Haptic Interface for Perceiving Remote Object Using a Laser Range Finder

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ABSTRACT

This paper describes development of a haptic interface using a laser range finder. The system consists of a laser range finder, computer and a 1 degree-of-freedom haptic apparatus. The haptic apparatus can generate a reaction force based on a distance to a remote object that is measured by the laser range finder. A user can feel the shape of a remote object by holding this interface and pointing the object. Through an experiment, the effectiveness of this system was confirmed.

Index Terms: H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems—Artificial, augmented, and virtual realities; H.5.2 [INFORMATION INTERFACES AND PRESENTATION]: User Interfaces—Haptic I/O;

1 INTRODUCTION

In the real world, we usually touch real objects which are put on reachable area. However, we cannot touch real objects which are put on unreachable area in daily life.

If status of remote objects can be measured in real time, we can feel a reaction force from the remote objects with a haptic interface. Meanwhile, the meanings of "unreachable objects" are not only they exist in distance, but also they exist in showcase or restricted area such as showpieces at science/ art museums. In addition, we can feel a reaction force from dangerous objects such as high temperature objects by using some sensors and haptic apparatus. This function can be helpful to understand the characteristics of the objects in educational situation.

As related works, Iwata[1] has developed an augmented reality system named "Feel-through". It consists of a see-through HMD on which image of virtual objects are superimposed, and a haptic interface. The users can feel a reaction force from remote objects. However, it should be prepared shape and location data of real objects before using the system. Nojima et al [5] have developed a haptic interface named "SmartTool". The interface is equipped with a proximity sensor at the end effector. It can detect the condition of people's affected part by using output data of the sensor and feeds back with a reaction force so that the user can notice the location of the dangerous part in an operation. Since the system uses a proximity sensor, the user cannot touch remote objects which are put on unreachable place.

In this study, a haptic interface with a laser range finder is proposed. By using this interface, a user can feel a reaction force from remote objects, even though they exist inside of a showcase which is covered with a glass plate. A prototype system was developed. It consists of a 1 degree of freedom haptic apparatus and a laser range finder. The haptic apparatus can present a force to the tip of the user's thumb based on the distance data from the laser range finder. The effectiveness of this system was evaluated through an experiment.

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2 PROTOTYPE SYSTEM

2.1 System Configuration

A prototype system was developed to evaluate proposed method. This system consists of a laser range finder (LRF), a 1 DOF haptic apparatus and a PC for controlling the system.

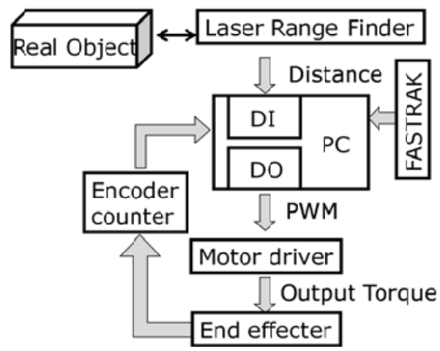

Figure 1: System configuration.

The LRF is LK-G500 made by KEYENCE, with its controller, LK-G3000, made by KEYENCE. The LRF has measurement range from 250 mm to 1000 mm. A distance between the interface and a target object is measured with the LRF. The distance data are read with Digital Input ports of a PCI board on the PC, PCI-9112 made by NuDAQ. The data are sent to the PC, PRECISION 470 made by DELL. The PC calculates a motor torque based on a haptic rendering algorithm described below. The torque data are translated to PWM pulse data and sent to a PWM pulse generator M66240P made by Renesas through Digital Output port of the PC with 8 bits resolution. The 1DOF haptic apparatus has a geared motor (super mini106-3001-1 made by SANYO DENKI, reduction ratio: 10.8:1) with an optical shaft encoder, RE12D-300-201-1 made by COPAL. ELECTRONICS which has 300 pulse/round resolution.

To apply a reaction force to the user's thumb, the interface has a lever which has 35 mm length determined by a feasibility study of working range of the thumb and rotates around pitching axis that means the lever tilts back-and-forward from a view point of the user. A cylindrical grip is put on the top of the lever. The user pushes the grip of the lever by his/her thumb and can feel a reaction force from remote objects. The maximum reaction force at the top of the lever is 19.3N.

The interface weighs 0.9 kg and is a little heavy to hold single hand for a long time. In this study, the subject holds the interface by double hand as shown in Figure 3 .

