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Perception-based High Definition Haptic Rendering

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1. Introduction

Haptic perception is essential for dexterous object manipulation in both real and virtual world. Recently, haptic interaction is being researched for manipulation in virtual environment.

Conventional haptic rendering employs penalty method which calculates feedback forces using only spring-damper model [RKK97]. High frequency (1 kHz-) simulation is required for stable control over haptic interfaces for meaningful haptic interactions. However, high frequency simulation tends to cause overflow of computational quantity and make simulation for virtual worlds in large scale difficult.

Perception-based High Definition Haptic Rendering (Perception-based HDHR) calculates feedback forces regarding not only physical law but also nature of human perception. This rendering is make possible using haptic interfaces whose frequencies are around 1 kHz and physical simulators based on analytical methods. Consequently, Perception-based HDHR presents rich haptic perception for large scale virtual worlds (Fig.1).

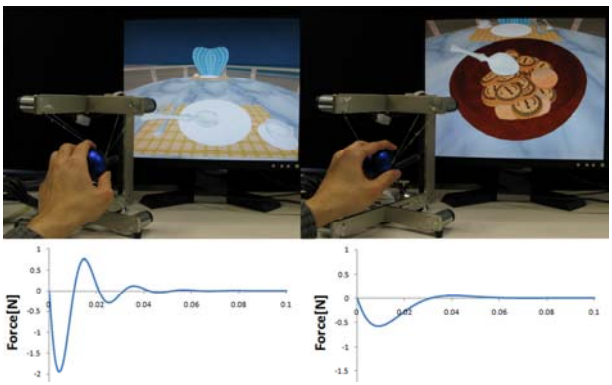

Figure 1: *Perception-based HDHR*

2. Perception-based High Definition Haptic Rendering

Perception-based HDHR displays properties of objects such as material, viscosity and elasticity respecting the nature of human perception and cognition under the constraints of controls and computational quantity. Humans perceive objects shape via normal forces, dynamics (inertia and viscoelasticy) from the relations of applied forces and motions of objects, and material properties from vibration forces caused by contact between objects.

First, let us consider perception of material. Vibrations are one of the major cues for perception of material and simulation of such kind requires high resolution deformable models and high frequency update. However, humans seem to perceive only spectrum and envelope of vibration or precise waveform of vibration seem not to be very important. Therefore, waveform of the vibration could be generated from spectrum and envelope model from experimental data aside from feedback force which represents object shapes [ODC01].

Another example is perception of inertial and viscoelastic properties. Humans perceive dynamics of objects from the relation between applied forces and motion of objects which are touched by hands. Simulations of this relation require high frequency update and consideration to effects of all objects that are in contact with the users hands. Therefore, we propose a linear model for the relation as an approximation and calculate the parameter of the model in the low frequency simulation for the whole virtual world. Then, the high frequency simulator calculates only the linear model whose computational cost is far small than the original simulation. The linear model cannot account for collision impulses given from objects not belonging to the contact group. Impulsive forces should be applied to the user's hand for consistency involving visual and haptic cues. Because visual cues have low time precision, these forces are easily achieved by simple transmission of impulsive forces.

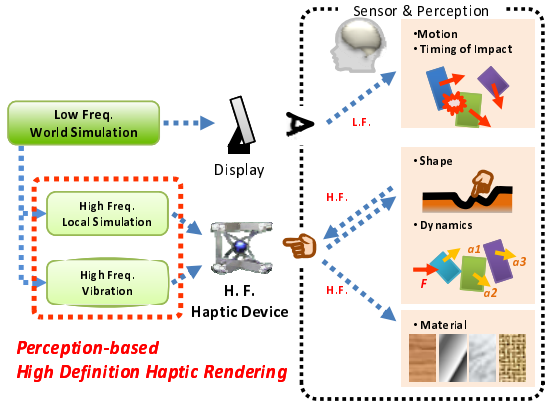

Figure 2: *The System Overview*

3. Concludion

Perception-based HDHR is an application of psychophysical knowledge of haptics. It brings high fidelity haptic sensation to low cost virtual environments with ordinary haptic devices. Thanks to psychophysical knowledge of haptics, Perception-based HDHR enables rich haptic interactions along with human perception without special devices.

Recent remarkable progress on haptics have been opened by inseparable developments of psychophysics and interface devices. We hope to involve haptic rendering into this revolution.

References

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