Whole Body Control for Haptic Interaction With Virtual Reality

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Abstract: Implementing haptic devices alongside virtual reality (VR) technology results in the ability of a user to physically feel a virtual environment (VE). Most haptic devices deliver force feedback to the hands and fingers for precision tactile details when grasping an object or brushing a hand along a surface. Whole-Body dynamic scenarios involve force feedback to the arms and legs of much larger contact forces. There are many robotic devices that are physically capable of producing these forces, but no available devices that can generate haptic feedback with a VE on this scale. The reason for this is the challenge of controlling a haptic device to create realistic contact forces for static and dynamic contact scenarios at any time, while otherwise not impeding the motion of a user. To address this problem, we present a Quadratic Programming (QP) based Whole-Body Control (WBC) approach to generating Haptic Interaction with VR. By identifying four WBC tasks, a Low-Impedance Task, two Virtual Contact Tasks, and a Privileged Position task, the controller serves as a general solution for generating haptic feedback for any interaction with a virtual object. Additionally, we present a method to decouple the real and virtual dynamics of the system through the introduction of a virtual Haptic Contact Object (HCO). The HCO is connected to a virtual model of the haptic device using a mass, spring, and damper system, which allows the HCO to maintain continuous interactions with a VE while the virtual interaction forces of the HCO are sent to the high-level controller as feedback. We implement our controller on a 10-DOF upper-body powered exoskeleton and demonstrate its effectiveness at generating sufficient haptic feedback for any contact scenario. The controller performance is evaluated on how closely a user experiences the expected virtual interaction forces.

Acknowledgement: This work received funding from the National Science Foundation (NSF) through the LEARNERs Project (Grant No. 2033592).