Shared Presence and Collaboration Using a Co-Located Humanoid Robot

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ABSTRACT

This work proposes the concept of *shared presence*, where we enable a user to “become” a co-located humanoid robot while still being able to use their real body to complete tasks. The user controls the robot and sees with its vision and sensors, while still maintaining awareness and use of their real body for tasks other than controlling the robot. This shared presence can be used to accomplish tasks that are difficult for one person alone, for example, a robot manipulating a circuit board for easier soldering by the user, lifting and manipulating heavy or unwieldy objects together, or generally having the robot conduct and complete secondary tasks while the user focuses on the primary tasks. If people are able to overcome the cognitive difficulty of maintaining presence for both themselves and a nearby remote entity, tasks that typically require the use of two people could simply require one person assisted by a humanoid robot that they control. In this work, we explore some of the challenges of creating such a system, propose research questions for shared presence, and present our initial implementation that can enable shared presence. We believe shared presence opens up a new research direction that can be applied to many fields, including manufacturing, home-assistant robotics, and education.

Author Keywords

Shared presence, robot control, telepresence, mixed reality, interfaces, human-robot interactions, human augmentation.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; I.2.9 Artificial Intelligence: Robotics – commercial robots and application, manipulators, sensors.

INTRODUCTION

What if there was a way to be two people, in the same room, at the same time? If someone could control a co-located robot, while still being able to use their body for non-robot-control tasks, we could enable one person to be able to perform complex tasks that typically require two people, or allow an expert to use their skills in two places at once: a nearby robot could be a cooking assistant, holding up bowls, passing small items, and performing other secondary tasks while you cook; someone could solder a circuit board, controlling a robot that holds the board and moves it to the best position, freeing up your hands (Figure 1); or a teacher could control a robot to transcribe dynamic notes and diagrams on a whiteboard, while they continue to lecture. We term this act of co-located robotic control while simultaneously maintaining control and awareness around your own body *shared presence*. However, there are many technical, interaction, and cognitive problems to investigate to make shared presence a reality.


Figure 1. A user controls a robot to help them solder, seeing the perspective from the robot’s hand camera in Google Glass.

Robots generally function as separate entities from the human perspective - users observe robots which perform tasks autonomously or cooperatively with the user. Alternately, a robot is a proxy for a person who is controlling it remotely, and the person becomes immersed, unable to perform any other tasks without also sacrificing some control of the robot. What if a user could “become” a nearby robot, accomplishing tasks from the robot’s point of view, while still maintaining their own perspective outside the robot?

This project sought to explore what is possible by sharing presence with a co-located humanoid robot, making use of a selection of interface devices (Figure 1). Our sample implementation offers one way to enable shared presence by streaming the robot’s vision to the user on a head-mounted display. Our implementation also investigates how to translate real-time user input to robot movements while leaving the operator’s hands free to work, making the user able to see and work from two different places at once.

HAI 2015, October 21-24, 2015, Daegu, Kyungpook, Republic of Korea
© 2015 ACM. ISBN 978-1-4503-3527-0/15/10..$15.00
DOI: http://dx.doi.org/10.1145/2814940.2814995

Shared presence is a new sub-field in human-robot interaction that could provide increased productivity for industrial and consumer applications. We define how shared presence differs and builds from current human-robot interaction research, outline challenges, and present a proof-of-concept implementation that enables shared presence. We hope that this work can inspire new ways for people to improve their lives and work with robots in the future.

SHARED PRESENCE

While we claim shared presence is a new concept in human-robot interaction, it is made up of a number of well researched concepts. In this section we describe how shared presence relates to its closest fields, how it differs from them, and some of the unique interaction challenges it presents.

