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Force and Position Feedback of Bilateral Master-Slave Control System in Robotic Simulator

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ABSTRACT – Bilateral controller system is a type of controller that involves two different sides for information passing. However, designs and data to transport to one another are complicated although the systems consist of only two manipulators; master and slave. In order to produce an ideal controller specification, the system must obey the expressed positions and force dimensions which lead to zero in total computed force. The performance of the bilateral control has been tested on actual robot system by using robotic simulator. Experimental results in form of position, velocity and force parameters for the joint in arm robot are discussed in this paper.

1. INTRODUCTION

In haptics, information can be transmitted into two ways, either in unilateral or bilateral control system. In unilateral, the information transmits in one direction without receiving feedback whereas for bilateral, there will be a reaction from the information transfer as found in [1,2]. Unilateral systems are undeniably easy to explore as the main goal for the slave is to follow the position reference obtain from the master, while the master itself acts as a passive device as in [3,4]. In the last decades, bilateral control is not a new concept in haptics study yet different studies have been implemented around the world. However, bilateral master-slave systems are preferable to study as it appeared to be able to reflect the force control applied by the slave to the master device then along the receiver's receptors and vice versa. The system block diagram can be seen in Figure 1. Appropriate information passed in the bidirectional system are expressed in terms of position control and force control. Tanaka et al. and Sugiura et al. [5,6] stated that the data can be used for deriving a formulation in the acceleration dimension (position) and following the law for summation of total force (torque) which, master-slave system must be zero.

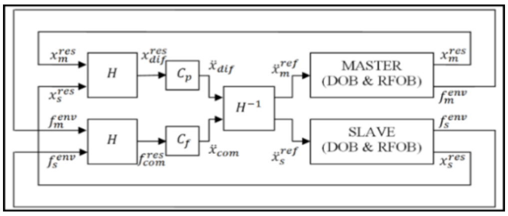

Figure 1 Block diagram for bilateral control system

Thus, a study was carried out in the existing robot arm KUKA youBot to study the performance and capability of bilateral master-slave control system. The system is developed in a simulation platform and the output values and readings from both master and slave are represented into graph form to visually illustrate the data gathered from the experiments.

2. METHODOLOGY

The experiment was conducted in robotic simulator, V-REP and commands for system to work and collecting the output data are written in Python. The simulations were carried out on the same two industrial KUKA youBot, labelled as master and slave respectively. A bilateral control system comprises of two sub-systems, called as master system and slave system to work independently. Both systems and settings are identical to each other and fixed in variables such as maximum torque of the base joint (10N) and initial position degree of the manipulators (90°). The simulation works when external cuboid manipulator swings in -45° and pushes the upper arm on master youBot forward. This will exert an external force on it. The joint on master will move accordingly on the side where the cuboid pushes since the compelled force is bigger than maximum torque of joint. Expectedly, the joint on slave will track the current position of joint on master as it reads the information passed from the other. Then, slave will be moving into the same position as the data it reads from the master. Beside the slave youBot, an obstacle is placed to block it from moving and affix on its recent position. When the slave operator stays, the movement of master also halts although there is no obstacle as it reads data passing from slave. This situation is shown in Figure 2.

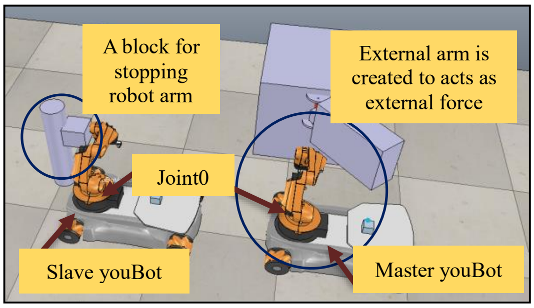

Figure 2 Overall view for bilateral control master-slave youBot system

3. RESULTS AND DISCUSSION

Initially, both position of joint in master and slave manipulator is set at 90°. Referring to Figure 3 and Figure 4, the reading for position and velocity of joint in both master and slave youBot starts at 1.8s when it receives the command from Python. Position of master reaches maximum values at 117° at 2.2s and maintained at 115° until the end because the external manipulator keeps pushing and giving greater force for master youBot. Transiently, position of joint in slave down to 81°, raised and maintained at 90° when t=2.0s until the simulation stop. This is because slave can't move further to follow the position of master as there is a block to obstruct and keep it at the current position.

