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Telepresence: immersion with the iCub humanoid robot and the Oculus Rift

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Abstract. In this paper we present an architecture for the study of telepresence and human-robot interaction. The telepresence system uses the visual and gaze control systems of the iCub humanoid robot coupled with the Oculus Rift virtual reality system. The human is able to observe the remote location from the visual feedback displayed in the Oculus Rift. The exploration of the remote environment is achieved by controlling the eyes and head of the iCub humanoid robot with orientation information from human head movements. Our system was tested from various remote locations using both local and wide area networks, producing a smooth control of the robot. This provides a robust architecture for immersion of humans in a robotic system for remote observation and exploration of the environment.

Keywords: Telepresence, human-robot interaction, virtual reality.

1 Introduction

Research on telepresence has grown in the last decades with the aim of providing humans with the sensation of being in a remote location. This aim has motivated the development of sophisticated devices for the study and implementation of telepresence in domains such as virtual reality, office settings, education, aerospace and rehabilitation [1]. Despite advances in technology, robust telepresence systems that offer a friendly and natural human-robot interaction are still under development. This is mainly due to the vast number of human behaviours [2], and the required technological features to make the human feel physically present at the remote location, e.g. vision, tactile and proprioceptive information, depth perception, facial expressions, language and minimised time delays [3]. In this work, we present an architecture for telepresence, which allows the remote control of the head and eyes of the iCub humanoid robot. The observation and exploration of the remote location is achieved by orientation information and visual feedback with the Oculus Rift. Our approach offers a platform to provide the human with the capability to be physically immersed in a remote location.

2 Methods

2.1 iCub humanoid

The iCub humanoid robot was chosen for the development of the telepresence system as it mirrors many human functions. The iCub humanoid is a robot that resembles a four year old child and has 53 degrees of freedom. The robot has integrated visual, vestibular, auditory and haptic sensory capabilities. It is one of the most advanced open systems suitable for the study of cognitive development, control and interaction with humans [4]. Its arms and hands allow dexterous, natural and robust movements, whilst its head and eyes are fully articulated. The iCub humanoid robot is also capable of producing facial expressions. The facial expression, e.g. sad, happy, are generated by LED (Light-Emitting Diode) matrix arrays located on the robots face, which can be controlled according to the feedback from the sensing modalities. Facial expressions are essential for providing a natural behaviour during telepresence and interaction with humans.

2.2 Oculus Rift

The Oculus Rift is a light-weight headset developed by Oculus VR that permits the immersion of humans in a Virtual Reality (VR) environment. The headset is composed by two adjustable lenses and was primarily developed for gaming, displaying virtual scenes. The stereo vision feature offered by the Oculus Rift provides the sensation of depth and more realistic immersion in a 3D world. The multi-axis head tracking capability integrated into the device allows humans to look around the virtual environment in a natural way as in the real world [5]. The Oculus Rift also includes a gyroscope, accelerometer and magnetometer, which together allow robust tracking of head position and orientation.

2.3 Control architecture

Our goal is to immerse the human in a remote environment, through both the observation of the world through the eyes of the iCub humanoid robot and via the remote control the head of the iCub humanoid robot. This offers the human the ability to look around and explore the environment in a natural way as humans do. Thus, the first step involved the development of a module which capture the visual scene from both eyes of the iCub humanoid robot and display this in the Oculus Rift. Second, a module was developed to control the head movements of the robot, by reading the orientation of the human head with the Oculus Rift. This module relied upon a cartesian gaze controller developed previously for the iCub [6]. This module was required to both calibrate and transfer into a suitable format, the orientation information arriving from the human and being sent to the robot. Both modules were precisely controlled and synchronised, thus achieving a smooth and natural behaviour of the iCub humanoid robot. These features, important for telepresence, provide the human with a more real

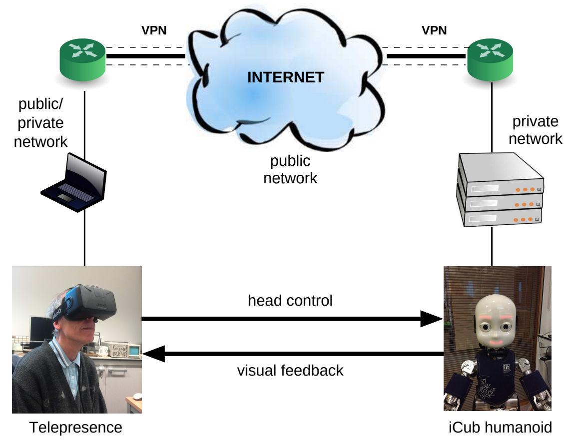

Fig. 1. Proposed architecture for telepresence with the iCub humanoid robot and the Oculus Rift via the internet. Visual feedback is provided by the iCub humanoid robot. Robot movements are controlled by information provided by the Oculus Rift.

immersion into the world of the iCub, allowing a natural exploration and interaction with the remote environment. Figure 1 shows the proposed architecture with the connections and communication established between the human and the iCub humanoid robot for remote operation through the internet. All modules were developed using C++ language and the YARP library (Yet Another Robot Platform), developed for robust communication of robotic platforms [7].

3 Results

Our architecture for telepresence using the iCub humanoid robot and the Oculus Rift was tested in different locations at the University of Sheffield. The Oculus Rift and the iCub humanoid robot software was installed and executed on two different computer systems. To provide mobility and test the architecture for telepresence from different locations, the Oculus Rift was controlled by a mobile laptop with the following specifications: Core i5 Processor, 4 GB RAM, NVS 3100M Graphic processor, 512 MB for CUDA. The iCub humanoid robot was set up in the Sheffield Robotics Laboratory and controlled by a dedicated computer system with the following features: Xeon E5-1620 Processor, 16 GB RAM, Nvidia Quadro K2200 Graphic processor, 4GB RAM for CUDA. These systems have the computational power to minimise temporal delays in processing of the visual and orientation information that would reduce the immersive telepresence experience. A Virtual Private Network (VPN) was established to provide a secure and robust communication channel between the human and the iCub humanoid robot. The VPN also permitted access from different locations outside the University of Sheffield, to the local static IP address assigned to the iCub humanoid robot (Figure 1). The teleprescence system allowed a human participant to visually explore a remote environment through the eyes of the iCub humanoid robot. Robust eye and head movements were achieved with the robot based on the orientation and position information from the Oculus Rift and the open source Cartesian controller developed for humanoids [6]. Also, provided the human with the sensation of visual depth and a feeling of presence in the remote location. For the current study, the delay between the human movements and the response of the iCub humanoid robot was imperceptible for the human. These results show the robustness of our architecture for telepresence.

4 Conclusions and future work

In this work we presented an architecture for the study of telepresence. The system was composed of the Oculus Rift and the iCub humanoid robot. As an initial approach, we used the eyes of the iCub humanoid robot for observation and exploration of remote locations. The telepresence system allowed the human to be successfully immersed in a remote environment by controlling the head and eyes of the iCub humanoid robot. Immersion using a telepresence system not only requires of vision but also all the sensing modalities available with the chosen robotic system. Thus, for future work we plan to develop and integrate tactile feedback, speech capabilities and the control of the arms, hands and facial expressions. This will provide a complete telepresence system for robust and natural human-robot interaction.

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