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Development of a Mixed-Reality Hands-Free Teleoperated Robotic Arm for Construction Applications

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Abstract : With recent advancements of automation in robotics, from self-driving cars to autonomous 4-legged quadrupeds, one industry that has been stagnant is the construction industry. The methodologies used in a modern-day construction site consist of arduous physical labor and the use of heavy machinery, which has not changed over the past few decades. The dangers of a modern-day construction site affect the health and safety of the workers due to performing tasks such as lifting and moving heavy objects and having to maintain unhealthy posture to complete repetitive tasks such as painting, installing drywall, and laying bricks. Further, training for heavy machinery is costly and requires a lot of time due to their complex control inputs. The main focus of this research is using immersive wearable technology and robotic arms to perform the complex and intricate skills of modern-day construction workers while alleviating the physical labor requirements to perform their day-to-day tasks. The methodology consists of mounting a stereo vision camera, the ZED Mini by Stereolabs, onto the end effector of an industrial grade robotic arm, streaming the video feed into the Virtual Reality (VR) Meta Quest 2 (Quest 2) head-mounted display (HMD). Due to the nature of stereo vision, and the similar field-of-views between the stereo camera and the Quest 2, human-vision can be replicated on the HMD. The main advantage this type of camera provides over a traditional monocular camera is it gives the user wearing the HMD a sense of the depth of the camera scene, specifically, a first-person view of the robotic arm’s end effector. Utilizing the built-in cameras of the Quest 2 HMD, open-source hand-tracking libraries from OpenXR can be implemented to track the user’s hands in real-time. A mixed-reality (XR) Unity application can be developed to localize the operator's physical hand motions with the end-effector of the robotic arm. Implementing gesture controls will enable the user to move the robotic arm and control its end-effector by moving the operator’s arm and providing gesture inputs from a distant location. Given that the end effector of the robotic arm is a gripper tool, gripping and opening the operator’s hand will translate to the gripper of the robot arm grabbing or releasing an object. This human-robot interaction approach provides many benefits within the construction industry. First, the operator’s safety will be increased substantially as they can be away from the site-location while still being able perform complex tasks such as moving heavy objects from place to place or performing repetitive tasks such as painting walls and laying bricks. The immersive interface enables precision robotic arm control and requires minimal training and knowledge of robotic arm manipulation, which lowers the cost for operator training. This human-robot interface can be extended to many applications, such as handling nuclear accident/waste cleanup, underwater repairs, deep space missions, and manufacturing and fabrication within factories. Further, the robotic arm can be mounted onto existing mobile robots to provide access to hazardous environments, including power plants, burning buildings, and high-altitude repair sites.

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