VIRTUAL 3D ARRAY FOR BILATERALLY CONTROLLED SURGICAL ROBOT

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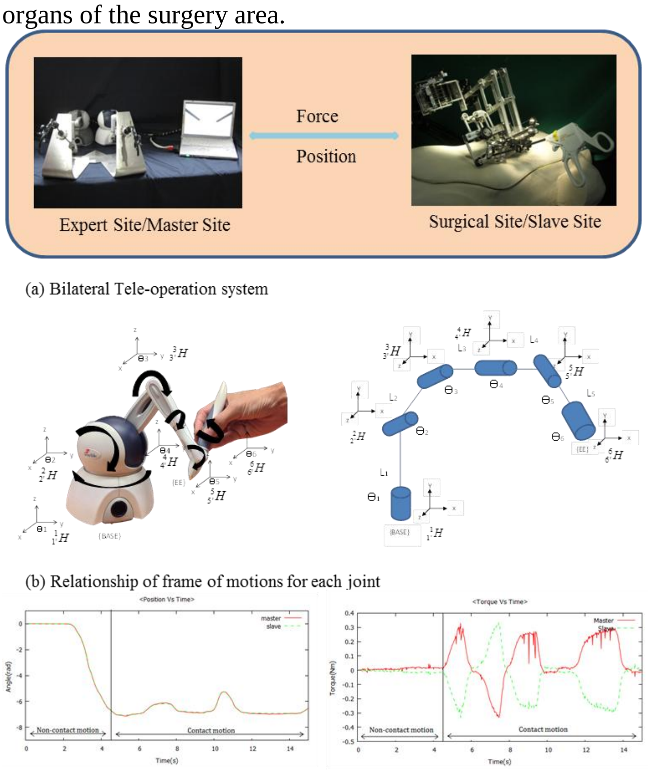
INTRODUCTION

Bilateral control systems can be used in surgeries [1]. If the bilateral control is used in a surgery, ideally the doctor should perceive the sensation of both the body tissue and the reaction force of the surgical tool. Many researchers have attempted to improve the operationality of the surgical tool using virtual models [2]. However, limited researches have carried out to control surgical tool movement in the surgery area. In this paper, a virtual three dimensional wall with vision [3] to protect body tissues and organs around the surgery area is proposed. In a bilateral tele-operation based robot surgery, master (doctor) and slave (surgical tool) may be placed at a distance as shown in Figure 1(a). In a usual robotic surgery, the doctor always has to pay his attention to protect the nearby body tissues and organs from the surgical tool. With the proposed virtual 3-D space created at the surgery area, doctor is able to conduct the surgery easily with a little consideration about the surrounding organs

METHODS

The modeling and development of the robot arm is carried out by applying kinematics and dynamics theories as shown in Figure 1 (b).The force sensation expected at this bilaterally controlled robot arm with the sensorless sensors. The research proposes to use DOB and RTOB based sensors and observers to improve the robustness of the system [1], [4]. Further, the system is modified to the slave robot arm to operate in a 3-D virtual space to protect the surrounding organs of the surgery area.



(a) Bilateral Tele-operation system

(b) Relationship of frame of motions for each joint

(c) Simulated position/ torque responses for 1 DOF

Figure 1: Overview of BART LAB Tele-surgical system

Advanced image processing techniques are used to incorporate the vision to the slave robot arm and it is seen by the surgeon at the master device. Figure 1(b) shows the relationship between homogeneous transformation matrixes of ${}^{EE}_{BASE}H$. It is computed to show the position and orientation of the end effector with respect to the base frame as (1).

$$ {}^{EE}_{BASE}H = {}^{1}_{7}H = {}^{1}_{1'}H\,{}^{1'}_{2}T\,{}^{2}_{2'}H\,{}^{2'}_{3}T\,{}^{3}_{3'}H\,{}^{3'}_{4}T\,{}^{4}_{4'}H\,{}^{4'}_{5}T\,{}^{5}_{5'}H\,{}^{5'}_{6}T\,{}^{6}_{6'}H\,{}^{6'}_{7}T \quad (1) $$

In actual application, the disturbance observer is effective not only for the disturbance compensation but also for the reaction force estimation. That is, the disturbance observer is able to estimate the reaction force without using a force sensor by identifying the internal disturbance of the system. The transmission of force sensation by Bilateral Tele-Operation is based on the action and reaction relationship. The disturbance observer calculates and estimates the reaction force as quickly as possible by increasing the cut-off frequency [4]. For our experiment, Motoman HP3RX 100 proposed as a surgical Robot. Figure 1(b) shows the relationship of frame of motions for each joint and the workspace measurements. The equation of motion for the Motoman HP 3 is shown in equation (1). It shows the position and orientation of the end effector with respect to the base frame.

RESULTS AND DISCUSSION

Figure 1(c) shows the simulated position and torque responses of the proposed system were one DOF was considered. This response proves that the proposed method performs satisfactorily when the estimated position and orientation of the end effector with respect to the base frame are close to actual system. The proposed research will be a great assistant for the existing bilaterally controlled robotic surgeries. The authors expect to research this technique with the aid of existing BART Lab Tele-surgical system. The outcome of this research will be verified with the help of medical surgeons by testing this tool in real world applications.

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