Aerial Manipulation Using Embodied Human-Intelligence For Bridge Inspection And Maintenance

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Mobile manipulation employs one or several robot manipulators that are designed for tasks such as object positioning, sensor insertion, and tool handling. These manipulators are attached to ground vehicles, aircrafts, underwater and space robots for operations. Aerial manipulation is an active research topic in robotics. Drones with serial, parallel, and bio-inspired manipulator have been deployed for operations such as valve-turning, structure assembly, package manipulation, and industrial applications. The rationale is that a mobile-manipulating unmanned aerial vehicle (MM-UAV) could replace workers in high-risk tasks that are being vertically lifted or suspended from a bridge, wind turbine blade, or power line. In the past decade, the state-of-art aerial manipulation have focused on autonomy. The notion is that a MM-UAV could autonomously identify the object, configure grasping, plan motions for desired goals. Many research groups have demonstrated this by simplifying design constraints: object geometries can be easily identified by computer vision; object rigidity is suitable for pinch or power grasp; linear or rotational path plans that are mainly like straight up-and-down or turning. Their works are valuable, but prevent full implementation, hence adoption. Recently, haptic-based human-in-the-loop approach has been addressed to shift the current paradigm of aerial manipulation. The main key is to include an expert worker and leverage their expertise to collaboratively perform aerial manipulation. In bridge inspection and maintenance, for example, the worker often touches rivets, pokes surfaces, and pries patches. In such tasks, haptic assessment provides important information to the worker. Thus, use of haptic device in aerial manipulation enables the worker to leverage the haptic feedback assessment of object properties to collaboratively complete tasks with drones. Several researchers (including our lab) have demonstrated this approach for drilling and peg-in-hole tasks. While the works above adding more value to aerial manipulation, one of challenges remaining is to give the operator a sense of presence; the operator does not feel the senses and actions transported to and from the drone. Lacking is sensory information about the physical layout and social interaction with on-site workers. To address this challenge, we integrate the immersive technologies like virtual (VR) and augmented reality, to the haptic-based human-in-the-loop aerial manipulation. The major benefit of these technologies is embodiment: delivering presence of the user in the real world to the virtual world; mapping human body gestures. In aerial manipulation, the embodiment could enable the operator to feel as if they are truly where the drone is, experiencing a sense of presence through it. Toward this vision, we present a human-embodied interface for aerial manipulation in bridge inspection and maintenance. The goal is to give the worker a sense of presence while performing tasks on the bridge using a MM-UAV. The interface differs from teleoperated aerial manipulation; the worker actually sees, hears, and feels what's happening on the worksite. The worker can physically interact with objects and socially interact with on-site workers through the drone.