Study on Telexistence LXXIV
Haptic Layer Design and Integration for Virtual Telesar

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In this paper, we present haptic sensor design as a part of virtual telexistence platform, which aims to aid the designer to select the proper sensors as a haptic sensor for robot hand. Profiling curve defines the relation between sensor's measurements from the simulated environment and its output providing to the display. By providing various profiling curves, we can have variations of the same sensor but with different characteristics for various applications. By assuming that the simulated environment provides a representation to the real physical environment, the sensor can be assumed as a candidate for physical utilizing. Here we provide an implementation for a pressure sensor as an example of the approach.

***Key Words*:** Virtual Reality, haptic sensing, telexistence

1. Introduction

On telexistence, haptic feedback plays an important role in maintaining the feeling of surface textures as well as the feeling of being actually existed in the remote environment. Actually we've already achieved to have haptic experiences with textures of clothes [1].

The sensors, which are embedded on the tip of robot's fingers, palms, fore arms, or etc., are required to be designed to fit some conditions; measurable range, dynamics following capability and so on when the sensor contacts with objects. It is still difficult to design proper sensor as well as to select a proper one, to position it and etc., because physical prototyping of the sensor obviously requires us to use the physical avatar robot to experience and evaluate the prototype. This is the reason why the simulator is necessary. However, it often uses an ideal physical model not referring property of physical sensors in order to calculate reactive forces in real-time [2] [3].

Thus, we propose a virtual prototyping method for telexistence, which reflects the actual sensor properties. It seems significant to provide real-time experience during evaluation in addition not only to choice a sensor based on a specification, but also to change the its position easily.

Therefore, in this study, we provide a model of physical sensor as a virtual one, implement a graphical user interface for editing the sensor profile and implement it as a part of virtual telexistence platform with physical haptic display[3].

2. Concept

2.1 System Architecture

As we reported before, Virtual Telesar [4] is designed modular based platform to provide an interactive visual experience to the operator as shown in in Fig. 1.

Virtual Telesar architecture contains physics simulation layer, to simulate a dynamics of avatar robot, which reflects user's behavior through a master cockpit. Addition to the architecture, we add a haptic layer, which provides contact positions and forces affecting sensor's surface as well as control the haptic display [3].

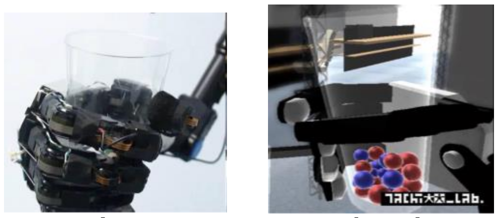

Fig. 1 Virtual Haptic interaction as in physical environment (L) Real Robot Interaction (R) Simulated Interaction

Basically, the focused haptic sensors we would integrate with this platform are: contact force feedback sensor, thermal sensor, and tactile sensor. Although there are several considerations to consider as a tactile sensor, in this paper, we focus on the pressure type sensor because it is consider as a proper sensor for receiving static force or dynamic force changing slowly. In contrast, texture sampling requires a property of high frequency response, for example, when stroking the rough surface defined in a virtual world. To evaluate the possibility of haptic layer design, we focus on the former one; force sensor receives static force.

2.2 Haptic Layer Design

This layer consists of the sensor appearance, profile, and driving ability of the haptic display to experience the force to the operator. The layer is independent from the core part of the simulator called Virtual Telesar.

The virtual sensor behaves as a transducer from contact force obtained between virtual sensor and the object into the measured value. The sensors can be defined by its transformation function. The function relates the inputs of the sensor (observed values) and converts those captured values into output value set.

By defining different transformation functions for each type of sensor, we can create multiple sensors simulating the behavior of different physical sensors. This method also is available for simulating a custom sensor. By using various sensor behaviors, we can either design custom sensors for the aim of experience, or we experience simulated sensors.

3. Sensor Model

3.1 Physical Sensor

Depending on the properties of the sensor, output signal can be linear or nonlinear. For most physical sensors, by plotting their characteristic chart we can notice the nonlinear behavior.

