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Bilateral control for a non-similar teleoperation system

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Abstract: Several teleoperation systems are composed of robot manipulators with the same open kinematic model. This is a benefit because either the control design and the trajectory planning can be carried out in joint space coordinates. On the other hand, parallel manipulators have certain advantages over serial ones, for instance they have low moving inertia, high force ratio and high accuracy, making them suitable in several teloperation tasks.

This work presents the control issues of a non similar teleoperation scheme composed by a serial manipulator at the master side and a parallel robot at the slave side. The different kinematic configuration and the strong nonlinearities in the slave robot dynamic model makes difficult the controller design. In this article we explore such difficulties and present a bilateral teleoperation output feedback control algorithm which does not require the dynamic model of the manipulators. Experimental results are presented to show the performance of the proposed control scheme.

Keywords: Teleoperation system, serial robot, parallel robot, PID control.

1. INTRODUCTION

Robotic teleoperation schemes allow humans to execute tasks from a remote and safety environment. According to Hokayem y Spong (2006), the first master-slave teleoperation scheme was built by Raymond Goertz in 1948. Since then, robot teleoperators have been used in a wide range of industrial applications, for instance handling radioactive or nuclear material, underwater and space exploration or even robotic assisted surgeries (Takhmar et al., 2015; Wang y Yaun, 2004). The fundamental issue to solve and that allows the majority of this applications to be possible is the development of control algorithms that command the slave robot follow the path performed by the operator on the master robot. The challenges that such algorithms face are principally the dynamic variation of the remote environment, the interaction with nonrigid objects and substances and the delays present in the communication channel, among others (Kemp et al., 2007). In addition, most of the control algorithms for robotic teleoperated systems proposed in the literature assume that the master and slave manipulators have the same kinematic model. For example, Yokokohji y Yoshikawa (1994) use two 3-DOF SCARA-type planar manipulators with identical configuration to test a control scheme that permits an ideal kinesthetic coupling such that the operator can maneuver the system as though he/she were directly manipulating the remote object. On the other hand, Arteaga-Pérez et al. (2016) use two 3-DOF Geomagic Touch robots to introduce a teleoperation control-observer scheme that achieves telepresence and position consensus in presence of delays. In addition, Gutiérrez-Giles y Arteaga-Pérez (2017) use the same robots to design a force/velocity observer that allows the operator to interact with unknow remote surfaces.

To the best of the authors knowledge, for control purposes there is a brief amount of literature where the teleoperation systems are composed by robots with different kinematic structure, being the work of Rodríguez-Angeles et al. (2015) one of the most representatives. They implement a system using two 3-DOF robots with different configuration in order to design a bilateral control scheme based on virtual surfaces. Nevertheless, both robots have an open kinematic structure with revolute joints, being the master shorter and lighter than the slave and with the disadvantage that its first joint is locked, reducing the maneuverability of the operator.

The assumption that both manipulators in the teleoperation system have the same kinematic structure simplifies the control design, trajectory planning and stability analysis. Even with all these benefits, from a practical point of view, the incorporation of a parallel robot instead of a serial one at the remote side entails some advantages for the system. Firstly, a higher structural stiffness (Patel y George, 2012) allows the remote manipulator to carry out tasks as precise position tracking and high load carrying, like those needed in medical teleoperation. Secondly, a better force performance makes the parallel robot suitable for certain applications such as remote interaction with highly stiffness environments where the forces are difficult to produce using serial robots.

On the other hand, the most notable drawback of having a parallel robot at the remote side is the relatively small workspace that its final effector can reach (Stock y Miller, 2003), making necessary the introduction of a scale factor which relates the parallel robot workspace to that of the serial robot. Moreover, the different kinematic structure makes convenient to design the control laws in Cartesian coordinates in order to avoid the workspaces robots mapping through their kinematic models.

In this work we present a first approximation to a teleoperation system with a serial robot at the local side and a parallel robot at the remote side, besides we light some features about a control scheme that was proposed previously in a system with serial robots in both sides.

This paper is organized as follows: the dynamic model of the teleoperation system and some properties are given in Section 2. The proposed output feedback control algorithm is presented in Section 3. Section 4 presents experimental results and finally, concluding remarks are given in Section 5.