Defining Shared Presence

Shared presence is the act of accomplishing a collaborative task by controlling a co-located robot. The operator completes tasks alone (but with a robot), leveraging both their own vision and ability to manipulate objects, as well as the new perspective provided by the robot, including the robot's sensors and manipulators. While controlling the robot, the operator should maintain some ability to actively participate in the task; for example, a robot soldering assistant's control method should leave the operator's hands and senses free to perform the soldering (Figure 1).

Key to the idea of shared presence is a person and robot co-operating to solve a task. Human-robot interaction researchers have studied a range of cooperative tasks – some between a person and an autonomous robot, and some between robots and other robots working independently. Unlike these works, shared presence focuses on controlling the robot, rather than co-operating with an autonomous entity.

Teleoperation, controlling robots remotely, and telepresence, feeling as if the operator was actually where a remote controlled entity is, are directly related to shared presence. These fields focus on operating a robot at a distance; in contrast, shared presence explicitly deals with a robot and its operator working together *in the same room*. Shared presence draws heavily from telepresence, as the co-located operator should have a sense of spatial awareness of and around the robot itself, but the operator is also participating in the task, and needs to maintain awareness of and around themselves. Being co-located also allows the operator to perform tasks that are difficult for robots, such as dexterous tasks, while controlled robots can improve how the user can understand and manipulate the environment (e.g. extra eyes, hands, sensors).

Challenges in Shared Presence

Shared presence presents a number of challenges in interaction design that include control, spatial awareness, and cognitive load. While many of these challenges are shared by other fields in human-robot interaction, the shared presence situation presents new constraints on these problems.

Teleoperation has the operator devote their full attention to controlling one or more robots. This is often done with mouse and keyboard, gamepad based controls, or a complicated custom controller. Additionally, operators often work at a distance, and look through a tablet or monitor to see what the robot sees. In shared presence, we envision the operator completing a task "by themselves" with the robot they are controlling. Depending on the task, it may no longer be appropriate to have the operator's hands busy with robotic controls, making the exploration of new control methods a priority. These control methods may also need to be mobile (not physically attached to the robot or a computer); for example, a welding assistant robot that manipulates large heavy parts may be controlled with the welder's legs via motion tracking technology, or a robot that helps someone carry large and heavy furniture may be controllable by detecting how the person shifts the weight of the object from the side they are carrying. Designing such task-based controls may make interfaces simpler and more applicable for domestic robots. Additional interfaces for shared presence may also spawn generalizable tools for the robotics community at large.

When controlling a robot, the operator often has access to one or more video feeds from cameras mounted on the robot. In a shared presence task, the user will also be using their own vision as they work with the robot. Switching perspectives to maximize the usefulness of all of the operator's faculties, as well as the robot's, provides a potentially huge cognitive hurdle for the operator. For example, the operator may be sitting across from their robot that is manipulating a circuit board so they can solder it easily (Figure 1). Switching back and forth between the robot's perspective and their own reverses the left and right directions, potentially confusing them and causing mistakes and frustration. Displaying multiple robot camera feeds to the operator may also mentally fatigue them. Additionally, the robot may include other sensor data such as temperature and sonar sensors that need to be presented to the user. Mitigating this cognitive load is an important challenge for shared presence research.

A person typically has an accurate mental image of where they are in relation to their surroundings, or spatial awareness. When controlling agents such as robots or characters in video games, people build a similar spatial awareness for their avatar [4]. Thus, shared presence operators must maintain a mental model of their own and the robot's surroundings and position. Techniques that help the operator do this should help reduce the operator's mental burden, and can improve the safety and efficiency of shared presence.

The above challenges are not unique to shared presence. Many of them, for example, reducing the cognitive load of an operator, exist individually in other fields. However, shared presence combines these challenges in a way that makes current techniques difficult to apply. For example, current gamepad-based robot controls are difficult to use for tasks that need the operator to have free hands. We see shared presence as a subfield with unique constraints and hope that solutions for shared presence's problems generate creative solutions that improve the field of human-robot interaction.

