https://doi.org/10.31256/Ev1Gb8W

Survey on Virtual Reality and Robotics

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***Abstract*—Remotely-managed robotic systems are becoming widely utilised in many domains, as they offer safe and precise control for operators. To improve comprehension for remote users, Virtual Reality can be utilised for enhancing knowledge acquisition. In this paper, we explore the variety of approaches used for the deployment of Virtual Reality in robotic applications.**

***Index Terms*—virtual reality, remote robotics, knowledge acquisition**

I. Introduction

Robotic systems are becoming larger and more advanced as technology improves. As such, it is important to communicate system information concisely and coherently to a user. For this purpose, Virtual Reality (VR) can be utilised as an effective medium due to the immersion it provides in perception, interaction and control.

Virtual spaces can be thought of as a computer-generated digital-twin to a space in the real world. In robotic applications, they are constructed using information about the robots (e.g. URDF, Maps, configurations) and sensory inputs (e.g. Camera, IMU, PointCloud). These spaces can be basic visual rendering of the data (e.g. RViz, Foxglove) but can also offer full physics simulations (e.g. Gazebo, CoppeliaSim).

VR is a window into the virtual space, offering users navigation over multiple degrees of freedom, and interaction capabilities with robots in the space. Benefiting from the improved environmental understanding gained from immersion, VR is already being utilised by remote operators for domains such as hazard cleanup [21, 9], and medical assistance [15, 17].

II. Perception of the Virtual Space

Early research in VR based robotics tended to use either a dedicated set of gear [12] or a flight-simulator style cockpit [2] to place the user in the position of the robot with a first-person viewpoint. In recent years, VR Headset technology has become more accessible and diverse, with competing devices such as the HTC Vive, Oculus Rift and Oculus Quest released into the consumer market.

VR headsets are not the only way to view a virtual world. Technologies such as Augmented Reality overlay digital information to a view of the real world, using devices such as smartphones for this purpose. [1, 11]. Mixed reality devices such as Microsoft Hololens, project the virtual world to the real world and allow for interactions between them [18]. Another approach for perceiving the virtual space is a CAVE system [4], where orthogonal planes of the world are projected onto blank walls of a room. Continuing developments to immersive technology and supporting software such as these, help to support the homogeneity of human/robot perception.

III. Interacting with a Virtual World

Observation of the virtual space is enough for monitoring the state of processes in an robotic system. With the use of input devices, the user is able to also remotely interact with the system. Methods which pass inputs to the outside without utilising the virtual space can be classified as meta-inputs; examples of which are standard keyboards, mice, and joysticks [22]. By utilising virtualised meta-devices the user is able to feel more immersion; this was shown by [7] in which a virtual button pad was included for users to select which drone to observe in a warehouse monitoring tool.

Many VR headsets come with controllers containing IMUs, buttons and joysticks. The IMUs can be used as motion trackers to project a users position and orientation into the virtual world. They can be used for tracking gripper positioning [3] or to select and actuate joints in robotic manipulators [21]. Buttons, and joysticks on these controllers can be used to select menu options [6, 7], or to manipulate the space to be observed from different angles [13].

IV. Controlling the Virtual World

Whilst being able to input commands into a system is useful, only with the utilisation of immersive interaction is the full benefit of VR Robotics evident [14, 7].

Approaches can generally be classified into two groups: tele-operation (third-person) and tele-guidance (first-person). Tele-operation refers to explicit control, e.g. remote robot control with a joystick [5], setting individual joint positions (forward kinematics) [8, 21], or setting explicit destinations for the robot to achieve (utilising inverse kinematics) [21].

The second grouping is tele-guidance, in which the remote robot becomes mapped to the user. In these approaches, the user is fitted with a set of trackers and the robot follows the changes of the user. This has been used for robot arm mapping [19, 20], grip estimation [19], drone positioning [10].

V. Conclusion

From the literature reviewed in this survey, two key areas have been identified as having limited exploration.

a) Exploration of Domains: When looking at the distribution of research domains in robotics and VR, there is a broad variety on published research in tele-operation and tele-guidance of robotic manipulators; the variety in content related to tele-guidance of mobile robotics and of multi-robot systems, is not as widely explored. Given the growing economic viability of robotic fleets in industrial applications, there is a lot of unexplored potential to diversify VR integration.

b) Exploration of Utility: Hardware to support VR applications has for a long time, been inaccessible at a consumer level, with any major research in this domain being restricted to industry development utilising large flight-simulator technology [16]. Consumer level VR is fairly new, and many tools are immobile [20], or lack computational resources [11]. This has amounted in fairly few use-cases being explored given the trade-off constraint between utility and accessibility.

In the last few years, this has begun to change, with consumer-grade hardware offering mobile, cable-less experience at lower-cost, and smartphones able to handle much more complexity. As a result of the greater availability of hardware, the trade-off constraint has lessened allowing for more diverse research applications. However, the current lack of variety in VR robotic application domains, with the major focus being on tele-operation, suggests that VR robotics is still immature and is unable to cement itself as a frontier in robot research.

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