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Authors(s)	Sandygulova, Anara, Campbell, Abraham G., Dragone, Mauro, O'Hare, G. M. P. (Greg M. P.)
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Immersive Human-Robot Interaction

Anara Sandygulova¹, Abraham G. Campbell², Mauro Dragone³, G.M.P. O'Hare⁴

CLARITY: Centre for Sensor Web Technologies, School of Computer Science and Informatics,

University College Dublin, Belfield, Dublin 4, Ireland

¹anara.sandygulova@ucdconnect.ie ²abey.campbell@gmail.com ³mauro.dragone@ucd.ie
⁴gregory.ohare@ucd.ie

ABSTRACT

Networked robotic applications enable robots to operate in distant, hazardous, or otherwise inaccessible environments, such as search and rescue, surveillance, and exploration applications.

The most difficult challenge which persists for such systems is that of supporting effective human-robot interaction, as this usually demands managing dynamic views, changeable interaction modalities, and adaptive levels of robotic autonomy.

In contrast of sophisticated screen-based graphical user interfaces (GUIs), the solution proposed herein is to enable more natural human-robot interaction modalities through a networked immersive user interface. This paper describes the creation of one such shared space where to test such an approach, with both simulated and real robots.

Categories and Subject Descriptors

I.2.9 [ARTIFICIAL INTELLIGENCE]: Robotics – *Operator interface*; H.5.1 [INFORMATION INTERFACES AND PRESENTATION]: Multimedia Information Systems – *Artificial, Augmented, and Virtual Realities*; I.3.6 [COMPUTER GRAPHICS]: Methodology and Techniques – *Interaction Techniques*.

General Terms

Design, Experimentation, Human Factors.

Keywords

Human-Robot Interaction, Mixed Reality, User Interface.

1. INTRODUCTION

This work addresses the problems of achieving effective human-robot interaction by creating a shared, Immersive Human-Robot Interaction (IHRI) space, as a means by which to enable natural forms of interaction, e.g. based on gestures and dialogue, with remote mobile robots. The proposed system addresses the limitations of more traditional, GUI-based, networked solutions to remote robot monitoring and control, such as the cognitive fatigue caused by having to deal with unintuitive and cumbersome interfaces, especially when multiple robots are involved.

In our solution, the user is placed in a CAVE-like system called the LAIR [Denby et al. 2009], where a virtual environment mirroring the remote robot site is displayed around the user. Since the user's workplace can be purposefully engineered, for example through the additions of video cameras, microphones, and gesture & posture tracking interfaces, such an approach makes it easy to recognize both user's deictic gestures, such as pointing and gazing together with user's vocal instructions, before transmitting them to the remote robots. By mirroring the location of the real robots in the virtual environment, both robots and human users are given the illusion of sharing the same physical space. Instead of having to understand the robots' situation as depicted on a 2D screen, select on the graphical interface the particular robot to instruct, and click a target's destination, the user of such a system will be

able to just look around, turn toward the robot, point to the target, and utter the instruction.

The remainder of this paper describes how we built upon these concepts to create a system where to test the effectiveness of natural forms of interaction with remote, networked robots.

2. RELATED WORK

Previous research has sought to address this problem of effective human-robot interaction with remote, networked robots. The Virtual Synergy [Tejada et al. 2003] interface is a means of communicating and monitoring a collective of mobile robots engaged in Urban Search and Rescue (USAR) operations. Robots and human operators in Virtual Synergy share a Collaborative Virtual Environment (CVE), which they "navigate" by controlling their avatar. Since the CVE mirrors the real, physical space where the robots operate, the position of the users' avatars can be relayed to the robots and used to help their search strategies. Tachi et al. [2001] developed an immersive telexistence cockpit where a human operator is provided with the information about the robot's site in the form of natural audio, video and force feedback gathered by the robot, de-facto assuming direct control of the robot's body. Odashima et al. [2003] exploited a virtual environment where an immersion type display captures human upper body motions to create virtual robot simulation and then presents the human with high presence of a virtual robot for greater perception of visual and auditory information.

Our IHRI approach differs from these works by utilising an immersive user interface. Additionally, our main focus is on testing effective human-robot co-operation attained through natural forms of interaction.

