COVER: Compact Oblique-Viewing Endoscope Robot for laparoscopic surgery

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Abstract. We developed a new laparoscopic manipulator to substitute for the human assistant, which utilizes the property of oblique viewing laparoscopes. Instead of panning around the fulcrum to move the laparoscopic field of view to left/right in the case of the "straight-viewing" laparoscope, only the scope cylinder of the "oblique-viewing" laparoscope attached to the manipulator rolls about its axis. By implementing this mechanism, we have developed more compact, simple, and easier laparoscope manipulator than ever. To evaluate the validity of this system, we conducted a laparoscopic surgery experiment in an *in vivo* environment. As conclusions, the proposed oblique-viewing endoscope manipulator could substitute for the human assistant during the operation.

Keywords: Oblique-viewing endoscope, Compact medical robot, Minimally invasive surgery, FAce MOUSe

1. Introduction

Recent years, many laparoscopic surgical operations are performed because of the advantage of fewer traumas. In this surgery, the surgeon performs the operation by using long surgical tools and a laparoscopic camera. The assistant holds the laparoscope for the surgeon and positions the scope according to the surgeon instructions. This method of operation is frustrating and inefficient for the surgeon, because commands are often interpreted and executed erroneously by the assistant.

To solve these problems, various laparoscopic robots have been developed[1]-[5]. For example, the AESOP system [2] developed by Computer Motion Inc. is an endoscope manipulator which consists of a robotic arm with a cylindrical base clamped to the side of the operating table. The EndoAssist [3] from Armstrong Healthcare Ltd. is a floor-standing arm. Clinical trials of the two endoscope manipulators are generally favorable as the lack of fatigue and tremor in the robot arms leads to a stable camera image and the safety and effectiveness of the surgery is not adversely affected. Although these endoscope manipulators perform well, they are generally large, heavy, complex, and expensive. In the limited space of a typical crowded operating room, the base of the conventional robot arms occupies a considerable amount of floor space next to the patient and the robot arm holding the endoscope may restrict full access to the abdomen of the patient.

To cope with this problem, several compact laparoscope positioning systems have been devised [6]-[8]. These systems, however, require “customized” laparoscopes with special and/or actuated devices.

We developed a new compact and light laparoscopic manipulator, which utilizes the property of oblique viewing laparoscopes. To evaluate the validity of this system, we conducted a laparoscopic surgery experiment in an in-vivo environment. As conclusions,

the proposed oblique-viewing endoscope manipulator could substitute for the human assistant during the operation.

2. Methods

We have developed a new Compact Oblique-Viewing Endoscope Robot (COVER) with the FAce MOUSe (FAMOUS) [1] interface (see Fig.1). The FAMOUS is an image-based human interface which tracks the surgeon's facial motions robustly in real time and does not require the use of any body-contact devices, such as head-mounted sensing devices. The surgeon can easily and precisely control the motion of the laparoscope by simply making the appropriate face gesture, without hand or foot switches or voice input.

The COVER has a 30-degree oblique viewing laparoscope and three degrees of freedom (Fig.2, Fig.3):

(A) Slide along the longitudinal axis of the laparoscope (L_2)
(B) Tilt up/down around the fulcrum on the abdominal wall (θ)
(C) Rotation around the laparoscope axis (φ)

Instead of panning around the fulcrum to move the laparoscopic field of view to left/right in the case of the "straight-viewing" laparoscope, only the scope cylinder of the "oblique-viewing" laparoscope attached to the manipulator rolls about its axis (Fig.4, Fig.5). By implementing this mechanism, we have developed more compact, simple, and easier laparoscope manipulator than ever.

The COVER can be easily mounted at the end of the operation table using a conventional passive instrument holder. This allows the surgeon to reposition the endoscope manipulator by hand at any time during the operation.

The measured parameters of the current endoscope manipulator (see Fig.2, Fig.3) are as follows:

Size: L_1 = 110mm, $215 \leqq L_2 \leqq 302$ mm
Mass: 860 g
θ: $25 \leqq \theta \leqq 135$ deg
φ: $-45 \leqq \varphi \leqq 45$ deg

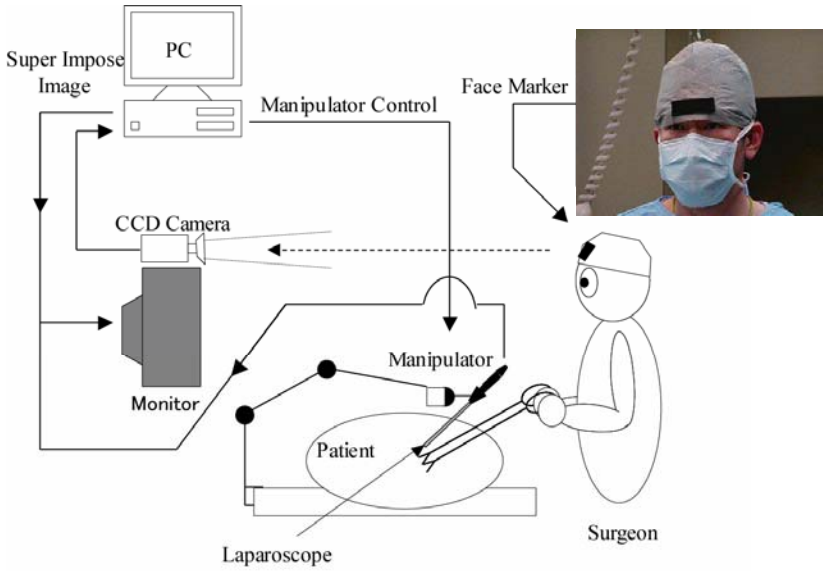

Fig.1. System configuration of the COVER using the FAce MOUSe.

