Enforced Telexistence:
Teleoperating using photorealistic virtual body and haptic feedback

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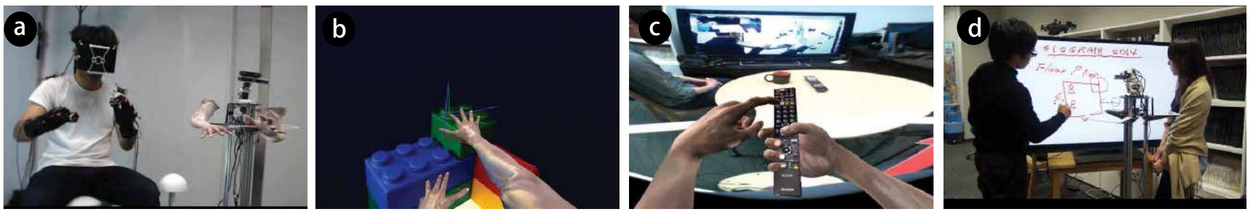

Figure 1: *(a) Superimposed Virtual Arms Concept on a Remote Telexistence Robot, (b) Touch and Feel Remote Objects using virtual arms, (c) Grabbing a Functional Virtual Copy of TV Remote, (d) Local-Remote Collaborative Digital Whiteboard.*

1 Introduction

Telexistence [Tachi 2010] systems require physical limbs for remote object manipulation [Fernando et al. 2012]. Having arms and hands synchronized with voluntary movements allows the user to feel robot's body as his body through visual, and haptic sensation. In this method, we introduce a novel technique that provides virtual arms for existing telexistence systems that does not have physical arms. Previous works [Mine et al. 1997; Poupyrev et al. 1998; Nedel et al. 2003] involved the study of using virtual representation of user hands in virtual environments for interactions. In this work, the virtual arms serves for several interactions in a physical remote environment, and most importantly they provide the user the sense of existence in that remote environment. These superimposed virtual arms follows the user's real-time arm movements and reacts to the dynamic lighting of real environment providing photorealistic rendering adapting to remote place lighting. Thus, it allows the user to have an experience of embodied enforcement towards the remote environment. Furthermore, these virtual arms can be extended to touch and feel unreachable remote objects, and to grab a functional virtual copy of a physical instance where device control is possible. This method does not only allow the user to experience a non-existing arm in telexistence, but also gives the ability to enforce remote environment in various ways.

2 System Description

To realize this concept, we developed a Master - Slave Robot system, a human sized ubiquitous telexistence robot that represents and avatar of the user in a different place. It synchronizes with the user's head and leg movements using a head tracking device (Oculus DK2) and a Pressure Pad (Wii Fit). The robot uses two binaural microphones and two Full-HD web cameras for audio and video transmission to the user.

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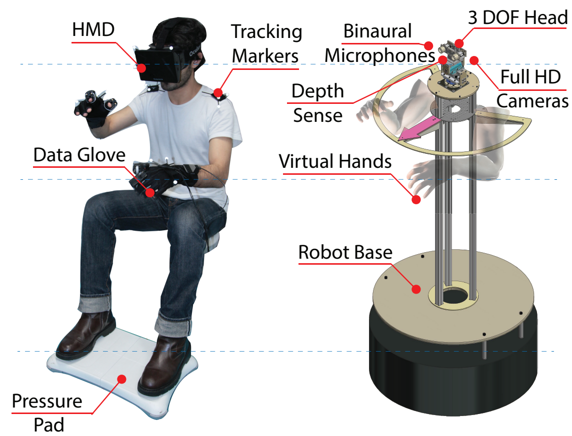

Figure 2: *Master-Slave System Overview*

As shown in Fig 2, the system tracks user's body movement using OptiTrack and data gloves to calculate the posture of the user. The measured posture is used to animate the virtual hands that act as a visual representation of his body on the remote place. The visual quality of the hand plays an important role in order to understand that virtual hand is your own. Image base lighting (IBL) is an efficient method to estimate lights of real environment images, and to use it to illuminate virtual objects [Debevec 2002]. Here we propose a method using the captured images from the telexistence robot to apply it into the virtual arms in real-time. Thus the visual appearance and colour tones of the hands matches the ambient colour of the remote place.