2. TELEOPERATION SYSTEM

The teleoperation scheme under study is shown in Figure 1. A serial manipulator is used as a master (local) device and a parallel robot as a slave (remote). Each manipulator has revolute joints with n degrees of freedom and it is assumed that the master workspace is a subset of the slave workspace. The equations of motion of the master robot are given by

$$\boldsymbol{H}_{\mathrm{l}}(\boldsymbol{q}_{\mathrm{l}})\ddot{\boldsymbol{q}}_{\mathrm{l}} + \boldsymbol{C}_{\mathrm{l}}(\boldsymbol{q}_{\mathrm{l}}, \dot{\boldsymbol{q}}_{\mathrm{l}})\dot{\boldsymbol{q}}_{\mathrm{l}} + \boldsymbol{D}_{\mathrm{l}}\dot{\boldsymbol{q}}_{\mathrm{l}} + \boldsymbol{g}_{\mathrm{l}}(\boldsymbol{q}_{\mathrm{l}}) = \boldsymbol{\tau}_{\mathrm{l}} - \boldsymbol{J}_{\mathrm{l}}^{\mathrm{T}}(\boldsymbol{q}_{\mathrm{l}})\boldsymbol{f}_{\mathrm{h}} \tag{1}$$

while the slave dynamics is modeled by

$$\boldsymbol{H}_{\mathrm{r}}(\boldsymbol{q}_{\mathrm{r}})\ddot{\boldsymbol{q}}_{\mathrm{r}} + \boldsymbol{C}_{\mathrm{r}}(\boldsymbol{q}_{\mathrm{r}}, \dot{\boldsymbol{q}}_{\mathrm{r}})\dot{\boldsymbol{q}}_{\mathrm{r}} + \boldsymbol{D}_{\mathrm{r}}\dot{\boldsymbol{q}}_{\mathrm{r}} + \boldsymbol{g}_{\mathrm{r}}(\boldsymbol{q}_{\mathrm{r}}) = \boldsymbol{\tau}_{\mathrm{r}} \tag{2}$$

where $\boldsymbol{q}_i \in \Re^n$ is the vector of generalized joint coordinates $(i = \mathrm{l}, \mathrm{r})$, $\boldsymbol{H}_i(\boldsymbol{q}_i) \in \Re^{n\times n}$ is the positive definite inertia matrix, $\boldsymbol{C}_i(\boldsymbol{q}_i, \dot{\boldsymbol{q}}_i)\dot{\boldsymbol{q}}_i \in \Re^n$ represents the Coriolis and centrifugal torques, $\boldsymbol{D}_i\dot{\boldsymbol{q}}_i \in \Re^n$ is the vector of viscous friction with $\boldsymbol{D}_i \in \Re^{n\times n}$ is a positive definite matrix, $\boldsymbol{g}_i(\boldsymbol{q}_i) \in \Re^n$ is the the vector of gravitational forces and $\boldsymbol{\tau}_i \in \Re^n$ is the control input vector. Finally, $\boldsymbol{f}_{\mathrm{h}} \in \Re^m$ is the force applied by the human at the master end-effector which is mapped in joint space coordinates by the Jacobian of the manipulator $\boldsymbol{J}_i(\boldsymbol{q}_i) \in \Re^{n\times m}$ (Siciliano et al., 2009).

Equations (1) and (2) describe the motion of the teleoperation system and they have the following properties:

Property 1. The inertia matrix $\boldsymbol{H}_i(\boldsymbol{q}_i)$ satisfies

$$\lambda_{\mathrm{h}i}\|\boldsymbol{x}_i\|^2 \leq \boldsymbol{x}_i^{\mathrm{T}}\boldsymbol{H}_i(\boldsymbol{q}_i)\boldsymbol{x}_i \leq \lambda_{\mathrm{H}i}\|\boldsymbol{x}_i\|^2, \quad \forall \boldsymbol{x}_i, \in \Re^n$$

where

$$\lambda_{\mathrm{h}i} = \min_{\forall \boldsymbol{q}_i} \lambda_{\min}\{\boldsymbol{H}_i(\boldsymbol{q}_i)\}$$
$$\lambda_{\mathrm{H}i} = \max_{\forall \boldsymbol{q}_i} \lambda_{\max}\{\boldsymbol{H}_i(\boldsymbol{q}_i)\}.$$

