Weaving Social Fabric with a Home-to-Home Network

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Abstract
We believe that the future of human-building interaction lies in the mediation of human-human interactions. In this work we introduce a smart home application called Ghosting, which is a two-way telepresence system that synchronizes the audio and lighting state of two homes at a room level. This allows users to converse as they normally would while sharing a home, such as by talking while in the same room or by shouting across the house. Users can additionally experience in real time the casual yet intimate interactions of daily shared living, like hearing the remote occupant walking from room to room, coughing and shuffling papers just around the corner, and seeing the lights turn on and off. Due to its broad appeal, shared virtual living could lead to the widespread deployment of space synchronization infrastructure, forming a global home-to-home network. We explore the new applications and economies that could emerge from such a network, given the capabilities of the Ghosting infrastructure.

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H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction

A compelling smart home application that holds mass appeal for users has yet to emerge. Only 4% of households contain an "Internet of Things" device, and market research reveals that most consumers consider the smart objects currently on the market to be "gimmicky" [1]. To envision the evolution of human-building interactions over the next few decades, we need to identify what smart home capabilities might provide real, compelling value to occupants.

Our key insight is that people want to interact with other beings, not buildings. As modern life increasingly isolates us, we turn more and more to technologically-mediated avenues of socialization to build and maintain social bonds across great distances. Homes enhanced with networked technologies are uniquely poised to serve as transparent facilitators of social interaction.

Smart homes are particularly suited to creating virtual shared spaces. With their sensor-actuator networks, smart homes can capture physical context, ship it vast distances, and quickly recreate it in new locations. Interactions with the remote context can be shipped back in real time.

While a significant body of existing HCI research explores ways to use networked technology to facilitate remote physical intimacy, these efforts often involve artificial interactions with smart objects or special-purpose devices. Such interactions are generally imposed on the users rather than serving as seamless extensions of naturally-occurring interactions. The experiences are also often transactional, requiring active attention and explicit initiation.

Passive indications of presence are an often overlooked yet important aspect of shared spaces. Partners in long-distance relationships report leaving Skype running in a room for long periods of time even when not actively conversing with the other partner, in order to "simulate shared living" [5]. Transactional communications that capture active but not passive interactions miss an important opportunity to create a truly immersive experience of remote presence.

In this paper we describe an approach to virtual shared living called Ghosting. Ghosting lets people separated by distance feel like they are living in the same house by synchronizing light and audio on a room level. While users can actively converse, users can also hear the remote occupant walking from room to room, coughing or shuffling papers just around the corner, and see the occupant turn lights on and off, as if they were actually present in the home. The capability for conversation combined with the casual emanations of presence creates a sense of shared living that may be valuable for people living away from their friends and family, partners in long-distance relationships, and the elderly or mobility-constrained who would nevertheless like to spend time with their friends and relatives [5].

Ghosting extends the natural mechanics of interaction in the home. Occupants avoid accidentally turning the lights on or off on a remote occupant the same way they would if they were actually there – by being aware of the other person's presence in the room, and by asking, if necessary. If a local occupant wants to talk to a remote occupant, then they need to walk to same room or shout across the house. Ghosting provides enough information and spatial "physics" that users can interact using many of the same social conventions they would use if they were physically co-located.

Widespread adoption of our space synchronization infrastructure would result in the incidental emergence of a global home-to-home network. In the remaining sections, we explore the ways that such a home-to-home network could potentially impact social bonds, encourage new applications, and create new economies.

The Haunted House

During a Ghosting session, each occupant feels like the remote occupant is in the home with them. Sounds generated in one room are picked up by local microphones and emerge from speakers in the corresponding room in the other house. Similarly, when an occupant turns on smart lights in one room, the lights in the corresponding remote room turn on. These real-time interactions let even distant homes feel like a single shared space.

Design Points

While there are a number of factors that could make implementations of Ghosting "too creepy" or uncomfortable to use, we believe overcoming these issues is feasible with good interface design.

Based on preliminary results [2], we have identified a number of principles that should be considered when implementing the system.

The first principle is to support curation. As with more traditional online services, users want the ability to manage their image and curate what they are sharing. For Ghosting, this means that the system should provide the ability to mute and unmute both transmission (TX) and reception (RX) before a call begins and at any time during a call, even if they are not carrying a phone or other computing device. All transmitting and receiving devices in each room should come with a hardware switch that allows for immediate enabling and disabling of operation.

The second principle is to support visibility into the system state. Users should always know at an ambient level whether or not the system is transmitting or receiving data, even when they are not carrying a phone. This means the system should warn all occupants that a call is about to begin, such as by blinking the smart lights on and off, and by turning them red or some other warning color. The system should also provide a visible indicator in every room to signal whether TX or RX are currently in progress. This could be achieved by placing small and unobtrusive LEDs somewhere visible.

The third principle is to support good telepresence. This means providing at-a-glance indications of both whether someone is in the room, and who is in the room. Not only does this enhance the core user experience, it also puts occupants at ease who might otherwise be concerned about invisible people, possibly strangers, secretly listening in and sneaking around their house. For the best telepresence experience, the system should also provide an avatar that represents the remote occupant, so that people have something to look at and focus on while speaking. This can be done in a number of ways, such as by dedicating a controllable light in each room to indicate presence and identity.

Supporting Infrastructure

Implementing Ghosting is technologically feasible. While their integration may result in new applications, the core technologies required for Ghosting are not complicated. At a basic level, each room needs a good microphone that can pick up ambient sounds from across the room, at least two (preferably wireless) speakers to provide auditory immersion, LED indicator lights, and a networked controller. A working system can be constructed using easily-obtained and reasonably-priced commodity components.

