A Mechatronic Interface for using Oblique-Viewing Endoscopes with Light Weight Robots for Laparoscopic Surgery

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***Abstract*—No mechatronic interface exists between a robotic arm and an oblique-viewing endoscope with rotational actuation and without kinematic singularity.**
Therefore, we developed an interface between a Franka Emika Panda manipulator and a rigid 30 degree oblique-viewing endoscope by Storz, which can be used during laparoscopic surgery. The design is easily adaptable to other camera heads and robotic arms.
As a next step, we will compare the design to a 30 degree endoscope without utilization of the rotational degree of freedom and to a 0 degree endoscope.

***Index Terms*—Laparoscopic surgery, 30 degree oblique-viewing endoscope, Franka Emika Panda robot, mechatronic interface, robot-assisted surgery**

I. Introduction

There are significant advantages of laparoscopic surgeries in comparison to conventional interventions. Reduced trauma, the possibility of solo surgery, and performing interventions on an outpatient basis, just to name a few.
Recently, several researchers have focused on robotic-assisted systems for laparoscopy to address the limitations and challenges placed on the surgeon [1]. However, many challenges and limitations remain in the current state-of-the-art technologies, such as limited space in the operating field and ergonomic difficulties. Surgeons that perform minimally invasive surgery experience work-related pain more often than open-approach surgeons [2].

II. Related Work

There are several robotic-assisted systems with the aim of holding an endoscope to relieve the human assistant and make solo surgery possible. A survey of motorized endoscope robots by Bihlmaier [3] from 2016 shows the history and development of these systems. However, there is still a need for an interface that provides the utilization of a 30 degree oblique-viewing endoscope with a robotic arm where the endoscope can be rotated relatively to the camera. Without relative rotation it is necessary to rotate the images afterwards to provide a stable orientation on the monitor. This image processing step leads to a loss of information and longer calculation time. Furthermore, it is necessary to determine the amount of required subsequent rotation of the image.
Without the utilization of a robotic arm, the system has to be held by a human assistant or mounted on a passive instrument holder, which requires to be released and re-positioned by hand frequently. A robotic manipulator provides a higher degree of spatial flexibility during surgery.

III. Design

Our design yields a robot with eight degrees of freedom (DoF) including the Franka Emika Panda manipulator (7 DoF) and a rigid 30 degree oblique-viewing endoscope with mono vision (1 DoF). As a means of sterility, the entire system is covered with a disposable plastic surgical drape during interventions. The interface is controlled through a ROS node or a Qt GUI with absolute or relative endoscope target angles. Fig. 1 illustrates the overall design view, including the Franka Emika Panda robotic arm, shown in dark grey. All parts that are necessary to mount the camera head on the robotic arm are shown in blue. Motor and potentiometer are depicted in green and the planetary gear system that transforms the movement of the motor onto the endoscope shaft is red. The endoscope, including camera head, is illustrated in black. The realization of the design and experimental setup is shown in Fig. 2.

IV. Results

We developed an interface between a robotic manipulator and an oblique-viewing endoscope with actuated relative rotation between endoscope shaft and camera head.
With the utilization of a 30 degree endoscope, which represents the current standard of care in clinics, it is possible to obtain left or right view shifts, even behind undercuts, through rotation of the endoscope. On the other hand, a 0 degree endoscope has to be moved horizontal and vertical to get the same view shift; a task that requires more space in the already scarce operating field. Furthermore, trajectory length in the joint space of a 0 degree endoscope can be larger, compared to a 30 degree endoscope. Thus, a trade-off remains between a less complex mechanism and the necessary space

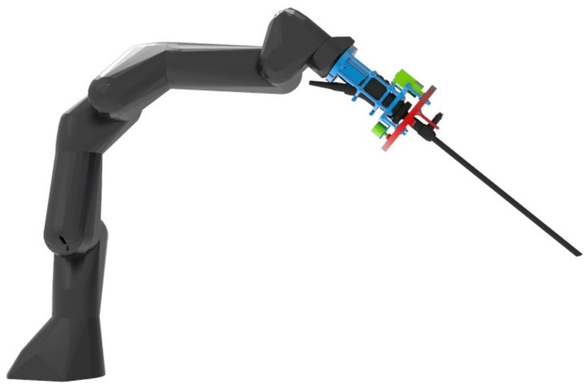

Fig. 1. Side view of a Storz endoscope (black) clamped into our mechatronic interface (blue, green, and red) on a 7 DoF light weight robot (dark grey).

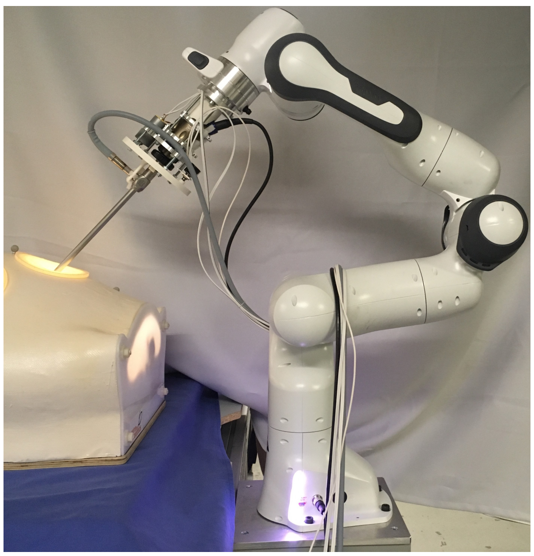

Fig. 2. Experimental setup for testing our design in a surgery phantom.

in the operation field to gain the same view.

V. Future Work

As a next step, we will quantify the differences, described in Chapter IV, which are mainly trajectory, calculation time, and information loss. To evaluate the validity, the system will be compared to a 30 degree endoscope without utilization of the rotational degree of freedom and to a 0 degree endoscope. The experiments will focus on certain camera poses that are necessary to solve an exemplary task. From those poses we will quantify the

- differences of the trajectory lengths to reach the poses and
- information loss and calculation time when using a 30 degree endoscope without utilization of the rotational degree of freedom.

After evaluation of the mechatronic interface we will use the setup to perform several telemanipulated tasks in the surgery phantom to analyze a human surgeon's behaviour. We will investigate the behaviour to lay the basis for automated laparoscopic camera guidance.

References

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