Invisibilia: Revealing Invisible Data Using Augmented Reality and Internet Connected Devices.

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Abstract
Invisibilia seeks to explore the use of Augmented Reality (AR), Head Mounted Displays (HMD) and depth cameras to create a system that makes invisible data from our environment visible, combining widely accessible hardware to visualize layers of information on top of the physical world. Using our implemented prototype, the user can visualize, interact and modify properties of sound waves in real time by using intuitive hand gestures. As such the system supports experiential learning about certain physics phenomena through observation and hands-on experimentation.

Author Keywords
Remote collaboration; Shared experiences; Telepresence; DIY; Augmented Reality.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Training, help, and documentation; H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces - Computer-supported cooperative work

Figure 1. (A) Real time feed from the HMD. The user is performing a gesture to amplify the sound wave of the radio. (B) The system uses a HMD with an embedded depth sensor and a camera to see the real world and overlay AR content. (C) The user can see sound wave parameters change when manipulating the physical radio buttons.

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

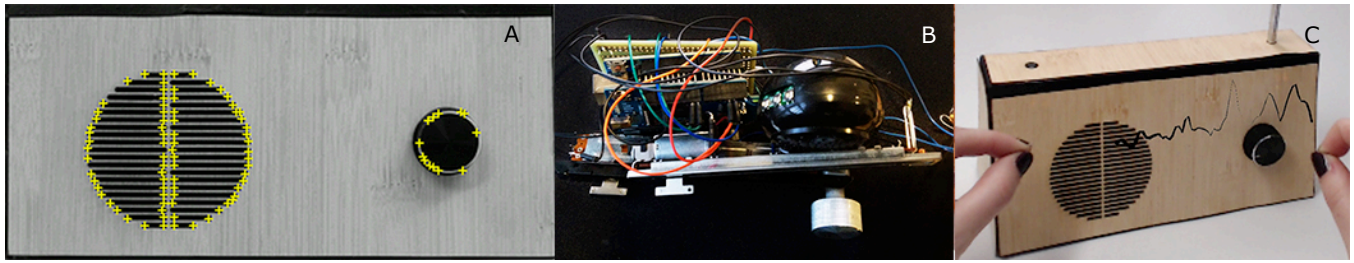

Figure 2. (A) Target image to detect and track. The yellow markings are the most recognizable features. (B) Electronics embedded inside the radio casing. (C) Final result of the prototype with overlaid real-time AR content.

Moreover, Invisibilia 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 thereby enhance the possibilities of augmenting daily physical objects to visualize hidden information, enabling the user to form a better understanding of certain physics concepts and phenomena. The system enables seamless interaction of this virtual content using natural gestures rather than forcing the user to learn a new interface language.

System Description

Invisibilia visualizes in real time sound data that is collected through a network of sensors placed in the environment and allows that remote users interact with them. We use augmented reality technology, a depth sensor and an HMD in order to create a fully immersive experience. The prototype consists of HMDs with embedded smartphones that have a camera and a mounted depth sensor attached to them (Fig. 1). The hands of the user are tracked using the depth sensor.

In order to test the viability of the project, we designed a customized radio (Fig. 2), which the users can interact with to learn about concepts such as sound waves, frequency, amplitude and pitch.

We created a do-it-yourself radio to allow the users to investigate sound waves, radio frequencies and in general the physics behind sound. We designed and laser cut a recognizable pattern (Fig. 1, A) that is integrated in the design of the radio (Fig. 1, C). The hardware design of the radio (Fig. 1, B) includes a microcontroller, a Wi-Fi board, a speaker, and a remotely controllable knob that can be operated by the user using hand gestures (mid-air hand gestures or directly controlling the radio). The augmented reality content is overlaid on top of the radio, in real-time showing the sound waves coming from the speaker (Fig. 2, C). At the same time, the depth sensor embedded in the HMD tracks the user's hands and detects multiple gestures. Pinching and stretching changes the pitch of the sound wave and zoom-in and zoom-out changes the amplitude of the signal (Fig. 1A). Once the system detects such gestures, the augmented reality will be tuned accordingly with the motion. Moreover, the knob will turn corresponding to the

motion even if the user is performing mid-air hand gestures without touching the radio.

Related Work

Our approach is informed by research that in one hand explores the use of augmented reality and tangible interfaces, and in the other hand, experiments using augmented reality for educational purposes.

Education researchers have argued that AR can positively affect the cognitive learning and enjoyment of a task. Ibáñez et al. [4] analyzed how the learning process of high school students was affected when learning electromagnetic basic concepts using an AR system. Other researchers [2] have explored how to diverge from WIMP/GUI interfaces towards reality-based interactions. For example, Mark et al. [3] and Gun A.Lee et al. [1] presented a variety of design principles and approaches for authoring tangible augmented reality applications.

Invisibilia differs from this work augmenting the real world object rather than creating a simplified representation. We take advantage of both the physical and virtual and enhance the tangibility of the real object. We created an immersive system that allows the user to learn about physical concepts in real time by visualizing them and enabling real-time manipulation via hand gestures.

Conclusion

In this paper we described *Invisibilia*, an augmented reality system for supporting experiential learning about certain physics concepts and phenomena. We offer a solution that allows users to form a better understanding of invisible data such as sound waves, through hands-on experimentation. The resulting system offers a more experiential understanding of basic concepts of sound waves and how they relate to actual sounds.

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