△

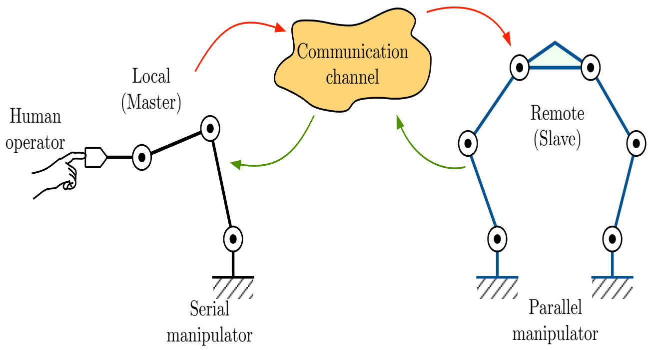

Fig. 1. Non similar teleoperation scheme

Property 2. The matrix $\dot{\boldsymbol{H}}_i(\boldsymbol{q}_i) - 2\boldsymbol{C}_i(\boldsymbol{q}_i, \dot{\boldsymbol{q}}_i)$ is skew-symmetric. △

2.1 Kinematic Considerations

Since the teleoperation system model is given in joints coordinates we need the forward kinematic equations of both robots in order to design a control scheme in cartesian coordinates.

The end-effector position of the local manipulator is given by

$$\boldsymbol{x}_{\mathrm{l}} = \begin{bmatrix} p_{\mathrm{lx}} \\ p_{\mathrm{ly}} \\ p_{\mathrm{lz}} \end{bmatrix} = \begin{bmatrix} \cos(q_{\mathrm{l}1})\,(\ell_{\mathrm{l}2}\cos(q_{\mathrm{l}2}) + \ell_{\mathrm{l}3}\cos(q_{\mathrm{l}2} + q_{\mathrm{l}3})) \\ \sin(q_{\mathrm{l}1})\,(\ell_{\mathrm{l}2}\cos(q_{\mathrm{l}2}) + \ell_{\mathrm{l}3}\cos(q_{\mathrm{l}2} + q_{\mathrm{l}3})) \\ \ell_{\mathrm{l}2}\sin(q_{\mathrm{l}2}) + \ell_{\mathrm{l}3}\sin(q_{\mathrm{l}2} + q_{\mathrm{l}3}) \end{bmatrix}$$

where $\ell_{\mathrm{l}2} = 0.1335[\mathrm{m}]$ and $\ell_{\mathrm{l}3} = 0.1335[\mathrm{m}]$ are the length of the robot links, while the forward kinematics of the remote manipulator is given by (Torres-Rodríguez, 2017)

$$\begin{aligned} p_{\mathrm{rx}}\cos(\phi_i) + p_{\mathrm{ry}}\sin(\phi_i) &= \delta_{1j}(\boldsymbol{q}_{\mathrm{r}}) \\ -p_{\mathrm{rx}}\sin(\phi_i) + p_{\mathrm{ry}}\cos(\phi_i) &= \delta_{2j}(\boldsymbol{q}_{\mathrm{r}}) \\ p_{\mathrm{rz}} &= \delta_{3j}(\boldsymbol{q}_{\mathrm{r}}) \end{aligned}$$

with $(\phi_1, \phi_2, \phi_3) = (105,\ 345,\ 225)[^\circ]$ and the nonlinear functions δ_{ij} (with $i = 1, 2, 3,\ j = 1, 2, 3$) are given by

$$\begin{aligned} \delta_{1j}(\boldsymbol{q}_{\mathrm{r}}) &= a\cos(q_{\mathrm{r}1j}) + (b\sin(q_{\mathrm{r}3j}) + d)\cos(q_{\mathrm{r}2j}) - c \\ \delta_{2j}(\boldsymbol{q}_{\mathrm{r}}) &= b\cos(q_{\mathrm{r}3j}) + f \\ \delta_{3j}(\boldsymbol{q}_{\mathrm{r}}) &= a\cos(q_{\mathrm{r}1j}) + (b\sin(q_{\mathrm{r}3j}) + d) \end{aligned}$$

where a, b, c, d and f are kinematic parameters (Torres-Rodríguez, 2017). Note that the forward kinematics of the remote robot are not in closed-form. The Sylvester's dialytic elimination method can be used to solve the aforementioned equations (Stamper, 1997). However, for the practical implementation of the proposed control law, the C-functions of the *Haptic toolkit* have been used to compute the end-effector position of the Falcon robot (Pascale y Prattichizzo, 2017). Section 3 Controller design

3. CONTROLLER

The objective is to design a control law with only joint position measurements for each manipulator such that when the human operator moves either the local or remote robot, the other tracks the commanded position.