For example, a plot for force sensor INASTOMER SF-R-3 φ77.2mm shown in Fig. 2, which shows how it responses better to low forces than high forces (this is a measured graph, not an official one). On the other hands, other sensors, such as LMA-A-5N with a linear response curve, have different characteristics and behavior towards the acting forces. Depending on the response curve, the application area and proper purpose might be different.

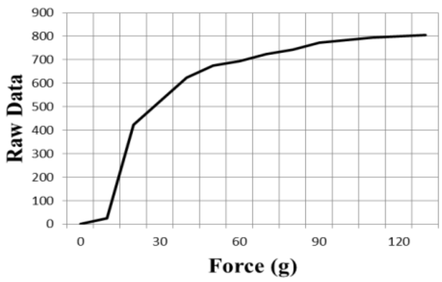

Fig. 2 INASTOMER sensor response curve

Thus, it is essential in the virtual environment to be able to define such curves for the sensors in order to estimate for the physical sensors. Or to provide proper output to the haptic display which would be reflected on the user experience.

Also, in order to decide the suitable characteristics curve for virtual sensor, it is important to understand the response curve for the haptic display.

3.2 Sensor Behavior

In the physical sensor case, it works by capturing the applied forces over the contact surface. As same as this, in order to obtain the amount of force affecting the sensor, we calculate the incorporated sum of the forces, which are affecting on the axis of the sensor using Eq. (1):

$$F_S = \sum_{k=1}^{M} F_k * (\overrightarrow{N_k} \cdot \overrightarrow{N_S}) \quad (1)$$

Where M represents number of contact points, F_k is force value. N_k represents force normal k on sensor's surface, N_s is sensor's axis and F_s is the result force. The inner product between normal in the previous formula acts as a weight to the force, measuring the force exerting the sensor's axis as shown in Fig. 3.

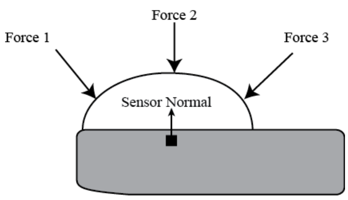

Fig. 3 Illustration of the applied force on sensor's surface

3.3 Profiling Curve

The modulation curve can be defined as a function G(F_s) in which is exerted on the force signal calculated in Eq. (1). Depending on how we want the sensor to respond to the force, and most of the time that would depend on the type of the display we are using, we can define a suitable function to achieve that. In this test we used a haptic display [3] to provide the measured forces into the finger. First we measured the display's response curve when the sensor was using a linear modulation function: $G(F_s)= F_s$. In order to design proper modulation curve for the sensor, we studied the display behavior towards its input.

To create the modulation curve, a GUI tool allows the designer to create such curve as in Fig. 4. The designed modulation curve is saved later as a separate profiling file to be assigned to the sensor.

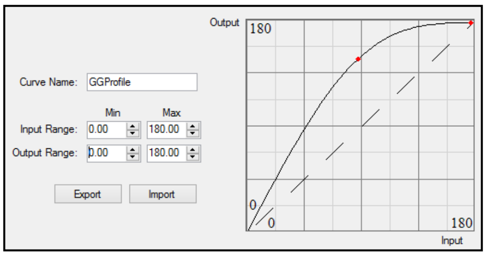

Fig. 4 Modulation curve design user interface

The maximum force we could generate before the saturation of the display was ~110g; this is due to display's limit. The modulation and converting the response to be linear helped to fix the experience when interacting with the virtual objects.

Using this method it would be possible to change the profile for the sensor at run time. The user of the system then can select the target profile depending on his application. Those profiles can be either to achieve an ideal sensor or to simulate the behavior of real sensors as in Fig. 2.

4. Conclusion

We proposed the haptic layer design to find the proper sensor with subjective experience. The layer behaves as a part of virtual telexistence platform and it contains the visual sensor with actual sensor profile curve. It also controls the haptic display to let the operator experience the static force. By using such method we can define various curves to gain different sensations when contacting the virtual objects.

As a next step, we proceed by implementing other types of haptic sensors using this approach of design to become part of the platform.

Acknowledgement

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References

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