FPD 운반을 위한 텔레로봇 시스템

Telerobot System for Carrying FPD

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Abstract

In this paper, intelligent filtering methodology for masterarm translation signal is proposed. Fidelity and stability are contradicting factors in teleoperation. Human hand trembling filtering is one of the problems in telemanipulation field. During every operation the hand has a certain vibration that can affect the quality of teleoperation, especially in carrying FPD (Flat Panel for Display), nanomanipuation and other precise tasks. It is very important to study the kinesthetic perception of the human and to optimize the teleoperation system accordingly. To cancel out the influence of human's hand vibration the signal from the masterarm should be filtered. One of the feasible solutions is to use an intelligent filter, which is a very flexible instrument. Applying intelligent filtering methodology, we can use some heuristic methods to solve the filtering problem.

Key Words : telerobot, intelligent filtering, FPD.

1. Introduction

From the early 1960s telemanipulators and video cameras were being attached to submarines by the US, USSR, and French navies and used experimentally. Also, from that time the race to the moon began. The early lunar teleoperator called Surveyor demonstrated vividly many control problems of time delay in an actual space mission. By 1970 the interest in teleoperation had turned to undersea applications, for there economic demand for offshore oil [1].

In 1976, robot arms were used on the Viking I and II space probes and landed on Mars. In 1993, the experimental robot, ROTEX, of the German Aerospace Agency (DLR) was flown aboard the space shuttle Columbia and performed a variety of tasks under both teleoperated and sensor-based offline programmed modes. In 2001, the first telesurgery has been performed when surgeons in New York performed a laparoscopic gall bladder removal on a woman in Strasbourg, France. In 2005, ROKVISS (Robotic Component Verification on board the International Space Station), the experimental teleoperated arm built by the German Aerospace Center (DLR), underwent its first tests in space [2].

The main concerns for the design and control of a modern telesurgical system can be summarized as follows:

1) fidelity in force-torque feedback;
2) stability-fidelity trade-off;
3) performance under time delay.

Fidelity and stability are contradicting factors in teleoperation. In conventional teleoperation tasks, involving manipulation of rigid objects for assembly, the interaction with the rigid environment is the main source of this stability problem.

It is also important to study the kinesthetic perception of the human and to optimize the teleoperation system accordingly. The coupling between the master-slave system can be chosen to minimize perceptual distortion rather than seeking an ideal response which is marginally stable and practically impossible to achieve. Also some variables of interaction can be amplified to improve sensation of manipulation for better performance [3].

In many teleoperation and telerobotic systems there is an unavoidable delay in time imposed between the operator's actions and the corresponding feedback. In information-only interactions, a certain amount of delay is natural. In contrast, in energetic interactions, we expect instantaneous response. In telerobotic systems, which can only support information interactions, a certain amount of delay is appropriate, but within teleoperator systems, which support energetic interactions, even a tiny delay (less than 100 ms) between a physical variable and its conjugate variable's response has no correlate in the physical world. Time delay in simulated energetic interaction creates the difficult technical challenge of system stability. But even if the stability problem is solved, it is doubtful that delayed feedback of a conjugate physical variable has any meaning to the human operator [4].

While using commonly applied filters, a certain time-delay is occurred because of complex mathematical operations performed by the system. Applying neural networks to real systems is also a very complex task because of the need to "teach" the network to perform required operations and to adjust all the weights. However, in case of using fuzzy logic, we can create a very simple system and reduce the computational burden of our controller, because fuzzy logic has following advantages for applying to the intelligent filter:

- Easy real systems implementation;
- Reduced computation time (time delay);
- Possibility to construct adaptive filter without using mathematical functions and equations.

2. Problem Statement

Most master-slave systems consist of arms with multiple DOF. However, let's consider a one DOF system in order to make the problem simple.

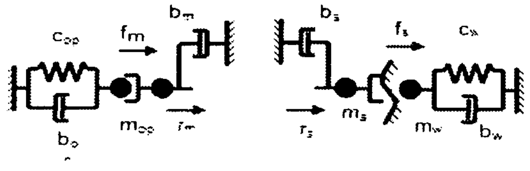

Figure 1: Common structure of a telerobot

The dynamics of the object interacting with the slave arm is modeled by the following linear system:

$$f_s = m_w\ddot{x}_s + b_w\dot{x}_s + c_w x_s \qquad (1)$$

where m_w, b_w, and c_w denote mass, viscous coefficient, and stiffness of the object, respectively, whereas $\ddot{x}_s$, $\dot{x}_s$ and x_s mean acceleration, velocity and translation of the slave arm, respectively f_s denotes the force that the slave arm applies to the object.