Since each manipulator has a different kinematic structure, the proposed control law for the teleoperation system will be designed in workspace coordinates. Let $\boldsymbol{x}_i = \left[\, \boldsymbol{p}_i^{\rm T} \ \boldsymbol{\phi}_i^{\rm T} \,\right]^{\rm T} \in \Re^m$ be the position vector in workspace coordinates where $\boldsymbol{p}_i \in \Re^{m-r}$ and $\boldsymbol{\phi}_i \in \Re^r$ denote respectively, the end-effector position and a minimal representation of the robot orientation. For simplicity's sake, it is assumed that $n = m$. The joint velocity $\dot{\boldsymbol{q}}_i$ is related to $\dot{\boldsymbol{x}}_i$ by

$$\dot{\boldsymbol{x}}_i = \boldsymbol{J}_i(\boldsymbol{q}_i)\dot{\boldsymbol{q}}_i \tag{3}$$

where $\boldsymbol{J}_i(\boldsymbol{q}_i) \in \Re^{n\times m}$ is the manipulator Jacobian. The position errors in workspace coordinates are given by

$$\widetilde{\boldsymbol{x}}_{\rm l} \triangleq \boldsymbol{x}_{\rm l} - \kappa^{-1}\boldsymbol{x}_{\rm r}, \quad \widetilde{\boldsymbol{x}}_{\rm r} \triangleq \boldsymbol{x}_{\rm r} - \kappa\boldsymbol{x}_{\rm l} \tag{4}$$

where $\kappa > 0$ is a scale factor.

As a first approximation to the bilateral control for a non-similar teleoperation system, we proposed the control law for the local robot as a classic PID controller

$$\boldsymbol{\tau}_{\rm l} = -\boldsymbol{J}_{\rm l}^{-1}(\boldsymbol{q}_{\rm l})\left(\boldsymbol{K}_{\rm pl}\widetilde{\boldsymbol{x}}_{\rm l} + \boldsymbol{K}_{\rm il}\int \widetilde{\boldsymbol{x}}_{\rm l}\, dt + \boldsymbol{K}_{\rm dl}\frac{d\widetilde{\boldsymbol{x}}_{\rm l}}{dt}\right) \tag{5}$$

as for the remote manipulator

$$\boldsymbol{\tau}_{\rm r} = -\boldsymbol{J}_{\rm r}^{-1}(\boldsymbol{q}_{\rm r})\left(\boldsymbol{K}_{\rm pr}\widetilde{\boldsymbol{x}}_{\rm r} - \boldsymbol{K}_{\rm ir}\int \widetilde{\boldsymbol{x}}_{\rm r}\, dt - \boldsymbol{K}_{\rm dr}\frac{d\widetilde{\boldsymbol{x}}_{\rm r}}{dt}\right) \tag{6}$$

where $\boldsymbol{K}_{{\rm p}i}$, $\boldsymbol{K}_{{\rm d}i}$ and $\boldsymbol{K}_{{\rm i}i} \in \Re^{m\times m}$ are positive definite matrix gains.

Assumption 3.1. We assume that the force applied by the human is described by a PD law of the form

$$\boldsymbol{f}_{\rm h} = \boldsymbol{K}_{\rm ph}(\boldsymbol{x}_{\rm l} - \boldsymbol{x}_{\rm hd}) + \boldsymbol{K}_{\rm vh}(\dot{\boldsymbol{x}}_{\rm l} - \dot{\boldsymbol{x}}_{\rm hd}), \tag{7}$$

where $\boldsymbol{K}_{\rm ph}, \boldsymbol{K}_{\rm vh} \in^{n\times n}$ are positive definite matrices and $\boldsymbol{x}_{\rm hd} \in \Re^{n\times n}$ represents the desired trajectory that the person wants to follow. △

Remark 1. Assumption 3.1 is a combination of the human dynamic behaviors proposed in Nuño et al. (2008) and Rodríguez-Angeles et al. (2015), where in the former the person is assumed to be a passive system and in the latter it is assumed to be a PID law. Note, however, that due to the inclusion of $\dot{\boldsymbol{x}}_{\rm hd}$ in (7), $\boldsymbol{f}_{\rm h}$ does not render the human passive behavior. △

The principal proposition of this work is summarized as follows:

Consider the bilateral teleoperation system (1)–(2) in closed loop with the control laws (5) and (6), and assume that

a) $\boldsymbol{f}_{\rm h} = \boldsymbol{0}$.

