Force Feedback Based Gripper Control on a Robotic Arm

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***Abstract*—Telemanipulation (master-slave operation) was developed in order to replace human being in hazardous environment, with using a slave device (e.g. robot). In this paper many kind of master devices are studied, for the precise control. Remote control needs much information about remote environment for good and safe human-machine interaction. Existing master devices with vision system or audio feedback lacks most of such information, therefor force feedback, called haptics become significant recently. In this paper we propose a new concept of force feedback. This system can overcome the bottlenecks of other feedback system in a user friendly way. Force sensor and laser distance sensor communicates the information from the gripper's status to the teleoperator by using force feedback module on a glove. Pneumatic pressure gives the operator distance information, while a Magnetorheological Fluid (MR-Fluid) based actuator presents the gripper's force. The experiment result shows the possibility of usage of such force feedback glove in combination with a robotic arm.**

Keywords—force feedback; haptic; gripper control

I. Introduction

Telepresence is defined as the ideal of sensing sufficient information. Between teleoperator (as master) and task environment (as slave) are communicating in a sufficiently natural way, such that the operator feels physically present at the remote site. [1].

Telemanipulation is very important in the recently technology system by extending human's sensing and acting capabilities to a remote environment. With manipulator and mobility, Telemanipulator is used wide range of circumstances where is a nuclear plant, under sea or even space [2]. Telemanipulation system can be divided into three parts (Master device, Slave device and Information transmitter channel). The master device creates connection between man and machines, the slave device works at the remote environment. The information transmitter channel connects master and slave device [3].

The way to improve control of the manipulator is to give the operator more information about remote environment's like (through feedback). Three human senses are used generally in telemanipulation feedback: the sense of vision, hearing and touch. The main devices for feedback are camera, microphone, displays and speakers [4]. This kind of communication between master-slave system is usually done by keyboard/mouse as master and monitor as feedback [5]. It has a weakness without robot reacting when operator task works to operator input [7].

To improve the interaction between master-slave systems, there are more and more systems using the sense of touch, called haptic. The term "Haptic" officially appeared for the first time in the Oxford English dictionary in 1933. The word "Haptic" is from the Greek word "haptikos", meaning is "able to touch or grasp". The simplest and cheapest movement force feedback device or haptic device is the force feedback joystick. This device is optimal for low quality telemanipulation application, e.g. "pick and place" operation. It can also be stated that such joystick with force feedback is very popular in recent video game systems. The challenge with telemanipulation can be summarized the following way: how to improve of master-slave system for higher level of task efficiency.

In this paper, we are focusing on the initial experiments for force feedback system. This paper consists of five sections. Chapter 2 presents literature review, while overview of whole components is described in Chapter 3. Explanation of force feedback experiments is shown in Chapter 4. Chapter 5 provides the summary.

II. Haptics in Telemanipulation

Telemanipulation

Telemanipulation can be divide into two strongly coupled processes. One process is the interaction between the operator and the master device at the human's end. The master device provides motion command to slave side. The other is the interaction between the remote environment and slave device manipulator. The slave device performs the manipulation at the remote site. If this device is used only for moving object by the human, it does not represent a problem: the reaction force from the distant environment has no significant effect on the performance, measurement of the operator's command and visual feedback may be enough. However, there is possibility of substantial problem source: this kind of slave device, can do damage in the remote environment (no force feedback), similarly cannot work with a delicate machine. Force feedback increases efficiency by giving operator information about remote environment. The information flow between the operator and remote site can be seen on Figure 1. In general,

