Robot Telekinesis: An Interactive Showcase

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ABSTRACT

Unlike large and dangerous industrial robots on production lines in factories that are strictly fenced off, collaborative robots are smaller and safer, and can be installed adjacent to human workers and collaborate with them. However, controlling and teaching new moves to collaborative robots can be difficult and time-consuming when using existing methods such as pressing buttons on a teaching pendant or directly grabbing and moving the robot by force (direct teaching). We present Robot Telekinesis, a novel robot-interaction technique that allows the user to remotely control the movement of the end effector of a robot arm with unimanual and bimanual hand gestures that closely resemble handling a physical object. Robot Telekinesis is as intuitive and fast as direct teaching, without the physical demands of direct teaching.

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1 INTRODUCTION

A new breed of small and safe robot arms called collaborative robots are entering the workplace. Unlike their large and dangerous industrial cousins in factories, which must be strictly fenced off, collaborative robots can be installed in close proximity to human workers and work with them side by side. These robots can perform repetitive tasks with high speed, precision, and endurance, so that the human workers can better focus on creativity and critical decision-making [Shah et al. 2011; Sheridan 1996].

Collaborative robots are expected to reach new, complex, and ever-changing workplaces where application of robotics was previously infeasible, such as a cramped workshop or the busy kitchen of a large restaurant. Unlike factories, the configurations and tasks in these environments may change frequently, so a way to quickly program new routines for new tasks is needed. However, controlling and teaching spatial moves can be difficult and time-consuming when using existing methods, especially for non-experts.

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Figure 1: Robot Telekinesis [Lee et al. 2020] allows the user to remotely control the movement of the end effector of a robot arm with hand gestures that closely resemble handling a physical object.

Controlling the spatial movement of a robot with many DOFs in real time is an inherently difficult task. Within the robotics community, a common approach has been capturing real-time movements of a human user (master) and mapping them to those of a robot (slave). These master-slave techniques, coupled with immersive visual and haptic sensors and displays, can convincingly simulate the first-person experience of stepping inside the robot's body [Fernando et al. 2012]. The ability to perceive and control the robot as a part of one's own body can improve the performance of mission-critical tasks such as nuclear reactor maintenance [Sheridan 1989] and remote medical surgery [Sung and Gill 2001].

However, with collaborative robots, the user needs to control and teach a robot that directly interacts with him or her from his or her own point of view, requiring the user to step outside the robot's body and perceive and control the robot as a remote object. Within the human–computer interaction (HCI) community, interaction techniques for manipulating virtual remote objects, such as CAD models, that closely resemble handling a physical object have been known to be intuitive and effective [Mapes and Moshell 1995; Ware and Jessome 1988]. Feng et al. presented a detailed survey of such unimanual and bimanual manipulation techniques [Feng et al. 2015].

In this interactive showcase, we present Robot Telekinesis [Lee et al. 2020], a novel interaction technique that allows the user to move the end effector of a robot arm with hand gestures that closely resemble handling a physical object (Figure 1). Using our technique, the user can quickly and easily control the robot from a distance, as if physically grabbing and moving the robot, without actually making physical contact or exerting physical effort.

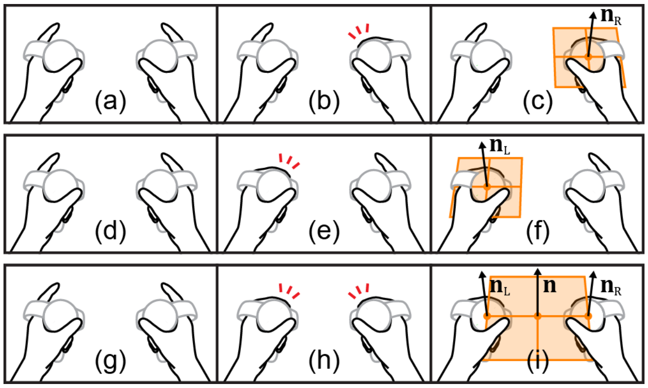

Figure 2: (a, d, g) The user holds two 6-DOF controllers. When the user activates (b) the right or (e) the left controller, a virtual plane with the normal (c) $\mathbf{n_R}$ or (f) $\mathbf{n_L}$ fixed to the controller is created. (h) When the user activates both controllers, (i) a virtual plane is created whose center is the midpoint between the two controllers, primary axis is the line segment between the two controllers, and normal n is the average of $\mathbf{n_R}$ and $\mathbf{n_L}$.

