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Effect of Dual-rate Sampling on the Stability of a Haptic Interface

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Abstract Conventional controllers in impedance-based haptic interfaces are sampled data systems that utilize position and velocity information for the necessary force feedback. In a canonical virtual wall simulation, this feedback force is generated based on interaction with the wall simulating certain stiffness and damping. Increasing the sampling rate of the controller increases the stable range of virtual wall stiffness. However, an increased sampling rate exacerbates the velocity information, decreasing the stable range of virtual wall damping. In this work, the authors propose a dual-rate sampling scheme in which the position and velocity loops of a haptics controller are decoupled and sampled at different rates. The scheme enables independent sampling of the position data at higher rates, while simultaneously sampling the velocity data at appropriate rates. In this paper, the authors provide experimental and theoretical implications of the effect of dual-rate sampling on the stability of a haptic interface. Experiments with a single degree-of-freedom (DOF) haptic interface reveals an enhanced region of stable virtual wall stiffness for a particular range of virtual wall damping, compared to the values with conventional uniform-rate scheme. Virtual wall stiffness ranging from 150 - 360 Nm/rad was stably implemented over a range of 0 - 1 Nms/rad of virtual wall damping using the proposed scheme at position loop sampling rate of 20kHz and velocity loop sampling rate of 2kHz. Whereas in the conventional scheme, the stable range of virtual stiffness dropped considerably ($\sim$ 0 Nm/rad) for the virtual wall damping above 0.1 Nms/rad when the uniform rate sampling of 20kHz was used for both the position and velocity sampling loops. Theoretical stability analyzes using classical control tools and simulations justified the effectiveness of the proposed scheme. The scheme is easy to implement and extensible to multi-DOF haptic interfaces as well.

Keywords Haptics · Dual-rate sampling · *Z-width*

1 Introduction

Haptics refers to the emerging science of sensing and manipulation through touch and generally refers to the technology that enables physical interaction with virtual reality environments through force-feedback. The interaction force to the operator is conveyed through a special robotic device referred to as haptic device. Applications span from teaching difficult surgical procedures to medical residents, rehabilitation, psychophysics studies, training of astronauts, virtual CAD (Computer Aided Design), etc.

Several researchers in the haptics community use the term haptic device and the haptic interface interchangeably. Adams et al. [2], however, refers to haptic interface as a link between operator and the virtual reality environment

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