RELATED WORK

Collaboration between robots and people is a central theme of human-robot interaction research. This has resulted in a wide range of advancements, such as how a robot's appearance and social cues influence its perceived usefulness [2,7], robots that can learn and work alongside people [3,10], and autonomous robots with advanced algorithms that can interpret voice commands and physical gestures from people [13]. Other researchers have seen robots as an extension of the human body, for example, a robotic third arm worn like a backpack that can automatically assist people in industrial tasks [11]. Our work compliments this body of work by focusing on controlling a co-located robot, rather than having a fully-autonomous robot. Additionally, shared presence focuses on sharing the robot's perspective with the operator, rather than interacting with a robot like a separate entity.

Telepresence, taking the perspective of a robot to solve problems has also been researched [1,9]. Telepresence allows users to operate at distances (e.g., teleconference robots), or keep people safe (e.g. military bomb squad robots) [12]. The majority of these applications deal with full immersion in the robot's perspective – vision from the user's perspective gives way to the vision from the robot's perspective, by way of a screen or other display device. We extend this research by exploring how operators can control robots while simultaneously using their vision and body to accomplish a task.

Researchers have shown that a shared visual and aural context (*co-presence*) between two co-located people establishes a type of practical dialogue between the two parties, and helps accomplish co-operative tasks [6]. Shared presence between a robot and its operator is similar and could leverage these benefits, but differs as the operator has exclusive control over all perspectives, rather than both perspectives being controlled by separate agents.

INITIAL IMPLEMENTATION

We present a sample implementation that could help research shared presence. Our collaborative setup has our user sit at a desk across from our robot (Figure 1). We share the robot's perspective by streaming it to a non-opaque head-mounted display worn by the user, and the robot's arms are controlled by the user's legs. This is just one potential implementation, and exploring different interfaces is important future work.

Vision Interface

Our interface to share the robot's perspective with the operator was inspired by the "picture in picture" mode available on many televisions. This mode imposes a second television feed over another; the second feed is positioned in a small square, usually in a corner of the screen. By using Google Glass, which positions a small screen in the top-right corner of the user's vision, displaying the robot's camera feed naturally copy the picture-in-picture interface (Figure 2). This small display may help minimize the cognitive load of being aware of two vision feeds by keeping the user's vision dominant, while allowing the user to always understand what the robot is doing simply by checking the corner of their eye.

Control Interface

One of the sample tasks we had in mind while designing this interface was soldering with a self-controlled robotic assistant. As such, we wanted to keep the operator's hands free, even while controlling the robot, so that simultaneous control of their own body and the robot's body could be achieved. We believed one solution from early human-computer interaction work about leg control could be a solution to our "hands free" problem [5]. While leg control (Figure 3) limits mobility for the operator, it is a situation that is applicable to many industrial settings such as assembly lines, where workers work in one place for stretches of time. However, controlling a robot's arms with your legs is likely unintuitive.

As such, we performed a small pilot study with four students to explore potential ways a person's lower body could control a robot. Participants were asked to move a water bottle from one table to another with lower body commands, describing out loud what their command should do. A researcher acted as the robot. With this method, we hoped to find an initial direction for what intuitive leg controls might look like. We video recorded the sessions and analyzed the commands for commonalities. From our limited sample, however, our results were not be generalizable; indeed our participants had large variance in what they perceived to be a natural leg control scheme. Future experiments are necessary to design a leg control scheme for our robot.

Hardware and Software

We use a number of hardware products in our implementation. Our robot is Baxter by Rethink Robotics, a humanoid robot designed for a variety of industry applications. Baxter has a head camera and a camera in each of its two grippers, allowing us to experiment with ways of sharing perspective. Our robot operators wear Google Glass [8] to leverage our picture-in-picture method to share the robot's perspective, even while moving, unlike, e.g., a stationary monitor.

