A Human-Embodied Drone for Dexterous Aerial Manipulation

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INTRODUCTION

Current drones *passively surveil*. Drones equipped with robotic arms shift this paradigm: the drone is actively interacting with the environment rather than simply sensing it. This would be needed to robotically enhance bridge-related work, called dexterous aerial manipulation: drones could hose decks; drilling on surfaces; and epoxy cracks. Such research is important to advancing bridge maintenance and repair.

Recently, the worker's experience was integrated in aerial manipulation using haptic technology. The net effect is such system could enable the worker to leverage drones to collaborative perform haptic assessments of the objects and complete tasks on the bridge remotely. However, the tasks were completed within the operator's line-of-sight.

Research gap: an immersive framework based on AR/VR is rarely integrated in aerial manipulation. Such framework allows drones to transport the operator's senses, actions, and presence to a remote location in a real-time. Hence, the operator can physically interact with the environment and socially interacts with actual workers on the work site.

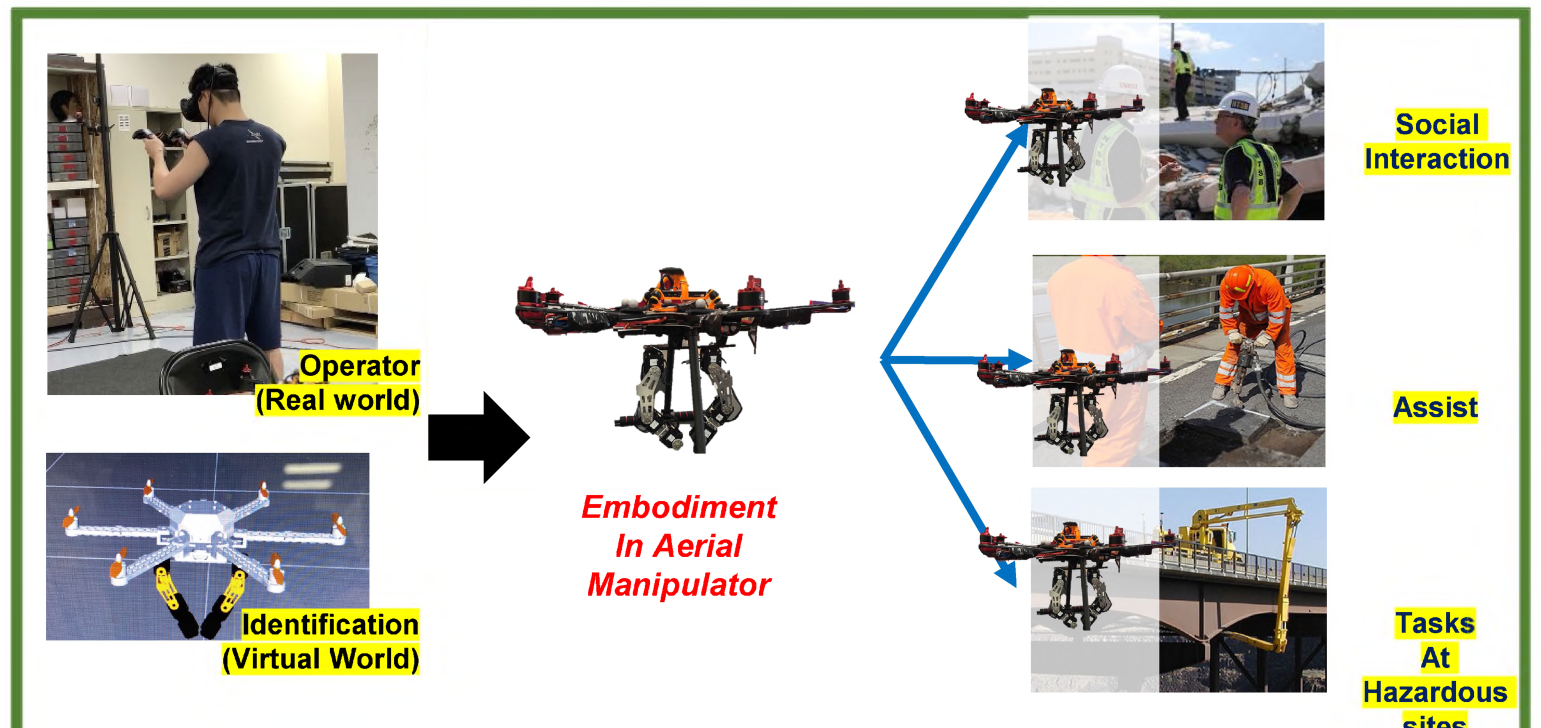

Fig 1: Overall scheme of the human-embodied drone interface

METHODS

Design *a "Human-Embodied Drone Interface"* (**Figure 1**):

Dual-Arm Aerial Manipulator: For dexterous manipulation. Visual sensing. Capture reaction forces from physical interactions.

