Roughness Feeling Telepresence System with Communication Time-Delay

Shogo Okamoto * Masashi Konyo * Takashi Maeno † Satoshi Tadokoro *
(*) Graduate School of Information Sciences, Tohoku University, Japan
(†) Department of Mechanical Engineering, Keio University, Japan
E-mail: {okamoto,konyo,tadokoro}@rm.is.tohoku.ac.jp, maeno@mech.keio.ac.jp

Abstract

A framework of tactile telepresence systems will be proposed in the present paper, which enables active touch with time-delay communication between a tactile sensor side system and a display side system. In the framework, a tactile display system can apply tactile stimuli to fingers of an operator in syncronization with touch motions based on physical parameters of objects which are estimated by a tactile sensor. To verify the concepts of the framework, was developed a roughness feeling telepresence system which produces vibratory stimuli computed by estimated surface wavelength of objects and rubbing speed of an operator. To implement the framework, real-time estimation of physical parameters of objects are required as core technology. System implementation and real-time estimation of surface wavelength will be also proposed.

1. Introduction

Tactile telepresence technology is expected to be applied to remote robotic manipulation, robotic palpation and so forth. However, conventional studies of tactile telepresence have not dealt with active touch with time-delay communication because of following two major reasons. First, presentation of tactile stimuli also delays when communication network is delayed. Second, the amount of information which is transmitted by a tactile sensor to a display side system is huge due to high frequency resolution of tactile mechanoreceptors and distributed area of stimuli. Therefore, a new framework of tactile telepresence system to realize active touch even with time-delay communication will be proposed. The framework emphasizes that approximate tactile stimuli can be reproduced by combining touch motions of operators and representative physical parameters of objects to touch. Also, stimuli generation based on touch motions at the very moment cancels communication time-delay between a slave side system. Implementation and experimental results of a developed roughness feeling telepresence system will be also described to verify the concepts of the framework.

2. The Tactile Telepresence System Based on Physical Parameters of Objects

The proposing tactile telepresence system is explained. Fig.1 is an example of the system. In the figure, a tactile sensor is installed on a slave arm, and it estimates physical parameters of objects. Estimated parameters are transmitted to a display side system and tactile stimuli are applied to a finger of an operator. The stimuli are produced using the current touch motions sensed by a master arm system so that the stimuli should not delay due to communication time-delay.

In the present study, due to psychophisically clear relationships between parameters and touch motions, will be proposed a roughness feeling telepresence system, in which mechanical vibration of f is produced as tactile stimuli. f is derived by $f = v/\lambda$, where v is rubbing speed of an operator, λ is a surface wavelength of an object.

3. Implementation of A Roughness Feeling Telepresence System

3.1 Real-time Estimation Method for Surface Wavelengths

Fig.2 shows a picture of the tactile sensor used in the system. The sensor emulates the structure of human fingers and same friction phenomenon are expected to happen in touching objects. Five strain gauges are embedded at the boundary of two layers and designed to acquire vibration in any contact statuses [1].

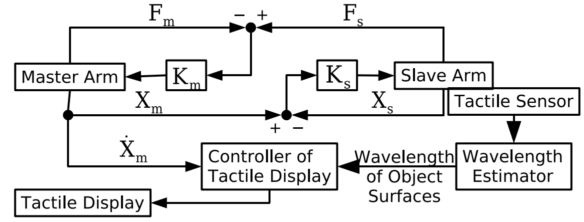

Figure 1. An example of a master-slave typed roughness feeling telepresence system

Second Joint EuroHaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems (WHC'07)
0-7695-2738-8/07 $20.00 © 2007 IEEE

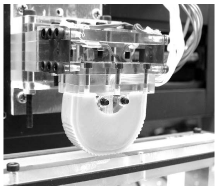

Figure 2. The human finger mimetic tactile sensor

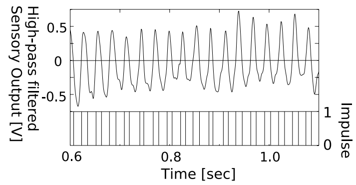

Figure 3. An example of sensory outputs and impulses

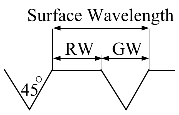

Figure 4. A roughness Sample for performance evaluation : GW=RW

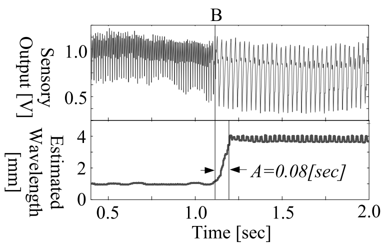

Figure 5. Experimental sensory outputs and result in sliding on 2 different samples