2.2 Haptic Rendering Method

As haptic rendering methods, a penalty method [4], [3] is used, in which the reaction force is proportional to the invasion of the lever to an object. When a representative point on the object is selected and the distance between the interface and the representative point is defined as the neutral distance. The lever's neutral angle is set to the vertical direction and the current surface position of the target object is calculated based on the difference from the current distance to the neutral distance. When a user pushes the lever and the

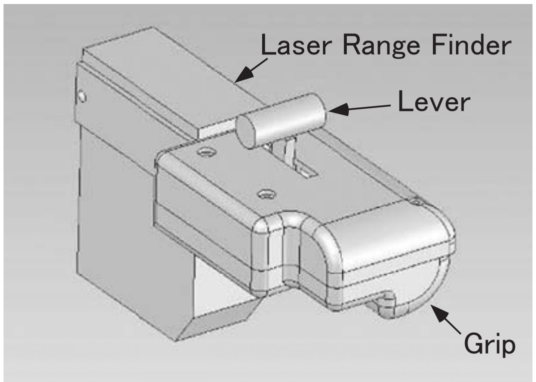

Figure 2: Shape of grip of the interface.

Figure 3: Overview of the interface touching through a glass plate.

lever invades the object's surface, the interface generates a reaction force which is proportional to the invasion from the object's surface. The output torque is calculated with following equation when the lever invades. Otherwise, the torque is set to 0.

$$\tau = J \cdot P \tag{1}$$

where J means Jacobian matrix and P means the vector of the reaction force.

3 Shape Recognition through a Glass Plate

To evaluate system performance, a shape recognition experiment through a glass plate was conducted. Subjects touched an object freely via the interface until they recognized which object he/she touched. At the same time, the subjects instructed to move sticking the interface to the glass plate during the experiment. Presented objects were a sphere, a cylinder, a cube which turned the flat surface, and a cube which turned one side shown in Figure 4. One of the objects was presented randomly at each trial and the subjects answered which object is touched. During the experiment, the subjects prevented from seeing the presented object directly by using a visor attached to the glass plate. 6 subjects conduced 16 trials at each haptic rendering algorithm.

The result is shown in Table 1. The number in each cell of the table means the number of times which the subjects answered (24-point is perfect.). The percentage of correct answers was 96.9 %. The subjects can perceive the shapes almost correctly. However, some subjects could not distinguish the cylinder and the ridge line of the cube. The subjects reported that they perceived a ridge line

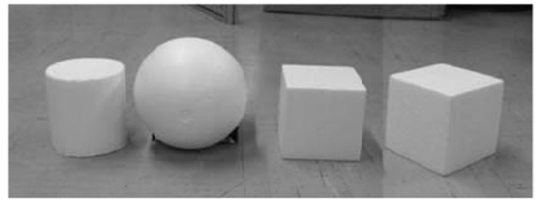

Figure 4: Shape of test objects.(Cylinder, Sphere, Plane, Ridge line)

Table 1: Shape recognition using this interface

	Sphere	cylinder	Plane	Ridge line
Sphere	24	0	0	0
cylinder	0	23	0	1
Plane	0	0	24	0
Ridge line	0	2	0	22

of the cube as a blurred line. The large differential limen of inclined angle caused this result.

4 Discussion

In this study, the effectiveness of the proposed system was confirmed. This system can be used for education, quality inspection of engineering products, welfare product such as fall-prevention.

However, due to the measurement limitation of the LRF, the LRF cannot measure correctly at some incident angles of the laser to a object's surface or at colors/materials of objects. Furthermore, It cannot measure back sides of the object and a deep hole, etc. To overcome these problems, a hybrid system with a stereo camera system and the LRF et cetera can be used.

Also, the scale of displayed distance is one of the topics of improvement. For instance, magnifying sensor data, a user can feel imperceptible texture of a surface like the tactile contact lens[2].

5 Conclusion

In this study, a haptic interface that can measure the distance between the system and a real object in real time, and generate a reaction force to user's finger tip was developed. The users can perceive the shapes of remote objects without touching them with his/her bare hand. Even though the object place in a showcase covered with glass planes. The threshold and differential limen in touching objects were measured. And through shape recognition experiment, the effectiveness of this system was evaluated.

As a future work, we plan to enhance degrees of freedom of the sensor and the apparatus for raising power of expression and to improve the haptic rendering algorithm.

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