Virtual Reality (VR) System: A visual immersion into the work-site. Human body motion capture. Haptic feedback to the operator.

Voice Communication System: Bandpass filter to eliminate drone propeller noises.

Flight trial scenario: Operator-Sender collaboration for a package delivery to validate the performance

RESULTS

Two 3-DOF robotic arms with parallel grippers were mounted on a rotorcraft drone to synthesize human arm motions. The gripper sensed reaction forces while interacting with objects. VR controller served as the haptic interface. A camera was attached to a motor on top of the arms to provide 2D visual feedback in real time. The motor tilted the camera following the operator's head motions. In addition, a 3D model of the test-site was pre-captured and rendered in the VR headset to provide better situational awareness. The key result was that the operator could use a drone to perform tasks and socially interact with people on the task-site. (**Figure 2**)

Figure 3 showed summary from the flight trial scenario. **Figure 4** successfully captured arm trajectories and haptic feedback. **Figure 5** showed the voice communication was barely interfered by drone propeller

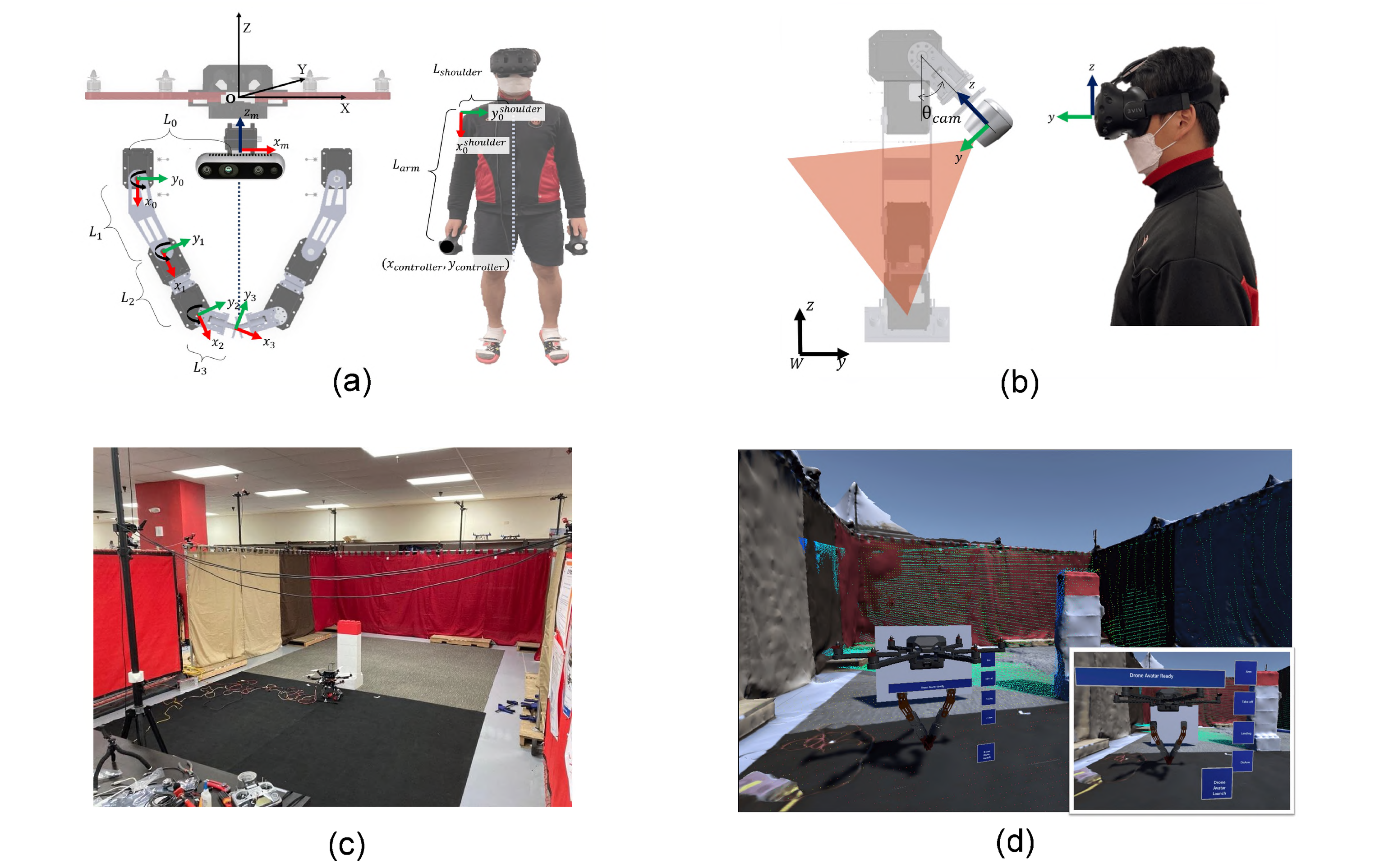

Fig 2: (a)-(b) Human arm/head motion mapping to aerial manipulator. The red triangle shows field-of-view of the camera, (c) Test-site in the real world, (d) Test-site and the aerial manipulator rendered in the VR headset

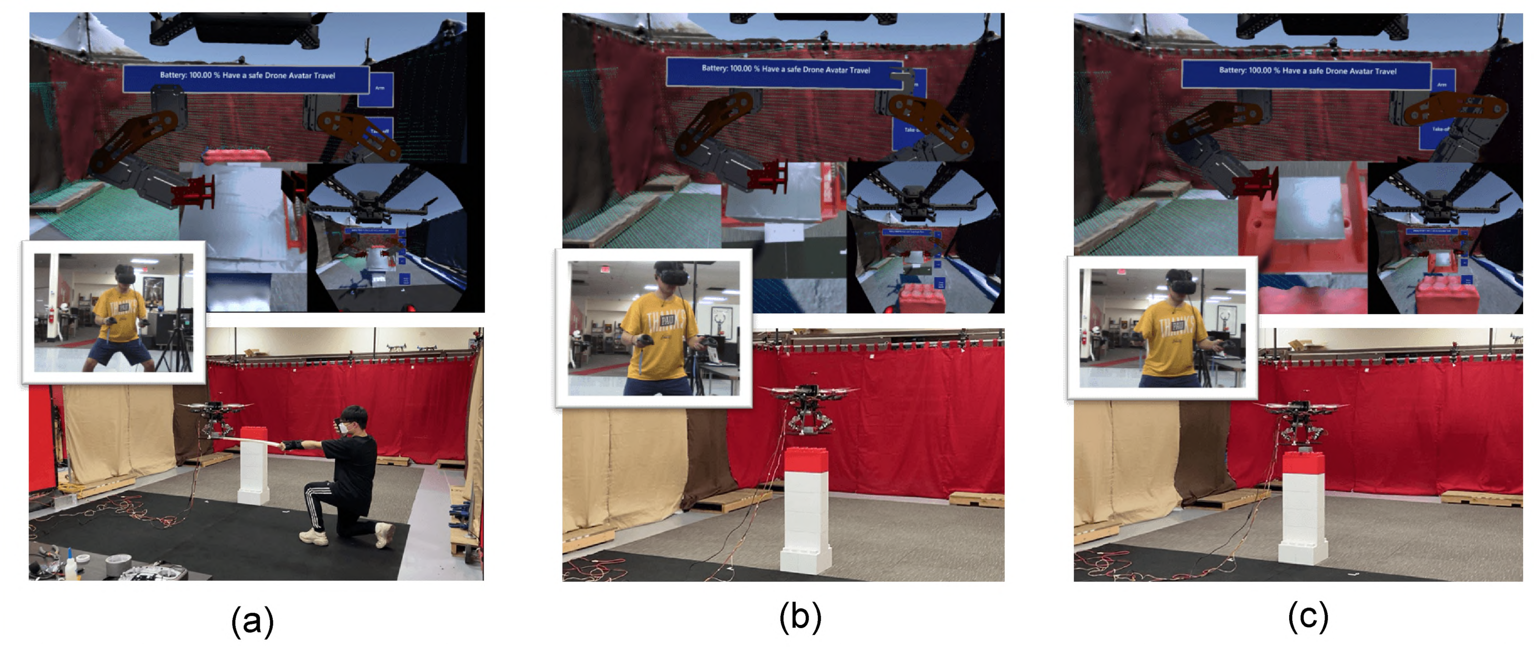

Fig 3: Flight trial summary, VR headset view (top), Operator (center left), Test-site in real-world (bottom): (a) Received the package from the sender after voice communication; (b) Arrival at the target delivery point; (c) Package delivery complete