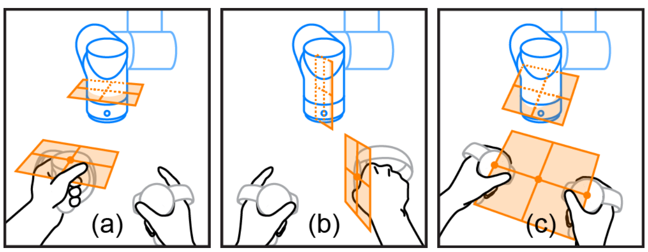

Figure 3: When a virtual plane is created at (a) the left hand, (b) the right hand, or (c) the midpoint between the two hands, another virtual plane with the same orientation is created at the center of the end effector of the robot arm. The handheld plane acts as a motion proxy to the one at the end effector.

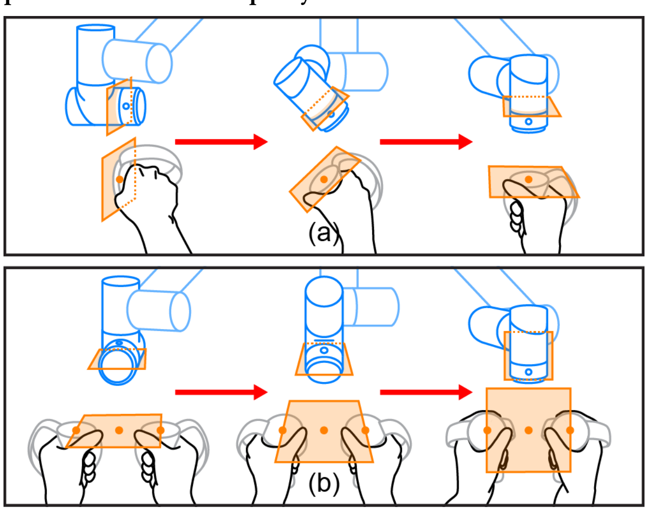

Figure 4: When the handheld virtual plane is translated and rotated, the motion deltas of the handheld plane are transmitted to the end effector in real time. The user can control the end effector as if physically holding and moving it by the planar handle, with (a) one or (b) two hands.

2 ROBOT TELEKINESIS

Robot Telekinesis [Lee et al. 2020] is an interaction technique for controlling the real-time movement of the end effector of a robot from a distance, using one- or two-handed gestures that resemble holding and moving a free-floating plane with one or two hands.

The user holds two low-cost, lightweight 6-DOF motion tracked controllers. By activating the controllers, the user can create and hold a virtual plane (Figure 2) with one hand (e.g. as if holding a small plate, Figure 2c, f) or two hands (e.g. as if holding a large tray, Figure 2i). At the same time, another virtual plane with the same orientation is created at the end effector of the robot (Figure 3).

When the handheld plane is translated and rotated, the motion deltas are transmitted to the plane at the end effector in real time (Figure 4). As a result, the end effector follows the hand motions as if the user were holding and moving a plane that is physically attached to the end effector.

The user can activate and deactivate controllers at any time, in any order, for clutching. For instance, the user can repeatedly clutch one controller by itself; alternatingly clutch between the left and right controllers; or repeatedly clutch both controllers.

Through clutching, the user can make larger movements through repetition, or make movements with more comfortable gestures. The user can also deactivate the controllers and walk to a better standpoint without affecting the robot during transit.

3 INTERACTIVE SHOWCASE

The interactive showcase implementation of the Robot Telekinesis technique uses the Universal Robots UR5 collaborative robot, a 6-axis robot arm with a working radius of 850 mm and a payload of 5 kg, and Oculus Rift infrared LED sensors and touch controllers, which capture the 6-DOF movements of the two hands in real time; the Oculus Rift VR headset is not used.

During the interactive showcase, attendees are given a tutorial of the interactions lasting a few minutes and attempt to collect 10 square magnetic tiles placed around the workspace with a magnet attached to the front-facing side of the end effector of the robot arm. This task, which typically takes roughly 10 minutes for an expert with a button-based teaching pendant, can be completed in roughly 1 minute by a novice attendee.

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