A Real-time Sensing and Rendering of Haptic Perception based on Bilateral Control

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1 Introduction

In recent years, various haptic devices and sensors have been developed. However, development of the haptic sensor is expensive, and there is a difference in performance between these sensors and haptic rendering devices (For example, measuring method, resolution, maximum measuring force of haptic sensor and maximum rendering force of haptic rendering device, and minimum moving distance, etc.). Therefore, it is difficult to render the difference of haptic impression by the obtained data with haptic sensor. Moreover, traditional researches on the haptic sensing can not measure the various haptic informations such as the shape, hardness, and friction at same time[Okamoto et al. 2012]. Therefore, we develop a real-time sensing method of haptic perception parameter such as the shape, hardness, and friction force, based on bilateral control while feeling the haptic impression.

2 Real-time Haptic Sensing and Rendering based on Bilateral Control

In this work, we used two novint falcon haptic devices of Novint Technologies, Inc. for the haptic processing. We control two haptic devices by bilateral control, capture the haptic perception parameter such as the shape, hardness, and friction force.

In bilateral control, we connected each haptic devices with virtual spring and damper. A synchronization force F_j between master-slave is calculated as follow.

$$\vec{F_j} = K(\vec{m_j} - \vec{s_j}) + D\frac{(\vec{m_j} - \vec{s_j}) - (\vec{m_{j-1}} - \vec{s_{j-1}})}{\Delta t} \qquad (1)$$

where, j is the update counter in the haptic process, $\vec{m}$ is the position of the master's grip, $\vec{s}$ is the position of the slave's grip, K is the constant of spring, D is the constant of damper, Δt is the update rate of the haptic process.

Then, we put a real object in slave side, and control a grip in master side (see Figure 1). If a slave's grip is contacted to a real object, we capture the haptic perception parameter while feeling the haptic impression at real-time.

Figure 1: *System Overview*

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If collision between slave's grip and a real object is detected, the distance between a position of master's grip and a position of slave's grip is increased. At this time, we estimate $\vec{s_j}$ is a first collision point $\vec{s_0}$. Then we calculate a surface normal of a real object from these collision points. If collision is detected, we calculate normal component $\vec{N_j}$ and tangent component $\vec{T_j}$ from $\vec{m_j}$ and $\vec{s_j}$. Where, $\vec{N_j}$ and $\vec{T_j}$ are the unit vector.

We estimate hardness E as follow.

$$E = C_h \frac{|(\vec{m_j} - \vec{s_j})\vec{N_j}|}{|(\vec{s_j} - \vec{s_0})\vec{N_j}|} \qquad (2)$$

where, C_h is a constant parameter, $|(\vec{m_j} - \vec{s_j})\vec{N_j}|$ is a stress, $|(\vec{s_j} - \vec{s_0})\vec{N_j}|$ is a strain.

Then we estimate friction force F as follow.

$$F = C_f \frac{|\vec{m_j} - \vec{s_0}||(\vec{m_j} - \vec{s_j})\vec{N_j}|}{|(\vec{m_j} - \vec{s_j})\vec{T_j}|} \qquad (3)$$

where, C_f is a constant parameter, and $\vec{s_0}$ is updated when position of slave's grip was moved while collision is detected.

3 Sensing Result

As an example, Figure 2 shows sensing results of a hardness of a rubber, silicon gel, and sponge. We obtained clear results of a difference of the stiffness.

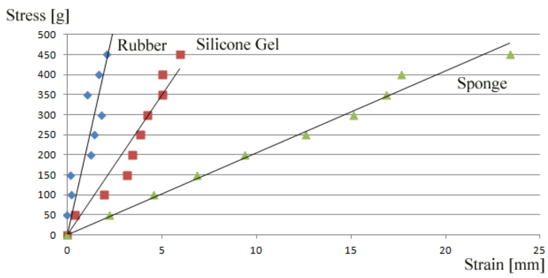

Figure 2: *Sensing Results of Hardness*

4 Conclusion and Future Work

We developed a real-time sensing method of haptic perception parameter such as the shape, hardness, and friction force, based on bilateral control while feeling the haptic impression. In future work, we plan to develop a real-time sensing and rendering system with multi finger haptic device.

References

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