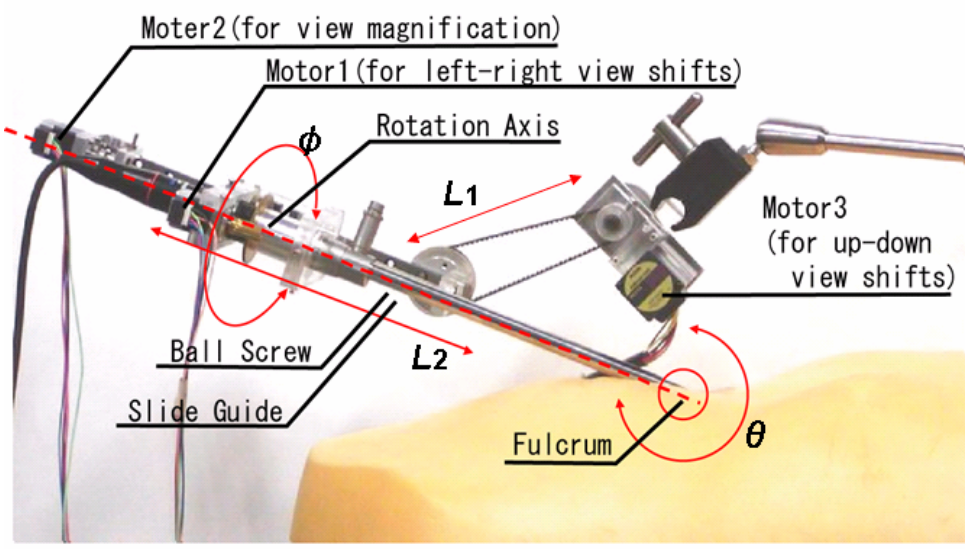

Fig.2. Overview of the Laparoscopic Manipulator.

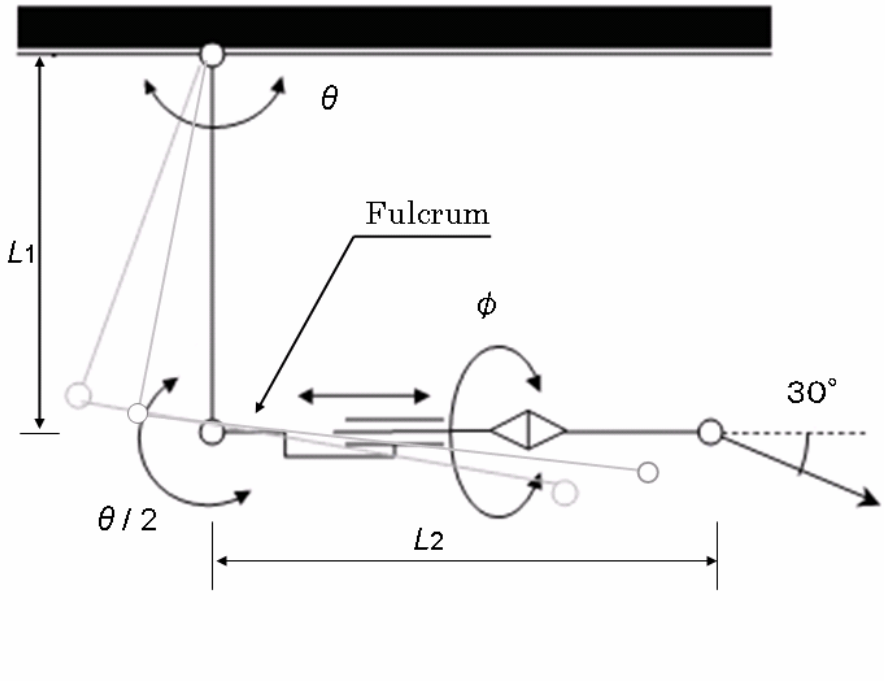

Fig.3. Kinematics and parameters.