It is also assumed that the dynamics of the operator can be approximately represented as a simple spring-damper-mass system:

$$\tau_{op} - f_m = m_{op}\ddot{x}_m + b_{op}\dot{x}_m + c_{op}x_m \qquad (2)$$

where m_{op}, b_{op}, and c_{op} denote mass, viscous coefficient, and stiffness of the operator, respectively, whereas τ_{op} means force generated by the operator's muscle's $\ddot{x}_m$, $\dot{x}_m$ and x_m denote acceleration, velocity and translation of the master arm, respectively. In addition, f_m denotes the force that the operator applies to the master arm. [5]

For example, human's hand vibration in terms of stability can be represented as some disturbance added to the dynamical equation. It has a certain influence on a master's behavior ($\ddot{x}_m$ in the upper equation), and the oscillation damping is very critical sometimes, especially in tasks where high precision is required.

Therefore, if both position responses x_m and x_s, and force responses f_m and f_s by the operator's input τ_{op} are identical respectively, whatever the object dynamic is, the operator can maneuver the system as he were manipulating the remote object himself [5]. But sometimes the position response and force response are not required to be identical. For example, in nanomanipulation or in telesurgery, it is required to reduce the position response of the slave robot and to increase the force response from slave to master; in some fields, like construction, it is necessary to increase the position response and to decrease the force response.

3. Intelligent Filter

Fuzzy logic as an intelligent algorithm has some advantages, which are ease of design of the control rules (straight out of an operator's manual), the lack of dependence on accurate process models, the "understandable" nature of the resulting control strategies by plant operators and other practitioners, and the inherit nonlinear nature of the fuzzy logic-based systems [6].

In the ordinary structure of a telerobotic system, the masterarm translation signal is fed directly to the slave robot, and force feedback is applied from slave to master. In our case, we implement the intelligent filter to filter the oscillations of the human hand:

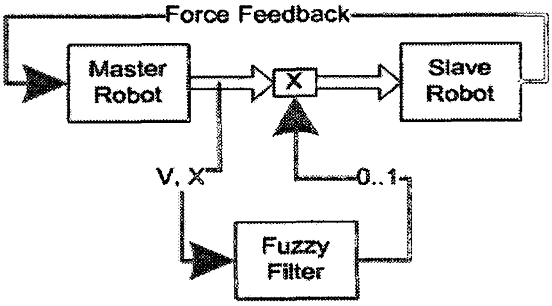

Figure 2: Telerobot control system with intelligent filtration

According to this structure, the signal from the masterarm is not fed directly to the slave robot controller, but is being analyzed by intelligent filter. If the input signal is a certain vibration, the output of the filter will be nil and no information will proceed to the slave robot after multiplication of nil and input signal. But if the vibration magnitude lies within accepted limits the intelligent filter will let the signal from the masterarm pass through to the slave robot controller.

4. Computer Simulation

The MATLAB and SIMULINK were used for the simulation.

One input of the suggested intelligent filter is the velocity of the actuator of the master robot. During vibration the velocity is relatively high within small translations. Thus, let's consider that if velocity is small (lies within some fixed limits) it means that the input signal is good and we need it; comparatively high velocity means that input signal contains vibration and we must not let it pass through. But we need at least one more input to distinguish the useful signal and vibration. Let consider this input to be the frequency of input (master arm) signal. If the frequency of the incoming signal gathered by the sensors is greater than some fixed value we set as a limit, it means that the operator's hand is trembling, the signal contains unavoidable oscillations and needed to be filtered somehow.

The proposed modeling scheme looks the following way:

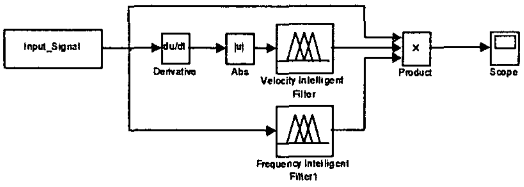

Figure 3: Intelligent filter

In the suggested system, the intelligent filter is divided on two filters (velocity intelligent filter and frequency intelligent filter) in order to show that they work separately from each other, but in fact, they represent one block.

This system works the following way: an input signal (let us assume that it is the translation of the master-arm actuator) is being differentiated, and the absolute value of the evaluated velocity is fed to the velocity intelligent filter. At the same time, input signal without any changes is fed to the frequency intelligent filter. After performing filtering, the output of the filter (in this case, of the both filters) is being multiplied by the input signal.

The following experiments were performed: at first, an input signal was a noisy circle - a signal contained a sufficient part of unavoidable oscillations.