Real-time wavelength estimation method will be proposed. The method estimates the vibratory frequency of the sensor by accumulating impulses in a certain period A. Once, the frequency is estimated, surface wavelength of roughness samples can be derived by $\lambda = v/f$. Fig.3 illustrates the basic idea of the proposing estimation method. The upper plot of Fig.3 shows sensory outputs of a strain gauge, when the sensor slides on a roughness sample shown in Fig.4. The method puts impulses when high-path filtered sensory outputs of a strain gauge goes over a zero level, shown in the lower part of Fig.3. A was designed to be $0.08[sec]$ so that it minimizes the formulation of expected estimation errors.

The basic performance evaluation clarified that a wavelength difference of $1[mm]$ can be sufficiently discriminated by the method.

Fig.5 shows an example of experimental sensory outputs and estimated wavelengths, where 2 samples of different wavelength, $1[mm]$ and $4[mm]$ were arranged side by side and the sensor slid on them. At the point B in Fig.5, the sensor just reached the boundary of 2 samples, and estimated value is almost roaming around $4[mm]$ within $0.08[sec]$.

3.2 Roughness Feeling Display by ICPF Tactile Display

ICPF tactile display [2] was employed as a tactile display in the system. ICPF actuators of the display were controlled to vibrate at the set frequency, which was derived by $f = v/\lambda$. It was confirmed that the display method could present differences of wavelength $1 \sim 4[mm]$ by $1[mm]$ using limitation methods.

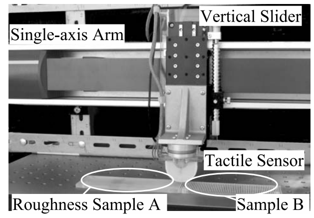

Figure 6. Slave side system

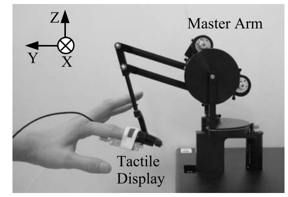

Figure 7. Master side system

3.3 Experimental Setup of Roughness Feeling Telepresence System

Fig.6 and Fig.7 shows the developed roughness feeling telepresence system. The sensor was attached to a single-axis arm in a slave side system. A subject equipped his finger with the tactile display and put his finger on a fingertip of the master arm.

4 Experiment and Results

Velocity of the slave single-axis arm was controlled to be same as x-axis velocity of the master arm. Two roughness samples were arranged beneath the tactile sensor. A subject answered which wavelength was longer. Four samples $1 \sim 4[mm]$ with $1[mm]$ interval were tested. The experiment was conducted by a pairwise comparison method, each pair was tested 10 times.

As a result, the subject could judge longer samples at the rate of more than 0.9 for 4 pairs among 6 pairs, where there are statistic significance with 95% significant level. For the rest 2 pairs, correct answer rates were 0.7.

5 Conclusion

The present paper proposed a new framework of tactile telepresence system for active touch with time-delay communication, in which tactile stimuli are produced based on physical parameters of objects and touch motions of operators. In the framework, real-time estimation methods of parameters are inevitable and a method for surface wavelength was proposed. Roughness feeling telepresence system was developed and evaluated, which showed an encouraging performance as a first stage.

References

[1] Y.Mukaibo et al., Development of a Texture Sensor Emulating the Tissue Structure and Perceptual Mechanism of Human Fingers, Proc. IEEE Intl. Conf. on Robotics and Automation, pp. 2576-2581, 2005

[2] M.Konyo et al., Tactile Feel Display for Virtual Active Touch, Proc. IEEE/RSJ Intl. Conf. on Intelligent Robots and Systems, pp.3744-3750, 2003