and muscle-strengthening exercise for a faster recovery.

Surgical robots are computer-controlled devices that can be programmed to position and manipulate various surgical instruments, with the purpose of helping the surgeon to perform more difficult and complex tasks. Like William Peine said, "Robots don't perform the surgeries, but they are tools that give the surgeon more dexterity". These robots may vary in shape and functionality, but they all share the same purpose: improve the quality and the accuracy of the healthcare services.

Most of the surgical robots that are currently on the market have a complex system structure and they often require large operation rooms and high configuration time. Therefore, future developments should focus on a new type of surgical robots, with a reduced size, weight, shape and robotic system complexity, improved decision-making and less time required for intervention and configuration.

The number of minimally invasive surgeries is expected to increase over the next decade, while some aspects of robotic surgery will replace or complement the open surgery. This is due to the many benefits of this type of surgery: better accuracy, smaller incisions, reduced recovery time, less amount of blood loss and hospitalization time. This will also have a major impact on the number of surgical robots used.

2. Fundamental Requirements of a Surgical Robot

This chapter presents the fundamental requirements which a surgical robot must meet in order to be used in the operation room. They are presented schematically in figure 1.

These requirements refer only to the actual architecture of the robot and do not take into consideration any specific requirements of data acquisition systems or control systems.

Among all these requirements, the most important one is the reliability requirement. It consists of seven criteria that must be met. These criteria are shown in figure 2.

The second requirement, compactness, ensures that the robot does not take up a large amount of essential space in the operating room and facilitates its relocation to other positions for different tasks.

The third requirement refers to the easy operation of the robot, to improve the learning time for the surgeons.

The last, but not the least, requirement is the requirement for simple sterilization. This requirement is crucial since any instrument in the operating room must be sterilized or covered with a sterile field to prevent the risk of infection.

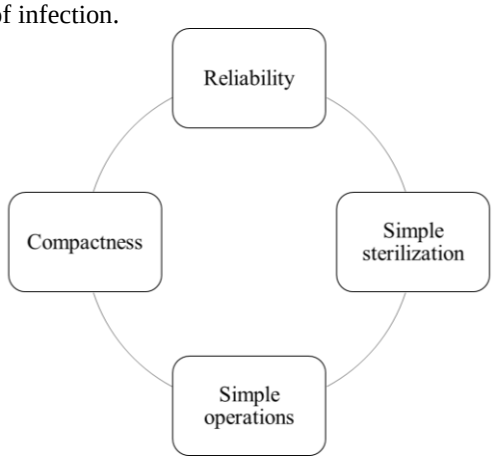

Fig. 1. Fundamental requirements of a surgical robot

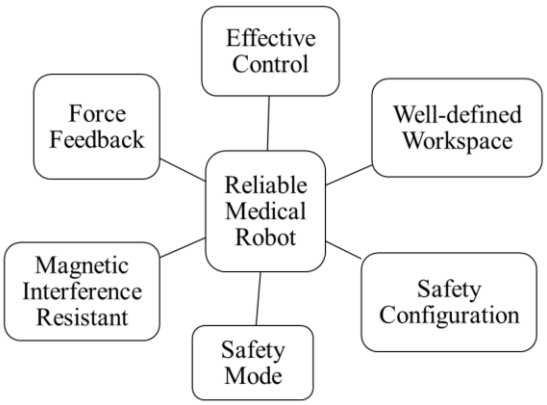

Fig. 2. Reliability criteria

3. Comparison between Serial Robots and Parallel Robots

Due to the presence of prismatic and spherical kinematic joints, the arms of the parallel robot are subjected only to traction and compression, and not to bending. This increases the positioning accuracy and allows a reduced structure. Parallel robots also have a higher rigidity since the mobile platform is supported by several arms simultaneously.

The main disadvantage of parallel robots is the limited working space, thus it is possible for their arms to collide. In addition, each arm has several passive joints which have their own mechanical limitations.

Another disadvantage of parallel robots is that they can completely lose their rigidity in singularities. Therefore, the robot receives additional degrees of freedom, which are uncontrollable, thus it begins to tremble.

However, due to their characteristics, parallel robots are considered to be more suitable to be used in medical applications, compared to the serial robots.