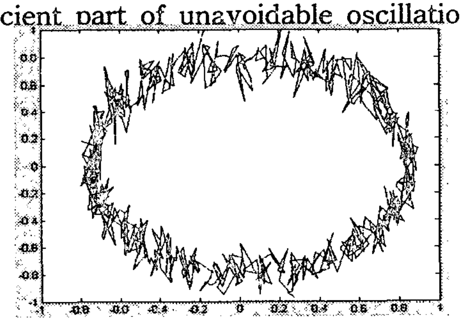

Figure 4: An input signal during first experiment (noisy circle)

In the input signal, vibration part was modeled as a random signal with the magnitude equal 35 % from the "useful" signal magnitude.

After applying intelligent filtration, we achieved such an output signal:

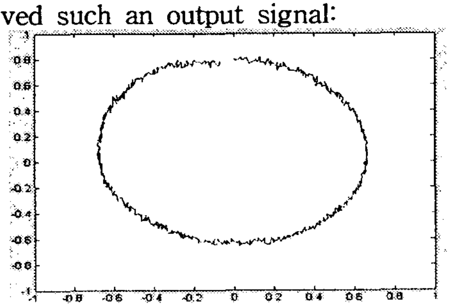

Figure 5: An output signal during first experiment (noisy circle)

As you can see, the signal became much smoother after filtration: the oscillations part came down to 7.3 %instead of 35 % within the signal from the master arm.

During next experiment, the input signal represented the capital "A" character. Before filtration it looked the following way:

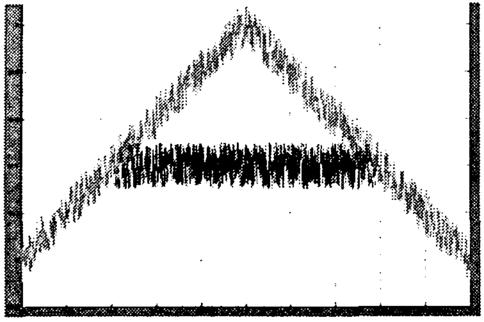

Figure 6: An input signal during second experiment (capital "A" character)

The vibration magnitude was set to the 10 % of the pure signal.

After applying filtration, the following signal has been achieved (as a result, we have a signal with a 2.4 % vibration part):

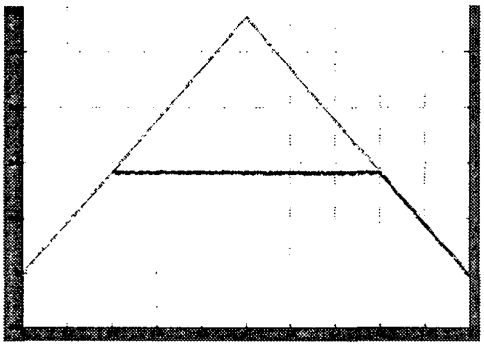

Figure 7: An output signal during second experiment (capital "A" character)

5. Conclusions

In this report, the concept of intelligent filtration methodology is suggested for human's hand trembling filtering. This kind of filtering may be applied in different fields where the noise reduction is recommended or required. Using fuzzy logic for both velocity and frequency filtering, we can design a really precise and flexible filter suitable for many applications. All the fuzzy membership functions within the internal structure of the filter can be made more complex and accurate or even new inputs can be added depending on the experimental data or any additional requirements. The borders of existing membership functions can also be adjusted to increase the precision of the filter and the smoothness of the outcoming signal, but even using these inputs and membership functions we achieved a much smoother signal that it was before the filtration.

In the future, it is planned to gather more experimental data of the human's hand trembling and the influence of different factors on vibration magnitude and frequency. Acquiring such data can help us to adjust the intelligent more precisely according to each operator's hand.

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References

[1] T. B. Sheridan, "Telerobotics, Automation, and Human Supervisory Control", The MIT Press, Cambridge, MA, 1992, pp. 99- 105.

[2] M. W. Spong, S. Hutchinson, M. Vidyasagar, "Robot Modeling and Control", John Wiley & Sons, Inc., 2006, pp. 30-31.

[3] M. C. Çavuşoğlu, F. Tendick, M. Cohn, and S. S. Sastry, "A Laparoscopic Telesurgical Workstation", in Proc. IEEE Int. Conf. Robot. Automat., 1999, vol. 15.

[4] B. Hannaford, "Feeling is Believing: History of Telerobotics Technology", in "The Robot in the Garden, Telepistomology and the Internet Robot", K. Goldberg, editor, MIT Press, 1999.

[5] Y. Yokokohji, T. Yoshikawa, "Bilateral Control of Master-Slave Manipulators for Ideal Kinesthetic Coupling - Formulation and Experiment", in Proc. IEEE Int. Conf. Robot. Automat., 1994, vol.10.

[6] Patyra, M. J., and Mlynek, D. M., "Fuzzy logic: implementation and applications", John Wiley & Sons Ltd. and B.G. Teubner, 1996