Remot-IO: a System for Reaching into the Environment of a Remote Collaborator

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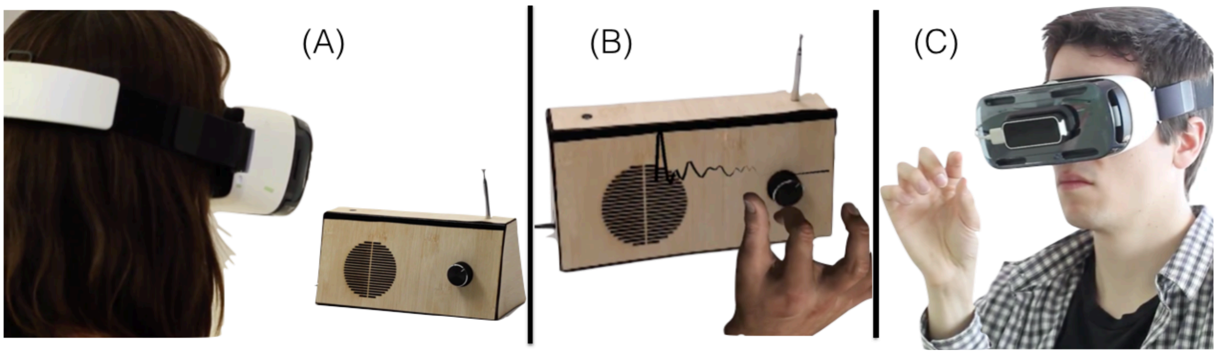

Figure 1. A novice user (A) shares her point of view and can see (B) the overlaid virtual real-time hand gestures of the remote expert and visualize, interact and modify properties of sound waves in real time by using hand gestures. The expert can remotely control the knobs and buttons of the radio and thus change the behavior of the radio using commonly used gestures (C).

ABSTRACT

In this paper we present Remot-IO, a system for mobile collaboration and remote assistance around Internet connected devices. The system uses two Head Mounted Displays, cameras and depth sensors to enable a remote expert to be immersed in a local user's point of view and control devices in that user's environment. The remote expert can provide guidance through the use of hand gestures that appear in real-time in the local user's field of view as superimposed 3D hands. In addition, the remote expert is able to operate devices in the novice's environment and bring about physical changes by using the same hand gestures the novice would use. We describe a smart radio where the knobs of the radio can be controlled by local and remote user alike. Moreover, the user can visualize, interact and modify properties of sound waves in real time by using intuitive hand gestures.

Author Keywords
Remote collaboration; Shared experiences; Telepresence; 3D interaction; Augmented reality; Hands free Interaction.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Training, help, and documentation;

UIST '15 Adjunct, November 08-11, 2015, Charlotte, NC, USA
ACM 978-1-4503-3780-9/15/11.
http://dx.doi.org/10.1145/2815585.2815738

INTRODUCTION
In the last 10 years, commercial teleconferencing systems such as Skype or Google Hangout have been increasingly used to enable communication with people that are in distant locations. Improvements in telecommunications technology have made it possible to collaborate with peers at a distance using cheap and widely available technology. However, these technologies do not support physical co-presence in the task domain and remote physical actions are not possible: a user can show a remote collaborator their environment but that collaborator cannot point at things in this environment let alone make changes or perform physical actions. For example, if a user needs help operating a device, they can call a remote expert, but the expert can only talk the user through fixing the problem, they cannot directly act upon the device.

The emergence of connected, "Internet of Things" objects and devices (IoT) makes it possible for a remote expert to do so. The Remot-IO system makes it possible for the remote expert to "reach" their hands across the Internet into the environment of the user who needs help so as to point and gesture at things as well as make actual changes to that environment simply by making hand gestures. We believe

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that Internet of Things technology can fill the gap between remote distance and physical presence through remotely controlled Internet devices.

However many phenomena of our smart environments are invisible for our visual sense, examples ranging from temperature, electromagnetic waves, pollution to audio and physical laws. This project visualizes hidden physical properties of the environment and allows the user to be immersed in another perception of the world, where the auditory sense and the visual sense are merged. We created a system that lets the user interact with and modify properties of sound waves in real time. We explore the usage of head mounted displays in combination with Internet connected devices in the context of a physical remote collaboration (Figure 1). We thereby enhance the possibilities of augmenting daily physical objects to visualize hidden information, enabling the user to form a better understanding of certain concepts and phenomena.

SYSTEM DESCRIPTION

The Remot-IO prototype consists of two HMDs that are connected via Wi-Fi and are used by a remote expert and a novice user respectively. Both users are immersed in the *novice's* field of view by sharing the video feed of the camera that is embedded in the *novice's* HMD (Figure 1A). The hands of the *expert* are tracked with a depth sensor and superimposed in real-time in the *novice* user's environment (Figure 1B). Both of them can see the *novice's* hands in the novice's environment as well as the virtual representation of the *expert* user's hands.

We also created a do-it-yourself radio to allow the user to investigate sound waves, radio frequencies and in general the physics behind sound. The system visualizes in real time the sound data that is collected through a network of sensors placed in the environment. We use augmented reality technology in order to recognize the pattern of the radio and display the hidden data. Moreover, the design of the radio includes a remotely controllable knob that can be either operated by the physical hand of the novice user as well as by the virtual hand of the remote user. The *expert* user can modify the behavior of the remotely located radio by performing hand gestures such as tuning the volume of the radio by placing the hand over the knob and performing a rotation gesture with the fingers. Once the system detects such a gesture, the knob button will physically move and turn according to the virtual hand gesture.

RELATED WORK

Some notable projects are inTouch [1], which is a system that creates the illusion that two people, separated by distance, are interacting within the same physical environment. Another project by Brave et al [2] presents a new approach to enhance remote collaboration based on touch and physicality. Physical Telepresence [3] presents a shape display as a shared workspace for remote collaboration. ShowMe [4] is a collaborative system where the users wear HMDs and can communicate with one another using 2-handed gestures and voice. BeThere [5] explores the use of 3D gestures and remote spatial input without any type of HMD.

Remot-IO differs from previous work by (1) providing a portable solution using HMDs, (2) enabling the devices users collaborate around to be operated locally as well as remotely using the same gestures, (3) creating the feeling of physical co-presence by the remote user acting as a ghost and finally (4) supporting free, natural hand gestures for remote interaction with devices.

POSSIBLE APPLICATIONS

The Remot-IO system is especially useful for applications involving remote maintenance and repair. For example, a remote expert could train or assist a novice user in how to operate a complex industrial machine. Both of them wear the system so the remote user can show to the novice operator how to manipulate the smart machine.

The Remot-IO system could also be used for telepresence applications. The novice's HMD could be mounted on a tele-operated robot which would enable a user to move around a remote space and interact with things such as light switches. The local user, if any, will see a change in the light level and would see the physical position of the switch change.

The system could also support experiential learning about certain physics phenomena through observation and hands-on experimentation.

CONCLUSION

This paper describes Remot-IO, an immersive platform that uses videoconferencing, 3D hand gestures and IoT technology to offer a solution for remote collaboration around smart devices with physical interfaces that can be operated locally as well as remotely using hand gestures.

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