Tab. 1

CHARACTERISTICS	SERIAL ROBOT	PARALLEL ROBOT
Accuracy	Low	High
Repeatability	Medium	High
Workspace	Large	Limited
Stiffness	Low	High
Velocity & Acceleration	Low	High
Inertia	High	Low
Workspace/ Robot size ratio	High	Low
Payload/ Robot weight ratio	Low	High

4. Applications of Surgical Robots

In this chapter are presented the most common applications of the surgical robots. As presented in table 2, surgical robots are used in all kinds of medical areas, including otorhinolaryngology, ophthalmology surgery, colorectal surgery and urology surgery.

Tab. 2

SURGICAL APPLICATIONS	
General Surgery	• Gastric bypass • Gastrectomy • Esophagectomy • Colectomy • Splenectomy • Cholecystectomy • Pancreatectomy
Cardiothoracic surgery	• Coronary bypass • Pericardiectomy • Lobectomy • Mitral valve repair • Interventricular repair • Tumor resection
Neurosurgery	• Brain surgery • Microsurgery • Schwannomy resection
Orthopedic surgery	• Total hip replacement • Total knee replacement • Bone surgery • Anterior cruciate ligament
Urologic surgery	• Cystectomy • Pyeloplasty • Pelvic node dissection • Radical prostatectomy • Nephrectomy • Ureteral reimplantation
Ophthalmic surgery	• Cornea surgery • Vitreoretinal surgery
Otorhinolaryngology	• Amygdala and tongue • Middle ear • Resection of supraglottic • Transoral surgery pharyngeal and laryngeal
Gynecology surgery	• Endometriosis • Myomectomy • Hysterectomy • Anastomosis of uterine tubes • Salpingooforectomy

Tab. 2 (sequel)

SURGICAL APPLICATIONS	
Colorectal surgery	• Rectum resection • Diverticulitis • Colectomy
Pediatric surgery	• Closure of the ductus arteriosus • Pyeloplasty

5. Advantages, Disadvantages and Possible Improvements

This chapter presents the advantages and disadvantages of the robotic surgery in different medical areas. It also shows the possible improvements that can be made in order to improve the overall process.

Tab. 3

MEDICAL AREA	ASPECTS
General Surgery	• Expensive • Operating time
Cardiothoracic surgery	• Expensive • Operating time • Limitations with conventional laparoscopic instruments
Neurosurgery	• Expensive • High degree of security and reliability
Orthopedics	• Expensive • Tibial alignment • Knee alignment • Femoral alignment
Urology	• Expensive • Operating time • Lack of tactile feedback
Ophthalmology	• Learning curve • Poor judgement • Expensive • Maintenance cost
Otorhinolaryngology	• Expensive • Poor judgement • Maintenance cost • Inability to use CO_2 laser

Tab. 3 (sequel)

MEDICAL AREA	ASPECTS
Gynecology	• Expensive • Lack of tactile feedback • Inability to reposition the patient • Bullkiness
Colorectal surgery	• Expensive • No differences found in operating time and length of hospitalization
Pediatrics	• Expensive • Larger size of the robotic instruments compared to the pediatric patient

6. Advantages and Disadvantages of Surgeons and Surgical Robots

In this chapter are presented the main advantages and disadvantages of surgeons and surgical robots. As it is presented in table 4, both have its strengths and its weaknesses.

Tab. 4

	SURGEON	SURGICAL ROBOT
ADVANTAGES	• Good judgment • Easy to be informed • Processes complex information • Flexible and adaptable	• Small incisions • High accuracy • Increased dexterity • Higher maneuverability of surgical instruments • Better view of the surgical field • Eliminates the risk of shaking hands • Reduced recovery time • Easier access to hard-to-reach areas in the human body • Reliability, performance and high speeds • Resistant to radiation, tremor and fatigue

Tab. 4 (sequel)

	SURGEON	SURGICAL ROBOT
DISADVANTAGES	• Limited dexterity • Limited geometric accuracy • Prone to fatigue and trembling • Prone to radiations and infections	• High equipment and maintenance cost • High surgery and treatment cost • Risk of equipment failure • Risk of programming errors • High programming difficulty • Delay in orders execution

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