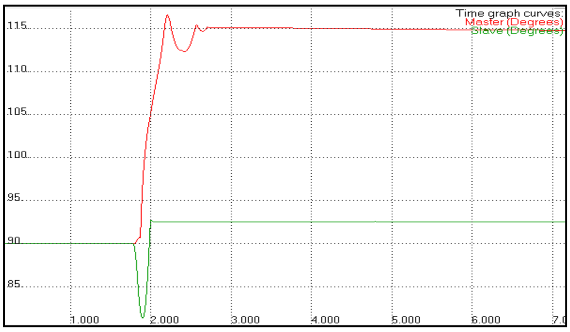

Figure 3 Position graph for master and slave youBot

At time less than 2.8s, the shape of graph for master and slave fluctuates. This is due to velocity of the joint in master and slave tries to counter the external torque applied and obstacles from the external manipulator and block when meets into contact with both master and slave robot. While, velocity graph in Figure 4 shows that the velocity of joint at t=2.8s is zero. It shows that the control system obey the differential mode equation where the total velocity for master and slave system is equal to zero as in (1).

$$\text{Differential mode, } \ddot{x}_{dif} = \ddot{x}_m - \ddot{x}_s = 0 \qquad (1)$$

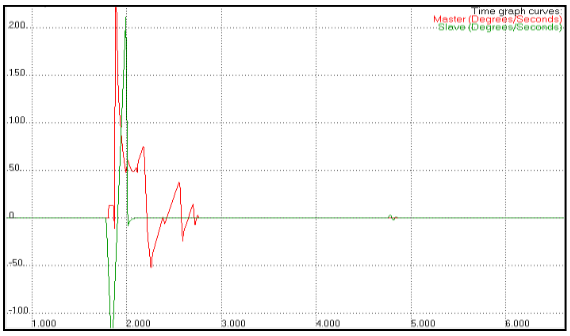

Figure 4 Velocity graph for master and slave youBot

Following force graph in Figure 5, at t=0s to t=1.8s, the reading of joint force in both master and slave youBot arm is 0 as because the slave arm is in free contact from any obstacle and no external torque pushing the robot arm. However, at t>1.8s, once the slave was blocked by an obstacle, it immediately has a reaction force to against the obstacle and trying to move further. The graph shows that master youBot arm has giving its maximum torque of 10N to move while slave youBot arm try to resist the bigger force from the block at -10N torque in the experiment. Note that 10N is predetermined value of maximum torque for joint in master and slave robot.

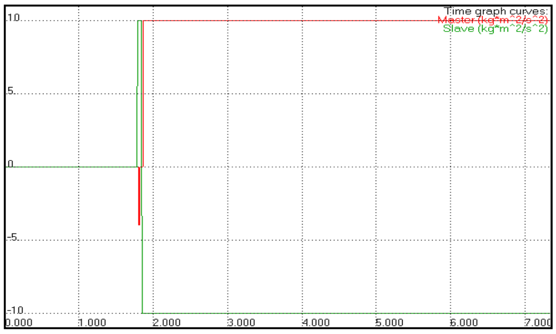

Figure 5 Force graph for master and slave youBot

Based on Figure 5, the bilateral control for both arm robot follows the law on force in common mode as in (2) where the summation of torque/force for the system is equal to zero.

$$\text{Common mode force, } F_{com} = F_m + F_s = 0 \qquad (2)$$

4. CONCLUSIONS

From the findings, the performance and feedback of the system is proven and obeyed the law for common mode and differential mode for an ideal bilateral control system. For future research, the system will be designed to be integrated with vision-based disturbance observer (VDOB) as it is expected to be carried out to eliminate the noise and errors in control system while reducing the time-delay in bilateral control communications.

ACKNOWLEDGEMENT

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