The software needs to be able to support configuration, contact management, and call interfaces. The configuration stage faces the most design challenges. First, a one-time configuration step needs to be performed during system setup, which discovers the hardware on the network and maps it to the rooms of the house. Second, every time a

new contact is added to the system, a configuration step must be taken to map the rooms of the two homes to each other. The design space for this step is large. The naive approach, which could serve as the default method, is to map two rooms with the same label. But what happens when there are multiple bedrooms in a home? Should the family room be mapped to the game room or the living room? How should the system handle the mapping between a large house and studio apartment? How about mapping specific lights to each other? What if the kitchen audio in one house captures the front door opening and closing, but the kitchen is far away from the front door in the other home? Careful design of this configuration process is crucial, as it ultimately impacts the overall user experience.

Augmented Reality Extension

An augmented reality interface for Ghosting could be added by integrating a localization system into the infrastructure and generating a mapping between the three dimensional metric spaces in the two homes. If each occupant were wearing a localization tag, then an occupant could pull out their phone and use it as a viewer that renders the remote occupant visible. The remote occupant would show up on the camera as a glowing avatar, moving around the home in real time, in the locations corresponding to their remote position. This would allow occupants to "see" each other walking around in the shared space, even while talking and interacting in the ways described above.

Precise and accurate localization can be achieved using recently developed systems like PolyPoint [4]. However, the mapping between the two spaces poses interesting design challenges due to the need to accommodate context. If the remote occupant is sitting on a couch near the kitchen, then should the mapping place them at the location of the local couch, or near the local kitchen? If addressed well, this augmented reality interface has the potential to greatly enhance the experience of virtual shared living.

Magic Mirror Extension

Physical visibility into the remote space could be achieved by using "magic mirrors." These would need to behave more like physical portals and less like camera feeds. They would need to be the size of walls or doors or decorative mirrors to give the illusion of looking into an adjoined space. More challenging still is the need to allow people to converse while looking at each other directly in the eyes. While the enabling technologies for a well-done magic mirror are not yet on the market, there are potential solutions that may be commoditized within a decade or so. For example, an Apple patent published in 2009 describes a system that allows two or more cameras to sit directly behind a screen by duty-cycling parts of the screen so fast that the human viewer cannot detect it, and stitching the camera frames together into a continuous video feed [3].

The Home-to-Home Network

We envision mutual telepresence through space synchronization as a killer app that results in the deployment of infrastructure in homes across the globe. In a Ghosting-enabled home, each room has a networked microphone, speakers, and a networked controller that can communicate with other homes, household devices, and online services. Consequently, the hardware and software infrastructure used for Ghosting provides the backbone for a global home-to-home network. Such a home-to-home network would enable a number of applications, and even new industries, which we describe next.

New Applications

A home-to-home network would enable a suite of new applications that provide opportunities for unusual and ca-

sual interactions. Ghosting itself improves social bonding for families and friends separated by diaspora, elderly and mobility-constrained populations who want to visit friends and relatives, and partners in long-distance relationships. However, there are other uses for Ghosting, such as house-sitting, checking in on kids or pets who are at home alone, or providing remote observation for those in at-home care.

With very little alteration to the original Ghosting application, other applications could be developed that overlay different kinds of social networks on top of the Ghosting capability. For example, Ghosting could easily support an immersive language and cultural exchange program. Ghosting could also give rise to ChatRoulette for homes. There are many online services like ChatRoulette and Omegle that allow strangers to meet from across the planet and have sometimes moving, sometimes strange interactions, and we expect that impulse to extend to the home-to-home network.

There are also potential non-real-time applications, such as the recording, transmission, and playback of home activity and other multi-modal messages. These applications could range from digital scrapbooking to burglary deterrence.

Having a microphone and speakers in every room would also support the ubiquity of vocal controls and vocal agent interaction. We could speak to our homes, and our homes could speak to us.

New Economies

A home-to-home network would generate opportunities for the emergence of new industries. For example, there could arise people who live (and sell) "model lives." Imagine a public visionary, executive, intellectual, artist, celebrity, athlete, or guru that has some quality that you admire. Now imagine having your house prompt you to wake up when their house says that they have woken up, eat what they eat, read what they read, work when they work. If living another's life in real-time does not seem feasible, the system could generate statistical models for lives optimized for particular qualities that users desire. Users could subscribe to the "fitness" lifestyle. Users could also assemble custom lifestyles from statistical aspects of the lives of people that they admire.

In addition to lifestyle subscriptions and model lives, the home-to-home network could also be the genesis of new classes of games. Imagine also the enhancements that could be made to movies if the movie could range around your house. The horror genre in particular could make excellent use of the Ghosting infrastructure.

The infrastructure for space synchronization is simple, yet powerful and versatile enough that it could support a diversity of applications and interests, which has historically been the strength of previously successful generative platforms like smartphones and the Internet.

Conclusion

The home-to-home network and its supporting infrastructure could positively impact society by strengthening social bonds and by revolutionizing the ways in which we interact with each other and our built environment. In this paper we described an example telepresence application called Ghosting, which enables shared virtual living through the room-level synchronization of homes. If widely adopted, the infrastructure for Ghosting could lead to the emergence of a global home-to-home network. This network could produce new ways to help us stay close to friends and loved ones from afar, break through the isolation of aging in place, live healthier lives, fund unique lifestyles, meet new people, and enjoy immersive forms of entertainment. The modern age

has scattered and isolated us. Smart homes can bring us back together.

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