Then, gains can always be found such that

i. All tracking errors are bounded.
ii. The system trajectories will satisfy $\boldsymbol{x}_{\rm r}(t) \approx \boldsymbol{x}_{\rm l}(t)$.

Fig. 2. Experimental set-up

iii. If the positions tend to a constant value, then all tracking and observation errors tend to zero.

If instead of condition a) we assume that

b) The human input force is described by (7) and it is bounded.
c) The human operator moves the local end–effector slowly.

Then, any closed loop variable is bounded. △

Remark 2. Condition b) is only included to carry out an stability analysis, but from a practical point of view is useless in the implementation of the control scheme. Certainly, the boundedness of the human force can be taken for granted.

4. EXPERIMENTAL RESULTS

To verify the performance of the control algorithms presented in Section 3, a set of experiments were carried out. The experimental set-up used for the experimental evaluation is shown in Figure 2. The local (master) robot is a *Geomatic Touch* haptic device with six degrees of freedom but only the first three joints are actuated by DC motors. The last three joints were mechanically fixed during the experiments. The remote (slave) manipulator is the *Novint Falcon* of *Novint Technologies, Inc.* with three degrees of freedom and a kinematic structure similar to the Delta robot (Pierrot et al., 1990). The control algorithms was implemented in PC a computer and programmed using Visual C++ and the *Haptics toolkit* with a sample time of $T = 1$ [ms]

Te correspondent gains for the controllers (5)-(6) were $\boldsymbol{K}_{\rm pl} = {\rm diag}(3.35, 3.35, 3.35)$, $\boldsymbol{K}_{\rm il} = {\rm diag}(1.5, 1.5, 1.5)$, $\boldsymbol{K}_{\rm dl} = {\rm diag}(0.5, 0.5, 0.5)$ for the local robot and $\boldsymbol{K}_{\rm pr} = {\rm diag}(15.5, 15.5, 25.5)$, $\boldsymbol{K}_{\rm ir} = {\rm diag}(5.35, 5.35, 5.35)$, $\boldsymbol{K}_{\rm dr} = {\rm diag}(0.35, 0.35, 0.35)$ for the remote robot. All of them tuned experimentally.
The first experiment consisted on using the *Geomagic Touch* robot as master manipulator. The operator takes the robot's end-effector and move it slowly all around the

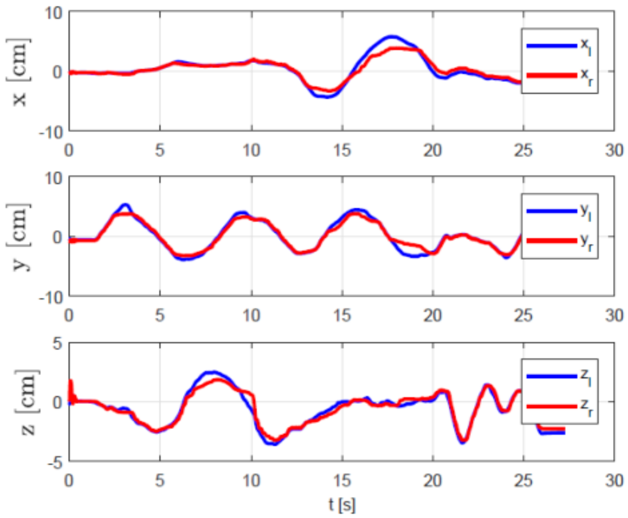

Fig. 3. Controller tracking with the serial robot as master: $\boldsymbol{x}_{\rm d}$ (−) and $\boldsymbol{x}$ (−)