Our Baxter robot was used with ROS Indigo, and our code was written in Python 2.7. Video streaming to Glass was done with OpenCV, WireCast, and YouTube's live broadcast feature. The feed was viewed with a YouTube player embedded in a webpage, using Glass' built in web browser.

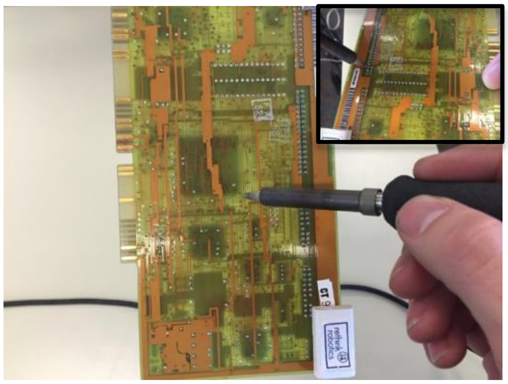

Figure 2. (mock-up) A user solders a circuit board, and can see the robot's view (top right) from one of its hand cameras which is displayed on the user's head-mounted display.

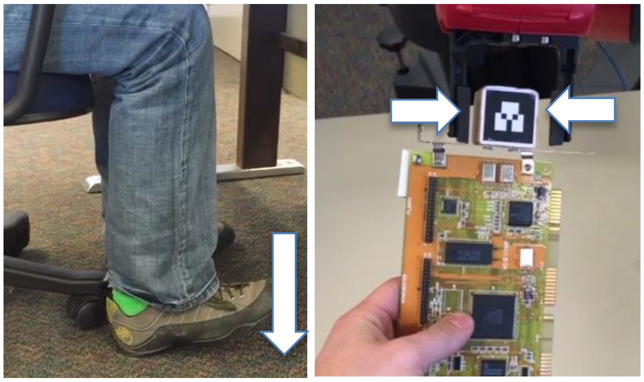

Figure 3. An example of leg control for a robot. Tapping the foot (left) commands robot's grippers to open or close (right). This leaves the user's hands free for other tasks.

DISCUSSION AND FUTURE WORK

While shared presence is made up of several well studied areas, it is unclear what previous work still applies, and what results from shared presence can be applied to other areas. Challenges in shared presence, however, may open up many avenues of research, and we propose several directions here:

1) (*Tele-robotics)* How can we reduce the user's cognitive load when presenting multiple vision feeds?

2) (*Robotic controls*) What interfaces allow a user to move their own body while controlling a robot?

3) (*Social Robots*) Do people still regard robots that are completely tele-operated by themselves to be social entities?

4) (*Telepresence*) What level of control is appropriate for semi-autonomous robots to aid shared presence situations?

5) (*Multi-robot control*) How can shared presence be applied to more than one robot?

Some of these directions may not be easily investigated with our proposed implementation; shared presence implementations can be realized using other methods and hardware. In fact, other hardware may even enable extremely different interaction methods. For example, the Oculus Rift (paired with a webcam to provide vision of the user's surroundings), may provide a more flexible platform to experiment with sharing vision (half-and-half screen splitting, dynamic perspective switching, etc.). Consumer EEG hardware is also exciting, and may even allow primitive forms of mind control for robots – we could map a robot motion to the user thinking about moving their imaginary tail, or imaginary third arm, freeing up the user's entire body. Thus, we encourage researchers to experiment with interaction hardware as well as software interfaces when investigating shared presence.

CONCLUSION

We introduced the idea of shared presence and aimed to explore how it can be leveraged to accomplish tasks that are difficult to be completed by one person alone. The idea of sharing awareness between one's self and another entity has been done before, but not with a controlled, co-located humanoid robot. In addition, we outlined some of the challenges presented by shared presence, and described one implementation that could be used to overcome such challenges. We suggested future directions for this research, and solutions may be influential in many other areas, such as teleoperation, multi-robot control, and robotic interface design. We hope that shared presence research can benefit both consumer and industrial robotics in the near future.

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