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Forceps Manipulator with Gimbal-mounted Parallel Linkage and Belt-Pulley Slider for Laparoscopic Surgery

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***Abstract*— A new 3-DOFs forceps manipulator with a gimbal-mounted parallel linkage for the pitch and the yaw axes, and a belt-pulley slider for the insertion axis attached to a commercial forceps has developed that can be used by a surgeon as a third arm during laparoscopic surgery. A prototype was constructed, and the performance was evaluated.**

I. Introduction

Laparoscopic surgery producing small scars has become widespread. By integrating locally operated surgical assistant robots such as forceps robot [1] and a laparoscope robot [2-3] in a sterilized area, a surgeon can perform robotically assisted laparoscopic solo surgery. For intuitive pivot manipulation of the forceps robot in a wide working area on the abdominal wall, mechanical remote center of motion (RCM) is suitable, and the robot should occupy a small space. In the present study, a new 3-DOFs forceps manipulator with a mechanical RCM that can act as a third arm for the surgeon was constructed, manually controlled forces for the easy rough positioning was evaluated.

II. Methods

A manipulator with 3-DOFs (pitch, yaw, and insertion) was developed as shown in Fig. 1. The prototype is motor driven after positioning at the initial orientation manually. The manipulator consists of a gimbal-mounted parallel linkage for the pitch and yaw axes, and a belt-pulley slider for the insertion axis attached to a commercial forceps. The operating range is 0 to 90 ° for the pitch axis, ± 45 ° for the yaw axis, and 0 to 200 mm for the insertion axis as shown in Fig. 2. The dimensions of the manipulator are 180 mm × 270 mm × 300 mm. The mass is 1.7 kg. The positional accuracy at the tip of the forceps when loaded by 3 N is 0.2 mm for the pitch axis, 0.4 mm for the yaw axis, and 0.2 mm for the insertion axis. The mechanical deflection is 1.3 mm, 0.2 mm, and 0.3 mm respectively.

The manually controlled force of the unpowered prototype for the three axes were measured using a force gauge (resolution 0.01 mm, max working load 50 N, ZP-50N, IMADA). The force was defined as the averaged static force at the initiation of the movement in five trials.

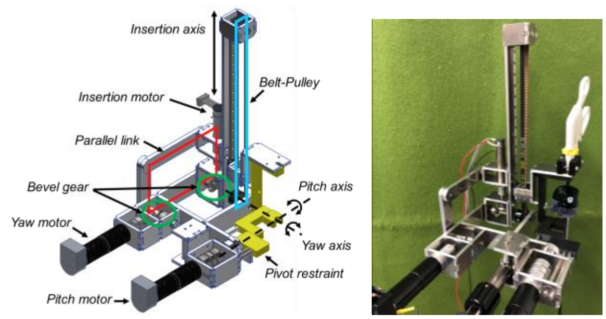
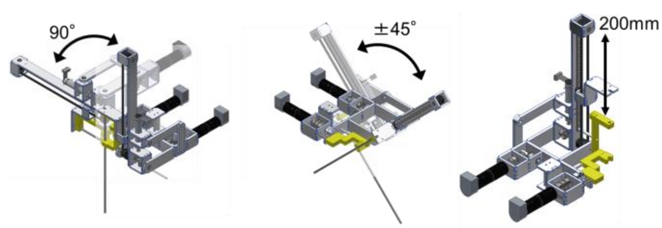


Figure 1. Mechanical design and prototype of the manipulator



Pitch axis Yaw axis Insertion axis

Figure 2. Operating range of the prototype

III. Results and Discussion

The manually controlled measured torque at the tip of the forceps was 1.3 Nm in the pitch axis and 0.5 Nm in the yaw axis. The manually controlled force at the handle part of the commercial forceps was 4.3 to 8.7 N for the pitch axis, 1.7 to 3.5 N for the yaw axis, and less than 6.5 N for the insertion axis. Future works include reducing the manually controlled force in the pitch axis under consideration of the center of gravity, and applying simulated surgery.

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