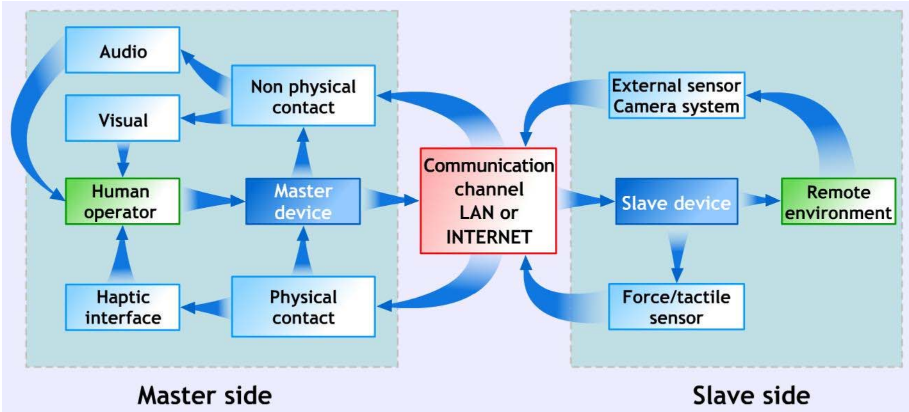

Figure 1. Structure of Telemanipulation [3]

only three types of information are feedback: visual, audio and sense of touch [6]. While human beings have five types of sensing from his/her surrounding environment, but only some of these senses are used during telemanipulation.

Master Devices and Haptic Interfaces

A tactile feedback has an important role in a man-machine interface. It is supposed, that the tactile parameters such as the force, texture, temperature and shape, are reflected as truly as possible in an unpredictable environment or achieving high levels of tasks in human-machine interaction or virtual environment [8].

Tactile feedback is one of the most user-friendly way to communication between human and machine. The tactile feedback exists in human's life, like touch based cell phone, dial key pad and push button [9].

Haptics or Force-reflecting interfaces which are used with display or force sensory systems from remote environment give a sense of touch or grasp in a special way [10, 11]. Because of that reason, it makes possible to interact with human in virtual reality or remote environment. Haptics improve work repeatability, scalability and safety by conveying physical force feedback [12]. There are 2-ways of using force feedback. The first thing is to recreate the experience of force sensation for the human being. The other one is to provide the feeling of abstract information [13].

In the field of telemanipulation, many haptic devices have been developed to be used as master device. The application of haptic devices covers various fields, such as medical applications, working in hazardous environments (e.g. nuclear plants), undersea and even military system. In the following, the most relevant master devices will be introduced:

- <u>Joystick with force feedback</u> was developed in the early stage of telemanipulation. Joystick is a very common and user-friendly for most of the people. Nowadays many kind of commercial joysticks with force feedback are available. This device is optimal for low quality application for recent video games, console systems. The main bottleneck of such joystick system is the limitation in degree of freedom (DOF). Joysticks are usually based on 2 degree of freedom. By extending the joystick with additional device, joystick can be used for precise operation. Until recently, joystick with force feedback was mainly used only for pick and place operations. Joystick is also developed and adapted for vehicle maneuvering, airplane and submarine control or even surgery simulation [14]. In Figure 2. such a joystick with force-feedback can be seen.

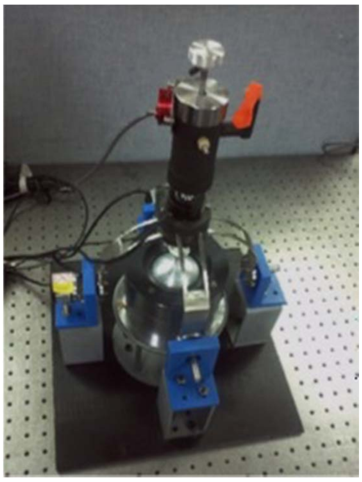

Figure 2. Joystick with force feedback [14].

- <u>The point type master device</u> has normally a six degree of freedom. The point type master device can manipulate from point to point at the remote site. One such a device is the Phantom (as shown on Figure 3), which is usually used as point type device. It has direct drive connection and high resolution. This type of device has normally a serial linkage structure. The tip type slave systems are studied in the medical fields as micromanipulation [12].