3. IMPLEMENTATION

The IHRI system is implemented on top of two pre-existing systems. The *Virtual Robotic Workbench* (VRW) [Dragone 2007] provided (i) the engine to control both physical and simulated robots, and (ii) the means to exchange telemetry and sensor information within UDP multicast groups. The IHRI system exploits the first feature to create self-autonomous robot control system that can be tasked through high-level goals, such *Explore*, representing the goal of wander in the environment trying to explore new sites while avoiding obstacles, and *MoveTo(?X,?Y)*, representing the goal to be in a certain location (expressed in global, Cartesian coordinates). Once such an instruction is received by one of the robots, the robot is able to identify its location by using a pre-existing map of the environment where it operates, and also track its movements by analyzing the sensor data gathered through its on-board laser and sonar range sensors. The robot's location, and the ID of the robot, is then multicasted to every entity logged to the workbench, including other robots (both real and simulated) and users operating user interfaces connected to the workbench.

The second system integrated in IHRI is the NeXuS Mixed Reality Framework [O'Hare et al. 2005], which provides the visualization and user tracking functionalities used in the CAVE.

Specifically, a 3D replica of the robots' environment is projected around the user while an infrared tracking system and a track pad are used, respectively, to track the user's gaze, and enable the user to move within the virtual environment. As the user "travels" on the track pad, the whole scene is updated in a smooth motion and the position of the user is multicasted within the workbench. In addition, in order to experiment with gesture-driven control, a Nintendo Wii Remote and the WiiGee [Schlömer et al. 2008] open-source gesture recognition library is used to recognize simple gestures, such as those used by the user to signal a robot to stop or to get close. Once these gestures are recognized, they are translated into instructions (such as *MoveTo(User)*), and transmitted to the robots. Finally, our setup allows the user to control (via voice commands) the opening and the closure of a 2D window showing the video feedback captured by the robot's camera, which is transmitted via real time video transmission implemented over the Java Media Framework (JMF).

4. EXPERIMENTS

To demonstrate the concept of IHRI and validate our system architecture, we run three experiments as depicted in Table 1:

Table 1. Interface Types Used in the Experiments

Experiment	Robot		Visualization & User Tracking	
	2D/Simulated	Real	3D/Desktop	CAVE
1	✓		✓	
2		✓	✓	
3		✓		✓

The first experiment (Figure 1) tested the system integration between the robot 2D simulation and the NeXuS framework running on a desktop in 3D.

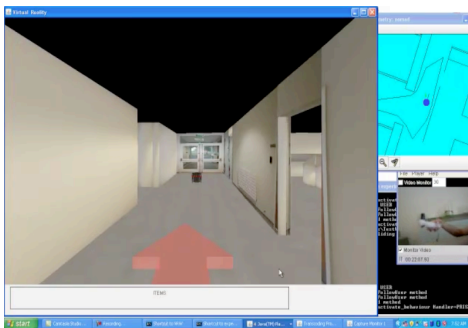


Figure 1. Simulated Robot & NeXuS on Desktop experiment, left: NeXuS snapshot, right: snapshot of 2D robot simulation

The second demonstration, shown in Figure 2, introduced the physical robots. Finally, we moved our tests to the CAVE, as shown in Figure 3. In order to exercise both robots' navigation skills and a simple set of gesture recognition modules, each experiment took the form of a simple Search-the-User game. Specifically, each robot was tasked to explore the environment and stop as soon as the user was in sight. At that point, the user was left to control the robot through the two gestures "Stop", and "Get Close", and also to open and close the video feedback window. The videos are available on the website <http://ubirobot.ucd.ie/content/demonstration-files>.

5. FUTURE WORK & CONCLUSION

The IHRI project addresses the questions of effective HRI by aiming to remove the dependency on traditional GUIs. In contrast, the user and the robots share the same space through Mixed



Figure 2. Physical Robot & NeXuS on Desktop experiment, left: robot in the office space, right: NeXuS snapshot



Figure 3. Physical Robot & NeXuS in CAVE experiment, left: robot in the office space, right: user in the CAVE

Reality technology while the user can use natural forms of interaction to manage the remote robot.

Future work will build on the prototype and conduct evaluations of IHRI with the help of HRI metric techniques, including task-based analysis, experiments and usability studies.

6. ACKNOWLEDGEMENTS

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