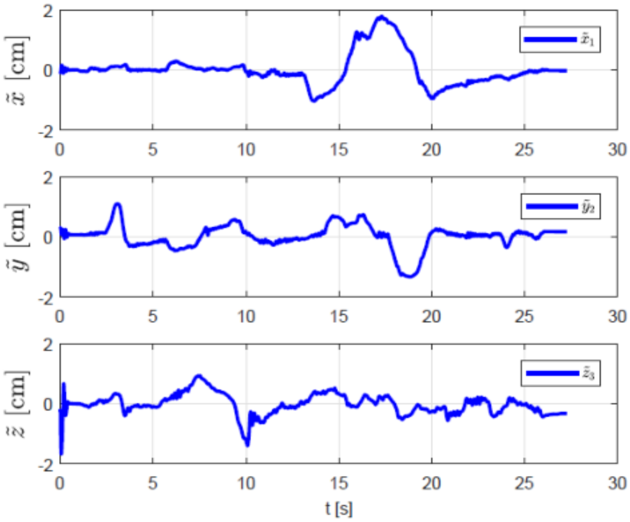

Fig. 4. Error tracking with the serial robot as master

workspace. The desired trajectory $\boldsymbol{x}_{\rm d}$ and the joint trajectory $\boldsymbol{x}$ are shown in Figure 3. As it can be appreciated, a good position tracking is achieved in a 30 [s] experiment duration. In Figure 4 the corresponding error tracking is presented. It remains in a band of $[-2, 2]$ for the three Cartesian coordinates. A better performance for the z coordinate is observed.

The second experiment consisted on using now the *Novint Falcon* robot as master manipulator. As before, the operator takes the robot's end-effector and move it slowly all around the workspace. The desired trajectory $\boldsymbol{x}_{\rm d}$ and the joint trajectory $\boldsymbol{x}$ are shown in Figure 3. As it can be appreciated, a good position tracking is achieved in a 40 [s] experiment duration. In Figure 4 the error tracking is presented. It remains also in a band of $[-2, 2]$ for the three Cartesian coordinates. However, the performance for the z coordinate gets worse.

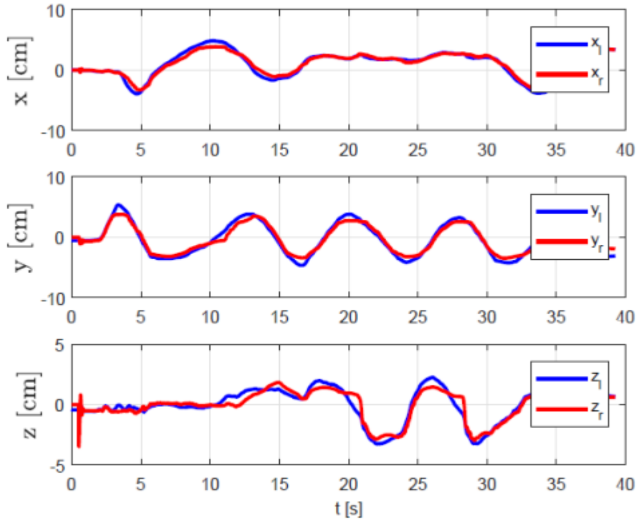

Fig. 5. Controller tracking: with the parallel robot as master $\boldsymbol{x}_{\rm d}$(−) and $\boldsymbol{x}$ (−)