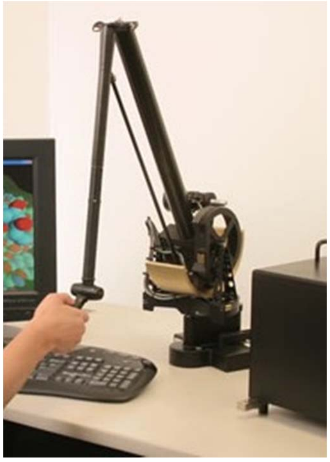

Figure 3. Point type master device [15].

- The arm type master devices can be seen in Figure 4, where the master device is attached to the human arm from shoulder to wrist. This solution has 6 degrees of freedom. The arm type haptic device replicates human motion. It is useful in applications, like painting or mining, where the goal of the control in the remote environment, is arm like slave device. In several applications the arm type master device has limitation in its movement, as 6 DOF is not enough to imitate human motion [16].

Figure 4. Arm type master device [16].

- The glove type master device allows any hand movement freely for hand motion (such a system could be observer in Figure 5). By extending a glove, it is possible to make a platform for haptic feedback small and lightweight. Also a glove is very familiar for human beings. This makes glove based systems even transparent, that sometimes people can forget that even they are wearing it [13]. Recently, additional functions are also getting integrated such as recognition of gesture.

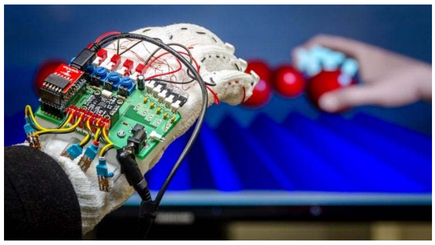

Figure 5. Haptic glove type master device [13].

III. Magnetorheological Fluid

Magnetorheological fluid is smart material, which is changing rheological behavior when an external magnetic field is applied. Magnitizable particles are located inside of the fluid with nomagnetic characteristic. This MR-fluid rheological state changes from the free flow state into the semi-solid state in few milliseconds [17].

MR-fluid can be combined with common passive actuators, such as rheological brakes, dampers and powder brakes. In case of MR-based brakes, it can achieve high controllability with fast response time, along with very low power requirements. Also it can work at high torque densities [18, 19]. As a result, MR-fluid can be used as a portable haptic device with low power consumption and minimized volume [20].

IV. System Overview

We propose a test-case using such magnetorheological system, which consist of three part: master device, slave device and communication channel. Master device is used to control the slave robot arm and gripper and receive gripper information from slave device. This connection is managed by a communication channel, which has PC interface (as seen on Figure 6 and 7).