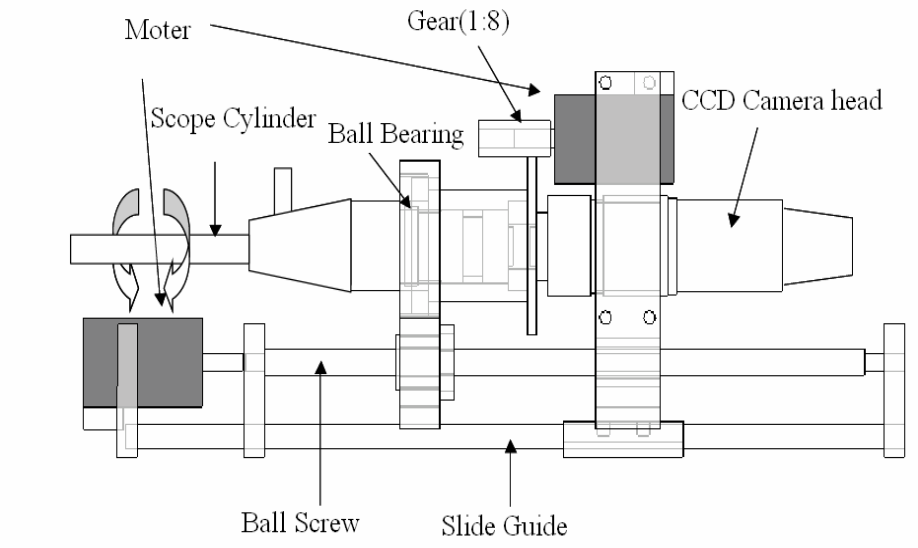

Fig.4. Manipulator mechanism.

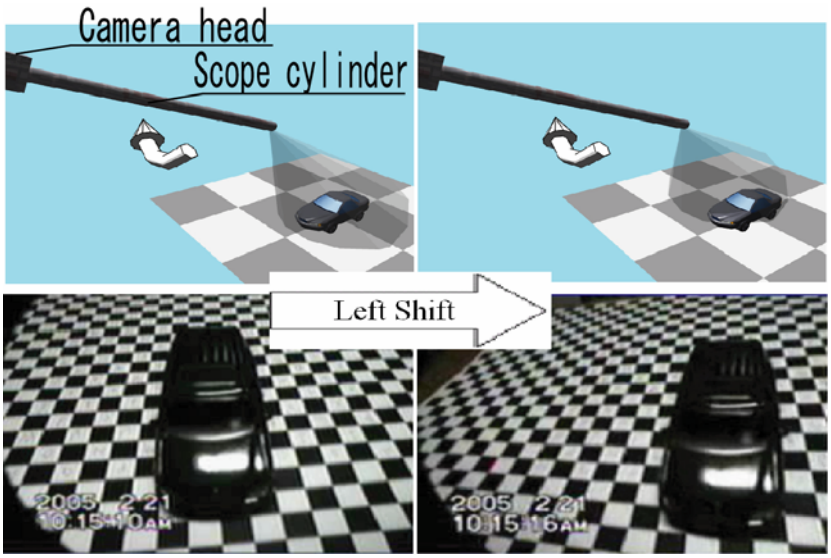

Fig.5. Oblique-viewing endoscopic images obtained by rotating the scope cylinder.

3. Results

To evaluate the validity of this system, an in-vivo laparoscopic cholecystectomy was performed on a pig. A photograph of the in-vivo experimental setup is shown in Fig.6. Instead of a human camera assistant, the system was used for the entire procedure until the removal of the gallbladder after trocar insertion. As a result, the whole operative procedure was successfully and safely completed by a single surgeon (Fig.6), which means the realization of "Solo-surgery". There was no need to re-setup the laparoscope manipulator during the operation. The operation time inclusive from trocar insertion until the removal of the gallbladder was about 62 min.

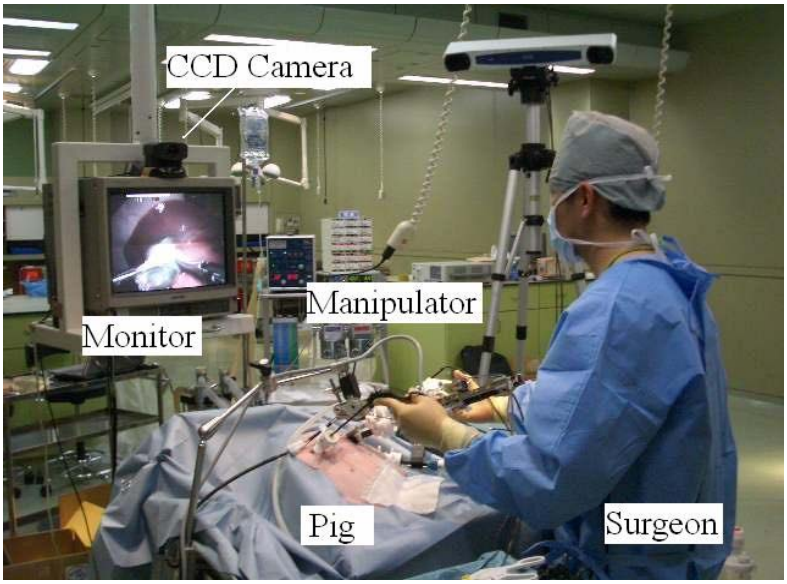

Fig.6. In vivo surgical experiment using the COVER.

4. Conclusion

We have designed a new compact laparoscopic robot called COVER, to minimize the size and the workspace and to avoid the interferences with surgeons. As conclusions, the proposed oblique-viewing endoscope manipulator could substitute for the human assistant during the operation.

Acknowledgements

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