In this system we are using Oculus VR DK 2 to measure head rotations, and to display the robot vision with the virtual hands presented on it. Robot and the user are connected with a IP network where the connection is initiated with a server-client network architecture. The robot head movement matches user's head movement in order to maintain looking direction of the eyes, and robot base movement is determined based on user's feet interaction with the pressure pad placed under. The user can drive the robot forward/backward and rotate the base sideways using the pressure pad. The robot provides the user a stereo-image FullHD video stream in realtime with latency less than 200 ms on a local wireless network.

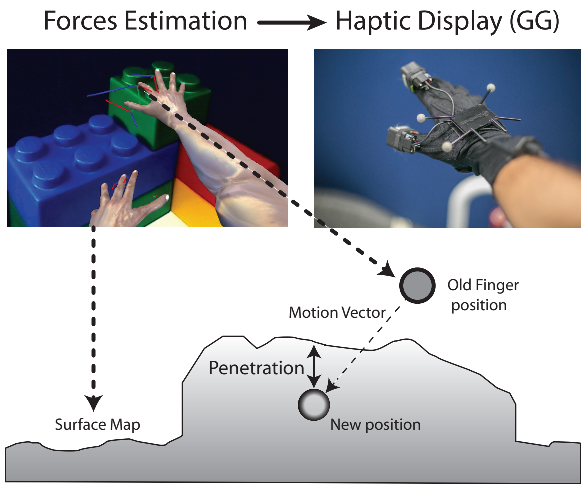

Figure 3: *Calculating touch forces using the reconstructed 3D map and user fingers motion vectors, and applying the forces to the haptic display (GG)*

A depth sensor array (PrimeSense) mounted on the robots head is used to reconstruct the remote environment into a 3D representation (surface map) in real-time at the user side. The purpose of this representation is to estimate the touch forces on user's finger tips when he interacts with the remote place objects. Virtual hand's fingers are converted into the remote environment 3D space, and based on the motion vectors of each finger the collision forces are calculated (vertical and shearing vectors). Fig 3 shows how to the motion vectors of finger tips are used with the generated surface map to calculate the touch forces. The estimated forces are applied to the haptic displays Gravity Grabber (GG) [Minamizawa et al. 2007] that are mounted on user's fingers.

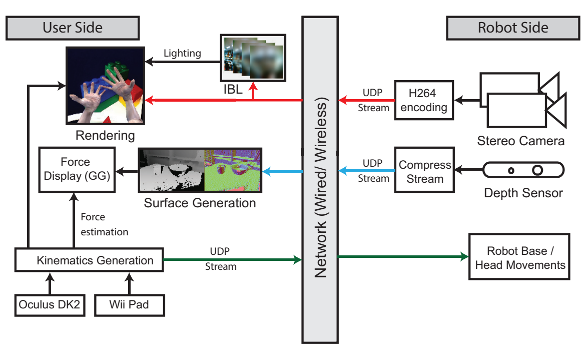

Figure 4: *General system diagram describing the main components used in this system*

A general diagram of the system is shown in Fig 4. It highlights the main components used at the local and remote sites to control the robot, and the flow to generate the virtual arms at user site using the calculated kinematics and IBL using the captured images from the remote site.

3 User Experience

SIGGRAPH Asia attendees can perform binaural communication with other attendees, and experience their own arms and hands being represented as virtual hands merged in the remote side. Furthermore, they could touch and feel the real objects (Fig 1(b)) as if they were touching them physically. Next, they can grab a functional virtual copy of a real Television Remote Controller (Fig 1(c)) and turn on the real Television on the remote side. Finally, attendees can draw in a digital telexistecne whiteboard (Fig 1(d)) together with a remote participant where both parties can feel that they are drawing in the same space with their own hands. The robot is completely mobile, and safe to move along with attendees in the demo booth side-by-side.

4 Acknowledgement

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