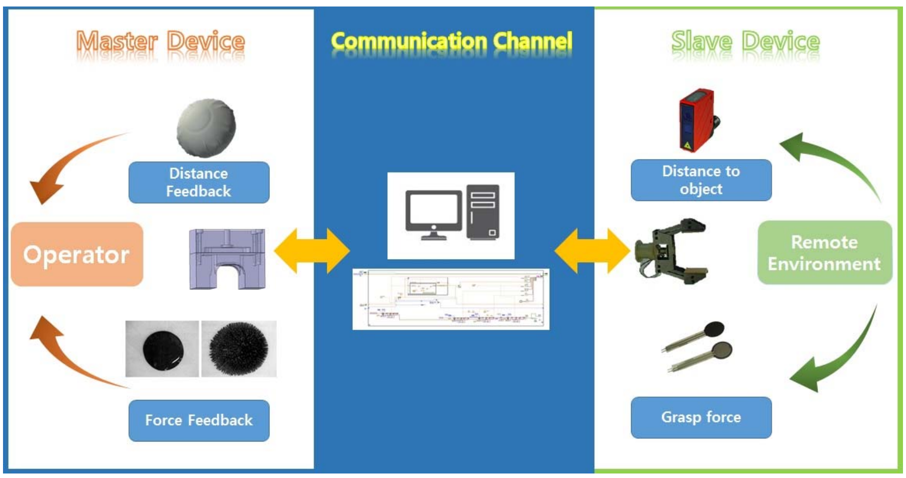

Figure 6. Structure of System

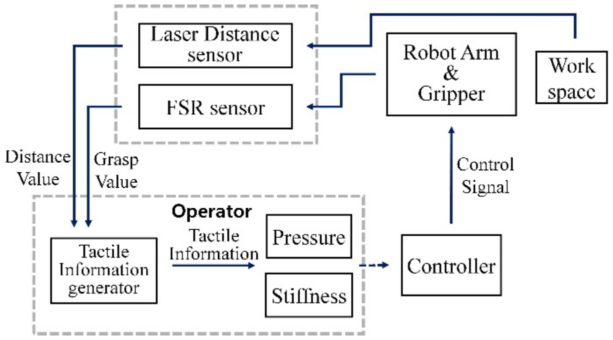

Figure 7. System configuration

A. Master device

Master device is made by proportional pressure valve, haptic module MR-fluid, electromagnet and a glove. Haptic device is connected with the proportional valve. The haptic module is filled with MR-fluid, which is controlled by proportional pressure. This is demonstrated on Figure 8. Like this way, the proportional valve compress the MR-fluid and MR-fluid express the information (e.g. distance) by applying pressure to operator's finger. In addition to this function, MR-fluid give a hardness information as grasping force feedback by applying electromagnetic field, resulting MR-fluid changes it's rigid state. This combined module is attached on the glove.

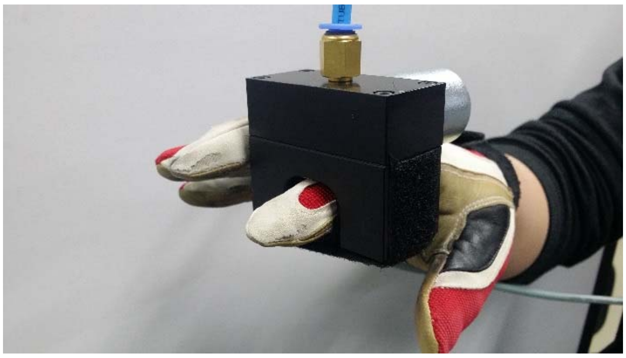

Figure 8. Master device

B. Slave device

In general, slave device which is consist of robot arm and gripper deal with pick and place motion. During a pick motion in teleoperation, the most important role is how to find and approach the obstacle.

Slave device consist of the gripper of the robot arm and sensors. Inside of gripper, Two FSR (Force Sensitive Resistor) sensors is located on the jaws. When the gripper catch some object, the FSR sensor resistance is changed [21]. The signal voltage is changed as FSR sensor compressed. FSR sensor can measure the force form 100g to 10 Kg. This is the way of predict grip is done or not. The other sensor is the optical distance sensor (ODSL 8/V66-500-s12). The optical distance sensor is located on the gripper which is aligned with gripper direction. Using this method, operator can predict the distance of object. Laser distance sensor can only estimate in front of the gripper. Measurement range of this sensor is from 20mm to 500mm, using the laser for measurement.

C. Communication channel

Communication channel is wired based. The sensors and the proportional valve is connected with DAQ (Data Acquisition, Ni-DAQ 6230 [22]) board and it is used to capture sensor signals. A LabVIEW software is used to change the sensor data of force feedback signals properly (As shown in Figure 9).

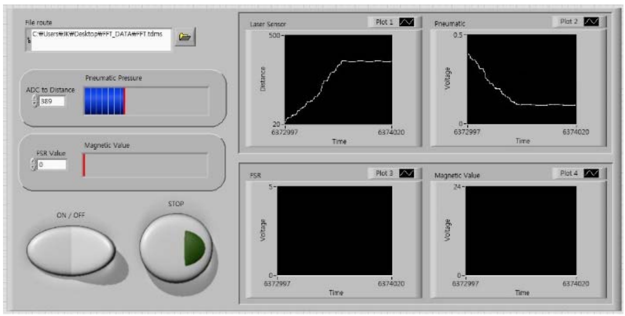

Figure 9. LabVIEW Interface.

