Consideration on Tactile Virtual Reality Technology for Telerobot

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ABSTRACT

Telemanipulator became one of refocused fields with the help of various technology integration concerned. As one of key technologies much simpler opeartion of manipulator by operators and feedback method to operator can be counted. For such purpose virtual reality techniques are being implemented and in this paper tactile feeling among human 5 feelings will be discussed. Movement manipulation in free space and gripper manipulation methods are discussed in combination with operator's organs. Tactile signal of telemanipulator's gripper is also integrated into tactile VR control system. Such tactile VR technology is regarded as one of important roles for advanced robot technology.

1. INTRODUCTION

Since the NC technology has been developed, manipulator is applied in many different areas, especially where higher power is required. The general operation methods are switch, joystick and master-slave. Because such control methods are normally open loop control, operator only sends out the command through his experience. The main difference between human work and conventional manipulator operation is that human work is feeling feedbacked from work surroudings and manipulator operation is executed without feeling from surroundings. Therefore more precise work cannot be done by conventional manipulator. There are also many telemanipulators, which equipped force feedback function from surroundings. But generally the problems of manipulator are the same :

- manipulator operation method is not natural to human beings' characteristics
- feedback devices are still poor.

For such problems now man-machine interface techniques are oriented to human characteristics. How to operate the telemanipulator like manual work itself? That means how to feel the manipulator surroundings, even if the operator does not work actually. This concept is identical with virtual reality technique. Because the operator gets the informations from surroundings through 5 sensing organs, VR technique for telemanipulator is summarized as the development of sensing methods, human-feeling like feedback devices and techniques. Among 5 human feelings visual, tactile and hearing feelings are more meaningful than others. In this paper tactile VR is discussed. Tactile feeling is more important, where precise work is required and visual sensing is not possible. Figure 1 shows conceptual telerobot system with virtual reality.

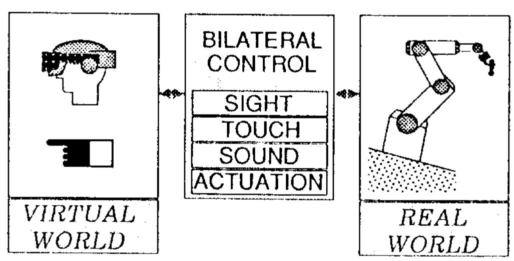


Figure 1. Telerobot with virtual reality

Tactile VR technology for Telerobot is one of very active themes in telerobot. Some Institutes (Stanford/JPL, Utah/MIT) developed such tactile feedback operation system for manipulators, but in the viewpoint of comfortability to human operator there are a lot of improvement in technology and devices left.

2. TELEROBOT

Telemanipulator is operated on site totally through human manipulation, and robot is operated through preprogrammed command, that means without human interaction on site. The characteristics of telerobot is the combination of human manipulation and robot self-activation. Such telerobot control routine can be configured in remote control, local control, and supervisory control routine. Figure 2 shows the typical telerobot control loops.

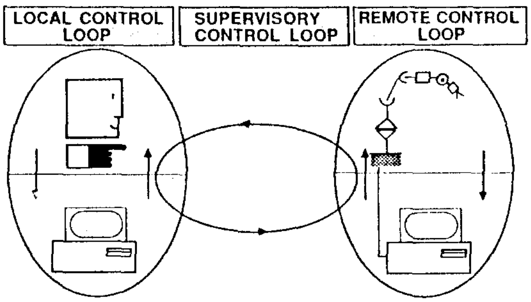


Figure 2. Telerobot control loop

Such telerobot control system can be applied in the same manner into tactile virtual reality control system for telemanipulator. Human tactile feeling system is combined in :
- arm movement
- load sensing
- finger movement
- tactile feeling
- brain.

3. TACTILE VR SYSTEM FOR TELEROBOT

3.1 Tactile Feeling Process

Human tactile feeling process can be proceeded sequentially as follows:
- object perception
- approach to object
- finger activation
- tactile sensing
- grasp force determination.

The technical requirements for each process is explained as follows:

(1) Object perception
- perspective function
- auto focusing

(2) Approach to object
- 6DOF interpolation
- fine position/orientation, velocity interpolation and controllability

(3) Finger activation
- finger motion control
- speed control
- gripping force control
- fine resolution

(4) Tactile sensing
- contact recognition
- analog array pressure recognition
- compliance

(5) Grasp force
- slip detection
- fast response time

Figure 3 shows the operator/telemanipulator system with tactile VR function.

