Design and Fabrication of RCM structure used in Surgery Robot System

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Abstract. Minimally invasive surgery is performed by using a slender rod-shaped surgical tool to penetrate into the body through a tiny incision on the surface of the human body. Compared with traditional open surgery, minimally invasive surgery can reduce surgical incisions and surgical scars, shorten recovery time, reduce bleeding volume and complications. At present, minimally invasive puncture surgery is basically performed by experienced physicians. The puncture procedure lasts for a long time and the physician's energy is limited. Therefore, the development of automated minimally invasive puncture robots is of great significance. This paper studies the structure and control of remote motion centers in minimally invasive surgical robotics.

1. Introduction
In order to meet the requirements of avoiding X-ray radioactive radiation injury and precise remote positioning of the puncture needle during the minimally invasive puncture surgery, the telescopic needle remote guiding robot and key components for minimally invasive surgery are developed to meet different parts and posture patients. The clinical needs of minimally invasive puncture.

Research and development of the virtual remote center of motion (Remote Center of Motion), six-degree-of-freedom manipulator path planning study, to ensure precise positioning and precise adjustment of the puncture needle; develop remote control operation and human-computer interaction platform to avoid radiation damage of doctors and reduce doctor labor strength.

To make surgery based on a more precise, more stable and procedural basis, develop a minimally invasive surgical needle remote control guiding robot with independent intellectual property rights.

Operating the surgical system requires absolute reliability, safety, and flexibility. Therefore, it is generally necessary to maintain the operation at a medium and low speed during operation so as to be able to correct and avoid accidental injury in time. Secondly, the intuitiveness of the robot ensures the operator's convenient and quick operation.
During the operation, the movement of the puncture needle is always limited by the puncture point of the body surface. The operation movement of each puncture needle is carried out around the puncture point, and the minimally invasive entrance is regarded as a point. A motion that maintains a point or expands in a smaller range and is operated by degrees is called a distal center motion. That is, during the adjustment of the posture of the puncture needle, it is also necessary to ensure that the needle tip position coincides with the puncture point. The constraint of this point on the puncture tool is called the fixed point constraint. This is the key and difficult point of the fixed-point adjustment posture when the minimally invasive surgical needle remote control guiding robot performs the puncture operation.

During the entire procedure, it must be ensured that a certain point or part of the instrument is always operated around a fixed point or a small area, without the need for additional constraints on the mechanical hinge. Such a mechanism is called a “distal virtual motion center” (Remote Center of Motion, or RCM). The most obvious operational feature of minimally invasive surgery is the operation of various operations around the incision of the epidermis. Therefore, the RCM mechanism is widely used in various types of minimally invasive surgical instruments. The most successful one is the minimally invasive surgery robot. The promotion has far-reaching significance.

2. Remote center of motion structure
If a certain part of a certain point of the mechanism is always moved away from a fixed point of the mechanism itself (or is constrained in a very small space) and the point is free of physical hinge constraints, then such a mechanism can be called "Remote Center of Motion".

The characteristics of this type of mechanism coincide with the operational characteristics of minimally invasive surgery, which has been extremely successful in minimally invasive surgical robots.

RCM uses the constraints of the structure itself to implement a minimally invasive surgical robot that does not introduce redundant degrees of freedom. Instead, it relies on a specially designed machine to allow a portion of the robot to always pass through a fixed point of space during motion. In percutaneous puncture surgery, in order to ensure the safety of the operation, the puncture needle must be fixed-point movement around the body surface incision. The methods for achieving fixed-point movement include passive joint, active control, and remote motion center mechanism.
Curved rail RCM mechanism as shown in Figure 3. The center of the curved guide rail is P, and the surgical tool is disposed on the guide rail seat in an arbitrary radius direction, and the design axis drives the overall movement of the guide rail through the rotary joint of the point P. In this way, when the tool moves under the action of the rotating joint and the moving joint, it will always pass the P point, thereby meeting the requirements of the minimally invasive surgical entry point constraint.

The paper studies the adjustment of the needle posture of the puncture robot by the curved guide rail and the double parallelogram. The RCM structure was shown in Figure 4 and Figure 5.
Figure 5. RCM structure with curved guide rail
After machining, the paper completed the structure of the remote motion center of the two structures, as shown in Figure 6 and Figure 7.

Figure 6. RCM mechanism with double parallelogram construction

Figure 7. RCM mechanism with curved guide rail

3. Remote center of motion structure

3.1. The overall structure of the surgical robot
The surgical robot structure scheme mainly includes a multi-degree-of-freedom robot arm, an operation platform and a fixed base composition as shown in figure 8. The final surgical robot was shown in figure 9.
The robot can be controlled by remote control or manual dragging to achieve spatial position adjustment of the end surgical tool.

3.2. Software and operating platform of Surgical robots

The control system of the surgical puncture robot adopts the distributed control (DCS) system architecture. The distributed control system adopts the design idea of decentralized control and centralized management and is divided into autonomous and comprehensively coordinated design principles, with hierarchical architecture.

The control system is as shown in the figure 10, the height is adjusted to trigger the stepping motor to drive the screw to achieve a certain height through the button; the passive joint locks the relevant position by manually changing the relevant position, and then locks the lock pressure and displays the lock pressure and monitors in real time. Pressure and joint angle; the angle of the RCM mechanism is adjusted for remote control in different rooms. The angle is adjusted by the wireless controller or the computer control platform, and the relevant state is displayed. The final puncture needle is also controlled in the same way.
The control system of the surgical robot was mainly divided into the mechanical arm drive control part, the industrial computer program control part, and the upper computer software part. The console and software were shown in Figure 11 and Figure 12.

4. Conclusion
Combining robotics with traditional minimally invasive techniques is widely recognized as a way to effectively address the shortcomings of traditional minimally invasive techniques. By implementing the rapid positioning and precise attitude adjustment of the passive arm and the RCM mechanism respectively, the project can realize the function of the minimally invasive surgical needle remote guiding robot. Through the error analysis, the performance index of the minimally invasive surgical needle remote guiding robot can be guaranteed.

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