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***Abstract*—Currently force feedback in teleoperation is subject to numerous constraints on time delay and accuracy. Nonetheless, results show that implementing this type of feedback in teleoperated robotic surgery gives vastly better results. In this paper we propose a new method of teleoperating the DaVinci surgical robot using force feedback. The various constraints are adressed individually in each section.**

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August 26, 2015

I. Introduction

Over the last couple of decades the use of robotics for minimally invasive surgeries has increased, because of its precession and the reduction in tissue damage [1]. One brand of the operation tools in use is called an Endowrist. These are constructed in such a way, that the operator of the tools has the ability to manipulate it as a human wrist.

The feedback to the operator right now is only done by live video transmissions. Due to this is the only kind of feedback the operator has to guess on how much force there is applied under the surgery e.g to the skin or organs. In experiments it has been shown that haptic feedback has an huge positive effect for the reduction in surgical error [2].

The purpose of haptic feedback is to feedback the external force applied to the end effector back to the operator. This should simulate the situation of the operator doing the operation by hand instead of remote.

The force feedback could be done as direct force feedback calculated from the resistance on the actuators but as the tool is highly non-linear the transparency of the controller will become less transparent. It would be possible to solve this problem by implementing a sensor to the end effector to measure the force but due to the demand of high hygiene the tools have to be sterilized at temperatures over a 100° C which could damage the sensor(s). Furthermore it is stated by law that each surgical tool has to be discarded after a few times in use. This means that the cost of the tool has to stay as low as possible and therefore make the idea of implementing an expensive sensor not ideal.

Therefore the force feedback got to be estimated through the actuators which gives a high demand for the feedback controller as it has to be as precise as possible to feedback the correct force to the operator.

Another important subject is the transparency of the feedback as the operator should have the feeling of doing the operation by hand and not remote. This puts a demand on the speed of the feedback loop as the faster the loop runs the more smooth the force feedback to the operator will feel.

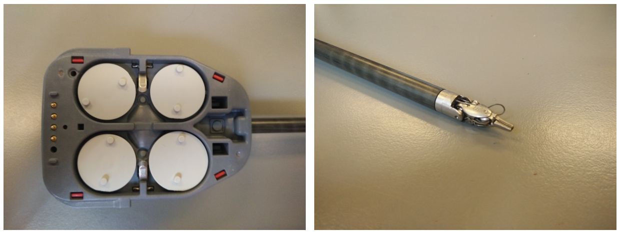
In the first section we will take an overview of our proposed control system as a whole, briefly presenting each of the components and their interaction. The second section will cover methods used to create a dynamic model of the Endowrist and proposed methods of translating the estimated force to actual force fed back to the operator. The third section contains descriptions of various problems pertaining the requirement of transparency and explanations of methods used to address them. Finally, we present (the expected) experimental results in section four and and draw a short conclusion in section five.

II. System overview

In out proposed system, the surgeon uses the Geomagic Touch joystick to control an Endowrist tool on one of the arms of the DaVinci surgical robot. It is imortant for the surgeon to have a feeling of resistance the tool is experiencing in order to adjust the position and grip strength and thus prevent damage to the patients tissue. To achieve this, we use the Geomagics force feedback feature in order to project the forces acting on the Endowrist to the surgeon. The communication between system components is done through the ROS operating system.

A. Endowrist

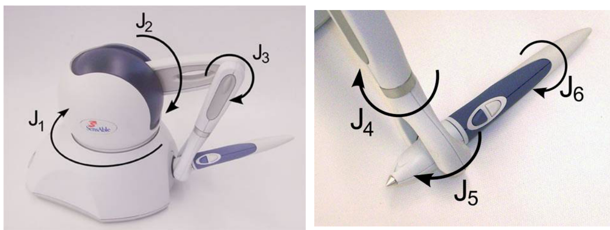
An Endowrist, see 1a is a surgical tool which can be manipulated as a human wrist. It is used in surgical procedures



(a) Actuator plates, which can alternate the end effector position

(b) End effector of the Endowrist

Fig. 1: The Endowrist and it's end-effector



(a) Overview of the Phantom omni's first three joints.

(b) Overview of the Phantom omni's last three joint

Fig. 2: Overview of all the Phantom omni's joints [**?**]

such as Laparoscopic surgeries, better known as minimally invasive surgery (MIS), where small incisions in the human body is made under the surgery. Because the incision cuts are small, blood lose under the surgery and the risk of infection is reduced. This has a positive effect on the recovery time for the patient.

As mentioned the Endowrist has the ability to be manipulated as a human wrist and thereby has four DOF, see 1b. This enables the movement of roll, pitch, yaw and an open closing mechanism that acts as the thumb and index finger of a hand.

The end effector is manipulated by the four wheels seen on 1a. Wheel one and three define the movement of the yaw and the closing mechanism. Wheel two and four moves the pitch and roll. The Endowrist is cable driven, which enables the opportunity of making the Endowrist small but it also makes the system nonlinear as the force acting at one end is not directly transmitted to the other end due to friction.

B. Geomagic touch

The geomagic touch is a haptic feedback device, which has the ability to manipulate its joints in such a way that the user feels resistance when moving the pin in a certain direction or way. The geomagic touch described in this section is the model Phantom omni and can be seen on 2.

As mentioned the Phantom omni has the ability to generate resistance for the user. In other words, when moved in a specific direction it can create a counter force in respect to

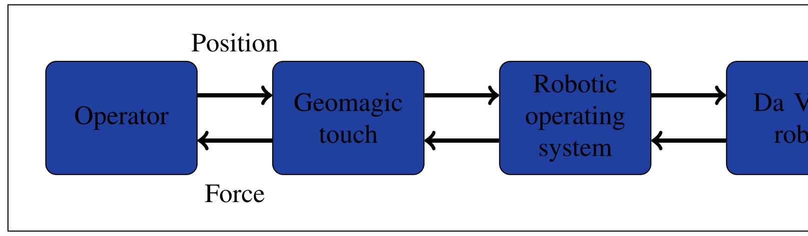


Fig. 3: Overall system with feedback in both direction

a certain position. On 2, it can be seen that the omni has six DOF, where only the first three can be actuated, see 2a. This means that the device only has the ability to generate force feedback with three DOF, in this case roll, pitch and yaw.

The connection to the omni can either be made directly through a ethernet cable or through ethernet cable to a usb converter into a computer. For programming the omni an API is included, which enables the connection to the omni. The Phantom omni has a lot of features which can be programmed through the language C++, e.g force rendering or drawing graphics.

C. Overview

As mentioned before , a fully featured DaVinci robot has 7 degrees of freedom on the Endowrist instrument. Since the robot has 4 arms, there are 4 instruments. Although our setup controls only 4 motors, in funcionality it is equivalent to one DaVinci arm.

As mentioned before, the sbRio board controls the test setup and as such represents the onboard computer on the DaVinci robot. In order to perform higher level functions such as force feedback control, it is necessary to remotely handle data and send high-level commands. This is handled by an external computer system that is connected to the Phantom omni device.

The sbRio board communicates with the computer using UDP communication protocols, while the Phantom Omni does so using TCP/IP. The computer also performs force estimation using a dynamical model of the test setup (or Endowrist, more precisely), this is vital for force feedback. In order to connect software components responsible for communicating with hardware and the ones responsible for the control algorithm and estimation. For this purpose we use the Robot Operating System (ROS), which uses a network architecture to share data between components via data streams.

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III. Conclusion

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ACKNOWLEDGMENT

The authors would like to thank...

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