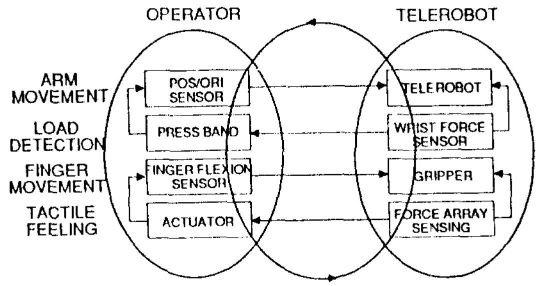


Figure 3. Operator/telemanipulator system with tactile VR function

Each process can be proceeded:

Arm Movement
Receive the tip position/orientation data Calculate the robot motion data Coordinate transformation Check danger Communication between computer and Robot controller

Load Detection
Receive the force/torque data at robot wrist Actuation of each corresponding part of press band/monitoring

Finger Movement
Receive the finger flexion angle data Calculate the robot gripper motion data Send data to gripper controller

Tactile Feeling
Scan all the tactile array sensor using address bus Calculate the current gripping force Detect slip Calculate the control value for tactile feedback device Send date to tactile feedback device controller

3.1.1 Telerobot Movement

There are several telemanipulator movement methods. Manipulation by switch is executed by sequential switch-on of each separate arm. This method is primitive and has following problems :
- unsimilarity with human arm movement
- no fine interpolated movement possible

The second manipulation method is master-

slave method. This method can be modified human arm. Merit for this method is as follows:
- no complicated calculation time necessary
- mechanical confiration of telemanipulator is always the same as operator arm
- collision situation is better near unpredictive object

But as the following disadvantages :
- installation cost is high

The final method is hand position sensing method. This method is simple at installation and accurate enough for robot manipulation nowadays. The disadvantage with this method ist reaction time delay because of calculation time and real-time communication between sensor and telemanipulator controller. In this experiment 6DOF magnetic sensor (Polhemus 3Space IsotrakII)is applied. The spatial resolution is as follows:

0.038 mm and 0.1 degree

Real time communication cycle between telemanipulator controller and computer is 120 ms.

3.1.2 Load Feeling

During gripping or working the acting force/ torque is to be feedback to human operator in order to feel virtual working reality. At manual work the worker's muscle acts to external loading. The feeling of such reaction of human muscle seems similar to the feeling during direct pressing of muscle. This process is not yet integrated in the experiments, but the way to integrate this function will be similar to mentioned above. For load sensing at telemanipulator wrist 6 DOF F/T sensor (10 Kgf class) is attacted at robot flange.

3.1.3 Finger Movement

In several literatures human finger has the following biological characteristics :
- sensing frequency range : 0-400 Hz
- response range : 0 - 100 g/mm^2
- sensitivity : 0.2 gms/mm^2
- spatial resolution : 1.8 mm

There are also several products for finger flextion sensing devices :
DataGlove, Dextrous Hand Master, Power Glove and so on. In this experiment DataGlove using optical fiber has been applied. The resolution lies between 1 and 2.5 degree. For the actuation from DataGlove signal 2 finger gripper is attached at robot flange. The gripper is shown in Figure 4.

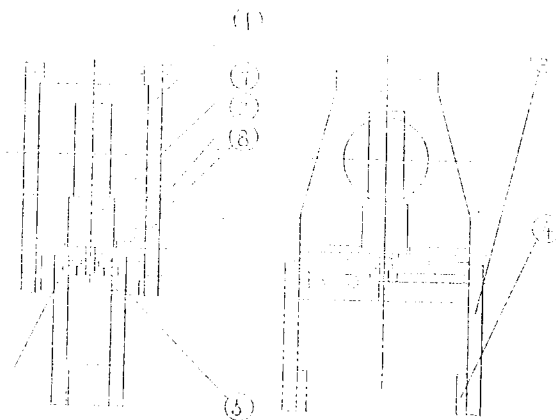


Figure 4. Telerobot gripper

3.1.4 Tactile Array Sensing at Finger Tip

The human skin has the following characteristics:
The outermost layer is called epidermis and 0.1 mm thickness. Underneath the epidermis lies dermi, which is1 mm thick and sensing nerves lie in this layer. There is underneath the dermis compliant layer, hypodermis called. The friction coefficient of the skin is about 3.0. There can be several models for human-skin like finger of telemanipulator gripper. Figure 5 shows 3 diferent models.