V. Experimental Result

It is known that human skin feels differences of texture. Tactile texture perception which is composed of pressure and roughness is used for understanding objects.

In this experiment, the possibility of tactile reception was tested. Seven participants (7 males, age range 27-32) took part in the experience with force feedback test. All of the participants were right-handed. The experimental evaluation is performed by a questionnaire. Experiment was performed in two ways. First one, how the user feels the change of pressure (sensation of pressure), how the user feels the stiffness of the module (sensation of stiffness). The aim of the first tests is to find the critical point. Every test is performed by stepwise way. Participants don't know about value of the control. Second test is controlled robot arm for catching obstacle using force feedback glove.

The pressure and stiffness values are changed accordingly as seen as in Table 1.

The result of experiments is the following:

TABLE I. User Impression According to Test Value

Pressure (Bar)	User's Feeling Difference	Input voltage for Electromagnet	User's Feeling Difference
0		0	
0.06	O	5	O
0.12	O	10	X
0.18	O	15	X
0.24	O	20	X
0.3	O	24	X

a. Note: In the electro magnet specification, Max magnetism is 1400G (± 5%) at 24V. Electromagnetic tested in 0.06 bar/ 0.12 bar Using MR-Fluid density 3.6 g/cm^3.

A. Sensation of pressure

In these experiments the following is studied: how the user feels pressure changes at the test module, using proportional pressure change. Small changes are applied at the proportional pressure valve and the change is continued until the user feels a deference than before. As the pressure is higher, the balloon is changing size and pressure level, as shown in Figure 9. Above 0.3bar level, the pressure feels uncomfortable to human finger. The region above 0.3bar was decided to be exclude after experiments.

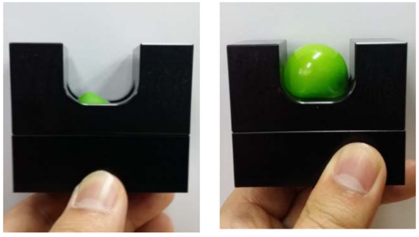

Figure 10. Baloon test

B. *Sensation of stiffness*

As mentioned before MR-fluid changes its' hardness along with the change of electromagnetic field. The very first observation was that the user do not notice any time delay when changing stiffness (setting desired value for the test module). The user was able to feel hardness and level of hardness. This sense of feeling is familiar to humans, when touching objects.

C. *Control test of robot arm*

The one of the advantage of glove is easy to use with other joystick or keyboard. Participants control the robot arm using the keyboard. To Compare using force feedback glove with without feedback, there is noticeable difference. Participants performance is improved accurately. With force feedback, Operator can pay attention to control robot arm in immersion way.

VI. Conclusions

A haptic feedback system for robotic gripper was developed. This system combines pneumatic system and MR-fluid. With such a solution, the user can easily approach any object by the robotic gripper, while the proposed system can give the information about grasp by using only few sensors. This system easily improves the operator's handling ability and is useful even for those who do not have experience about teleoperation. It can be demonstrated that without this system, it is not easy to telemanipulate a robotic gripper based only few feedback information. By using only vision system as a visual feedback, it has a limitation of cognitive space. The proposed system is light weight, easy to use, the user only needs to take the glove on the hand. It is possible to feel (feedback) two difference sense: pressure in your finger give you the information about distance of an obstacle and hardness of the feeling in your finger let you know how is the grip force on the obstacle.

Further improvements can include a wireless system. With using a wireless system, the haptic system gets mobility and flexibility of the use. The operator is free to move in remote environment and the system with such a glove can be combined easily with any master device.

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