Rigid-body Collaborative Manipulation among Remote Users with Wearable Cutaneous Haptic Interfaces

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Abstract. We present a novel system architecture and its constituent components for multiuser haptic interaction, where geographically distributed multiple users collaboratively manipulate a shared virtual rigid-body evolving in SE(3). Wearable Cutaneous Haptic Interface (WCHI) and passivity-based real-time simulation and consensus control are employed for dexterous hand motion tracking with fingertip cutaneous haptic feedback and stable shared rigid-body manipulation on partially-connected imperfect communication network. Experiments of two users cooperatively handling a virtual rigid bodies are performed to validate the feasibility of the proposed system architecture.

Keywords: Remote Multiuser Interaction · Rigid-body Peg-in-Hole Manipulation · Wearable Cutaneous Haptic Interface · Multi-DOFs Finger Tracking · Cutaneous Haptic Feedback.

1 Introduction and System Components

Networked multiuser haptic collaboration is a concept, that would enable many interesting and useful applications combined with recent rapid-advance in information technology and consumer electronics technology. Some such applications include: virtual cooperative sculpting, virtual training of mechanical skills, virtual gym in the cyberspace, hapticallyenabled networked games, to name just few. This concept may also fundamentally revolutionize our current way of interacting with each other in the cyberspace, on top of many flourished social network service (SNS) platforms.

In this demonstration, we propose a system architecture and its necessary technological components for this multiuser shared haptic collaboration of the geometrically-distributed users over the Internet. First, we employ the Wearable Cutaneous Haptic Interface (WCHI), which consists of the Finger Tracking Modules (FTMs) and the Cutaneous Haptic Modules (CHMs), for a finger-based dexterous haptic collaboration. While existing VR interfaces [1, 2] can only track the multi-DOF finger motions with or without simple vibro-tactile haptic feedback, this WCHI is able to estimate the finger motion with soft sensors and

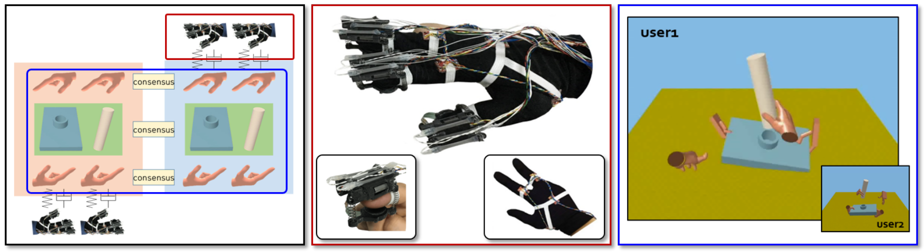

Fig. 1. Total system and its components: P2P control architecture (left), wearable cutaneous haptic interface (middle), and passivity-based VR simulation (right).

IMUs and to display three-DOF cutaneous haptic feedback on the fingertip as in [3]. Second, we employ the passivity-based real-time simulation and haptic rendering which is introduced in [4]. This passivity-based VR simulation enables our system to adopt the peer-to-peer (P2P) control architecture by enforcing discrete-time passivity while enhancing overall stability. Finally, we employ the P2P control architecture and passive consensus control similar to [5] for rigid body collaborative manipulation among remotely placed multiple users. This P2P control architecture is possible due to the open loop passivity of the local VR simulation [4]. Total system components are illustrated in Fig. 1.

2 Experiment

To validate the feasibility of the proposed multiuser hpatic interaction system, we conduct dual-arm rigid-body peg inserting experiment among two users. Both users simulate their own virtual worlds while the two virtual world communicate with each other via UDP network. On the other hand, we use the HTC VIVE tracker for localization of a wrist position, since the WCHI can only estimate finger position and rotation from the wrist. Finally, the snapshots of dual-arm peg inserting VR simulation is given in Fig. 1 (right).

Acknowledgment

Research supported by the Global Frontier R&D Program on <Human-Centered Interaction For Coexistence> (NRF-2013M3A6A3079227) of the National Research Foundation (NRF) funded by the Ministry of Science, ICT & Future Planning (MSIP) and the Industrial Strategic Technology Development Program (20001045) of the Ministry of Trade, Industry & Energy (MOTIE) of Korea.

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