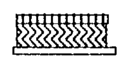
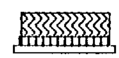
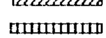
Model 1	Model 2	Model 3
		
Force Sensing Resistor with No Compliance	FSR on Compliant Layer	FSR underneath Compliant Layer

Figure. 5 : 3 different finger tip models

 Back Plate
 Compliant Layer
 Sensing Layer

The human finger ia similar to model 2.
The following is the characteristics comparison among 3 models.

Model 1 has the following characteristics:
- sensing possible merely at contact area/ points
- no positional uncertainty
- between the sensing matrix sensing not possible
- no similarity with human skin because of the lack of compliance

Model 2 has the following characteristics:

- sensor array deforms to pressing shape, this characteristics is similar to human skin.
- positional uncertainty.

Model 3 has the following charactersitics:

- FSR adhesion to back plate is easy
- low sensing sensitivity because of compliant layer.

The comparison of sensing signals between model 2 and model 3. is analyzed as follows.

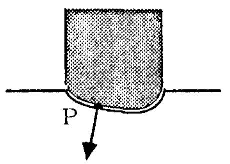
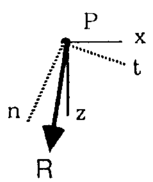


Figure 6: Difference of sensing values between model 2 and 3.



Sensing value at Model 2 : R_n
Sensing value at Model 3 : R_z

Figure 7 shows the technical principle of applied Force Sensing Resistor (FSR).

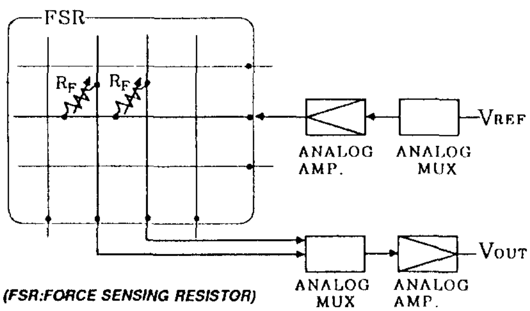


Figure 7: Tactile array sensor

3.2 System Configuration

The total system configuration for tactile VR for telerobot is Figure 8. In this system sight parts are omitted.

FUNCTION	SUBFUNCTION	COMPONENT	
ACTUATION	ROBOT MOVEMENT	POS./ORI. SENSOR	DATA-GLOVE
	ENDEFFECTOR MOVEMENT	FINGER BEND SENSOR	
SIGHT	STEREO VIEW	2 CAMERA /STEREO DISPLAY	
	HEAD ROTATION	POS./ORI. SENSOR (HELMET)	
	EYE DISTANCE FOCUSING	DISTANCE SENSOR / MOTOR	
	EYE ANGLE FOCUSING	DISTANCE SENSOR / MOTOR	
	EYE WIDTH ADJUSTMENT	MOTOR	
TOUCH	GRASP FORCE FEELING	TACTILE SENSOR / ACTUATOR	
SOUND	WORK NOISE HEARING	STEREO MICROPHONE/EARPHONE	

Figure 8 : Tactile VR system for telerobot

And the control system configuration is shown in Figure 9.

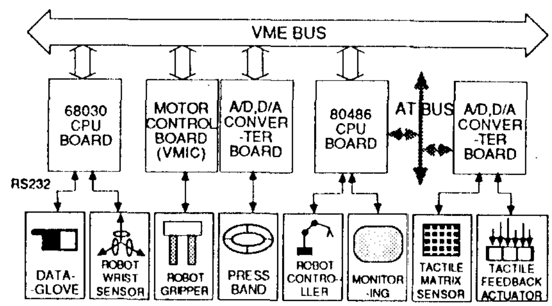


Figure 9: Control lay-out for tactile VR for telerobot

4. SUMMARY

Virtual reality technology plays an important role in telemanipulator operation in terms of operator-friendliness. Tactile function is one of important part for telemanipulator operation with real-like feeling in virtual atmosphere. There are a lot of improvements to do for virtual real-like operational feeling of telerobot, because the word, feeling, is not objective but subjective and not qualitative but quantitative. This paper shows the one way to improve human feeling in telerobot manipulation in virtual world.