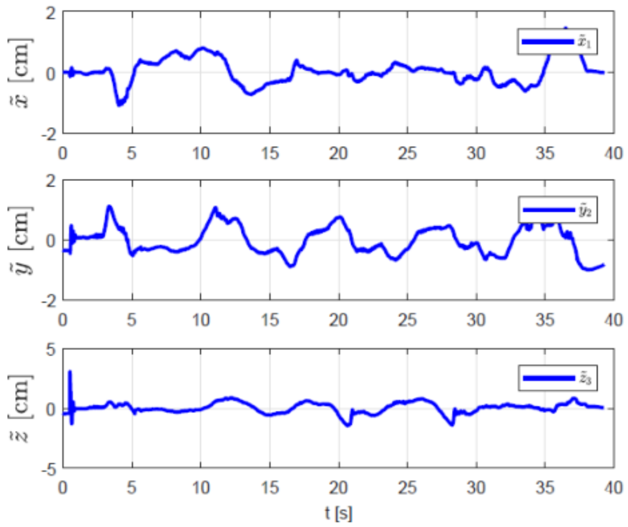

Fig. 6. Error tracking with the parallel robot as master

5. CONCLUSIONS

The problem of control a non-similar teleoperation system where each manipulator has a different kinematic structure is addressed in this paper. An bilateral controller that guarantees that the tracking errors are arbitrarily small is proposed. In the system studied, we have observed that, unlike a *Geomagic Touch* similar teleoperation system, the *Geomagic Touch–Novint Falcon* system presents some differences to consider. The most important is that the controller have to be designed in task-space coordinates due to the fact that both robots have different kinematic structure. This implies that one of the forward kinematic models of the robots must be used. In addition, a scale factor must be used since the *Novint Falcon's* workspace is smaller than that of *Geomagic Touch*. As for the controller design, a classic PID control guarantees that the human dynamics does not affect the position tracking when the motion applied is slow. There are some differences between using either the parallel or serial robot as master manipulator. The most visible performance change occurs in the z direction and it is assumed to be due to the gravity. Further mathematical analysis is required to confirm this assumption. Also is convenient to test other control algorithms on the experimental platform because control of non-similar teleoperation systems remains as an open problem. As additional future work, the implementation of a force control scheme is suitable in order to test the differences between the force magnitude applied on the master side and on the slave side, since many applications require a wider force range that a *Geomagic Touch* robot cannot provide.

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REFERENCES

Arteaga-Pérez, M.A., Morales, M., López, M., y Nuño, E. (2016). Observer based bilateral teleoperation for delayed systems: New proposal and experimental results. In *IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society*, 755–760. doi: 10.1109/IECON.2016.7793861.

Gutiérrez-Giles, A. y Arteaga-Pérez, M.A. (2017). Transparent bilateral teleoperation interacting with unknown remote surfaces with a force/velocity oberver design. *International Journal of Control*, 1–18. doi: 10.1080/00207179.2017.1371338.

Hokayem, P.F. y Spong, M. (2006). Bilateral teleoperation: An historical survey. *Automatica*, 42, 2035–2057.

Kemp, C.C., Edsinger, A., y Torres-Jara, E. (2007). Challenges for robot manipulation in human environments [grand challenges of robotics]. *IEEE Robotics & Automation Magazine*, 14, 20–29.

Nuño, E., Ortega, R., Barabanov, N., y Basañez, L. (2008). A globally stable pd concontrol for bilateral teleoperators. *IEEE Transactions on Robotics*, 24(3), 753–758.

Pascale, M.D. y Prattichizzo, D. (2017). The haptik library - A component based architecture for uniform access to haptic devices. *IEEE Robotics & Automation Magazine*, 14(4), 64–75.

Patel, Y.D. y George, P.M. (2012). Parallel manipulators applications - a survey. *Modern Mechanical Engineering*, 57–64.

Pierrot, F., Reynaud, C., y Fournier, A. (1990). DELTA a simple and efficient parallel robot. *Robotica*, 8(2), 105–109.

Rodríguez-Angeles, A., Arteaga-Pérez, M., Portillo-Vélez, R., y Cruz-Villar, C.A. (2015). Transparent bilateral master-slave control based on virtual surfaces: Stability analysis and experimental results. *International Journal of Robotics and Automation*, 30(2), 128–139.

Siciliano, B., Sciavicco, L., Villani, L., y Oriolo, G. (2009). *Robotics: Modelling, Planning and Control*. Springer-Verlang.

Stamper, R. (1997). *A three degree of freedom parallel manipulator with only translational degrees of freedom*. Ph.D. thesis, University of Maryland.

Stock, M. y Miller, K. (2003). Optimal kinematic design of spatial parallel manipulators: Application to linear delta robot. *Journal of Mechanical Design ASME*, 125, 292–301.

Takhmar, A., Polushin, G., Talasaz, A., y Patel, R.V. (2015). Cooperative teleoperation with projection-based force reflection for MIS. *IEEE Transactions on Control Systems Technology*, 23(4), 1411–.

Torres-Rodríguez, I. (2017). *Start up of the parallel robot Novint Falcon*. Master's thesis, Faculty of Engineering, UNAM.

Wang, W. y Yaun, K. (2004). Teleoperated manipulator for leak detection of sealed radioactive sources. *Proceedings of the IEEE International conference on robotics and automation*, 2, 1682–1687.

Yokokohji, Y. y Yoshikawa, T. (1994). Bilateral control of master-slave manipulators for ideal kinesthetic coupling-formulation and experiment. *IEEE Transactions on Robotics and Automation*, 10(5), 605–620. doi: 10.1109/70.326566.