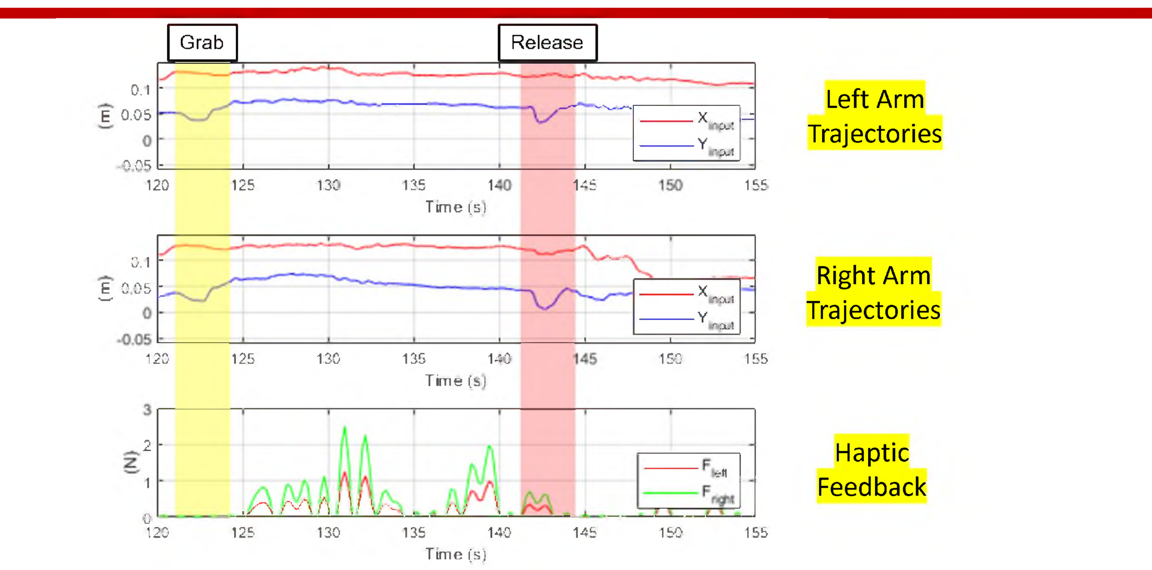

Fig 4: Arm motions and haptic sensing results during the flight trial

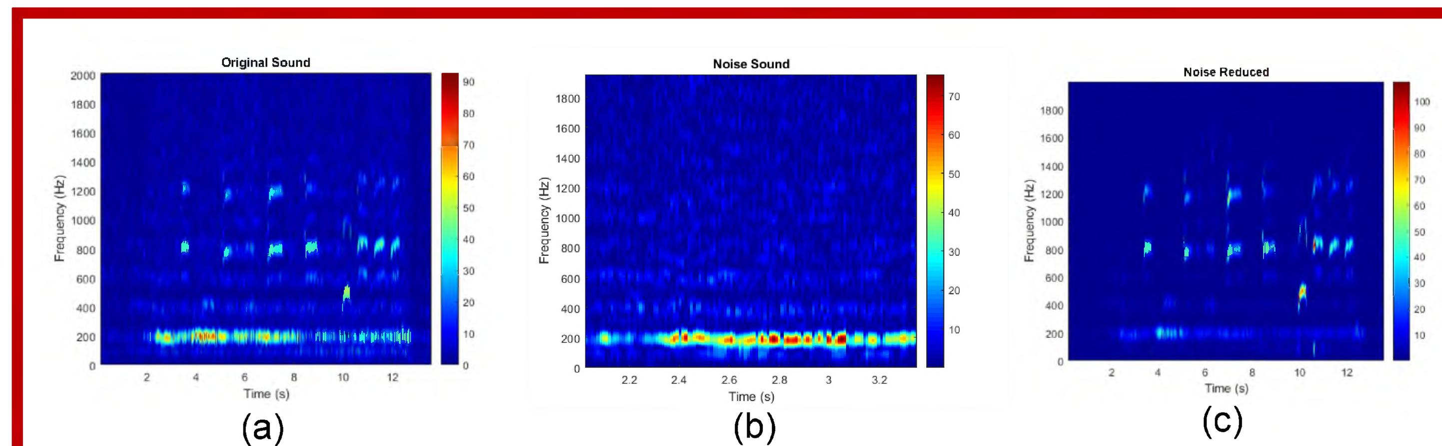

Fig 5: Propeller noise filter results during voice communication. (a) Original sound, (b) Noise sound, (c) Noise-filtered sound

CONCLUSIONS

Key contribution of this research is "*Embodiment*". Flight trial well demonstrated promising results. The operator successfully performed package delivery with no *a priory* information about the package or the environment. The operator could also socially interact with the package sender during the flight.

Future work:

- Improvements of the robotic arm design for bridge-related dexterous manipulation tasks: epoxy cracks; horizontal drilling; tool manipulation
- Integrate 360 camera to provide real-time 3D visual feedback

Human-embodied drone interface would help workers augment their *intelligence* for the desired tasks

REFERENCE

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