AeroNette: Human-Marionette Interaction for Upper Body Kinaesthetic Feedback

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Figure 1: AeroNette uses a (a) hexacopter drone that carries a pair of robotic arms. These arms provide kinaesthetic feedback to the user via tethered strings, allowing for applications like (b) real-time tele-operation and (c) assistive motions.

ABSTRACT

Kinaesthetic feedback refers to muscle and joint actuation, yet, systems that can fully actuate the upper body tend to require the user to attach a bulky or heavy setup on them. We propose AeroNette, a drone-based system that provides kinaesthetic feedback to a user via human-marionette interaction. AeroNette utilizes a drone's lifting force with a pair of robotic arms attached to the user via strings to provide full upper body rotation and arm movement. This allows the user a higher spatial freedom to experience kinaesthetic feedback, as well as provide kinaesthetic control from a remote user. Additionally, the user is also free from any additional load and can operate both indoors and outdoors environment. We propose several applications for AeroNette and prepared a 5 minute demo experience to showcase its potentials.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; *Redundancy*; Robotics; • **Networks** → Network reliability.

KEYWORDS

human-marionette interaction, kinaesthetic feedback, drone

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1 INTRODUCTION

The full range of motion for a human is a complex system to model, and creating a system that can perform full body actuation remains a challenging task. Such an actuation relies on kinaesthetic feedback, which is the feedback necessary for any muscle and joint actuation like the shoulder and wrist movement. Technology that can achieve this may prove useful in a myriad of applications. For example, motion guidance, remote learning, assistive motions, haptics in virtual reality, and bodily communication are some of the examples applications where the feedback to the motor system can help achieve. However, most approaches seen in past research has a limited amount of spatial freedom. They tend to be only operatable in a fixed space and is limited to specific movements. Furthermore, most systems require the user to carry a heavy payload that houses complex mechanisms, limiting any ubiquitous possibilities.

To that end, we propose AeroNette, a system that is based on human-marionette interaction to provide full upper body kinaesthetic feedback. A hexacopter drone carries a pair of lightweight robotic arms that when combined, can move the user's upper body via tethered strings. The advantage of such a control system is that the user is entirely free from any attached mechanisms. Additionally, the use of a drone provides a higher degree of spatial freedom and can operate both indoor and outdoor efficiently.

2 RELATED WORKS

There has been some past works that explored upper-body kinaesthetic feedback [Saraiji et al. 2018]. However, this can be quite bulky and heavy for the user. Thus, we draw our inspiration from marionettes, which is a puppet that can be controlled via strings. The concept of human-marionette interaction has been proposed before [Lin et al. 2018; Sakashita et al. 2017], yet, they are mostly related to control of puppets. Other works that rely on tethered haptics are Wireality [Fang et al. 2020], which tethers the hand to provide the sensation of feeling virtual objects. For AeroNette, we address the aforementioned limitations using an aerial drone that performs the bulk of the mechanical work and strings attached to the user for full upper body kinaesthetic feedback.

3 AERONETTE OVERVIEW

AeroNette uses a hexacopter to carry a pair of 2 degree-of-freedoms (DOFs) robot arms. Strings are attached to the user via the left and right shoulders, and the left and right wrists. The shoulder points are attached to the drone frame to drive the user whereas the wrist points are attached to the corresponding robot arms to drive the user's arm position. The system diagram is shown in Figure 2.

The hexacopter drone is equipped with six 10 inch propellers and 1000kV brushless DC motors which provides sufficient lift for a pair of lightweight robotic arms. Each of the motors are connected to the Pixhawk[1] flight controller via a 30A electronic speed controller. A radio telemetry system operating at 433MHz was used to wireless communicate with a laptop. To obtain accurate positioning indoors, we rely on the OptiTrack[2] system where tracking markers were attached to the drone's body. For the robotic arms, we utilized a pair of Tinkerkit Braccio[3] arms due to its full plastic build. We modified the structure and inverse kinematics of the arm to only operate in 2DOFs to further reduce the load. Both arms are connected to an Arduino board that powers and sends signals to the laptop.

[1]https://pixhawk.org/
[2]https://optitrack.com/cameras/v120-trio/
[3]https://store-usa.arduino.cc/products/tinkerkit-braccio-robot

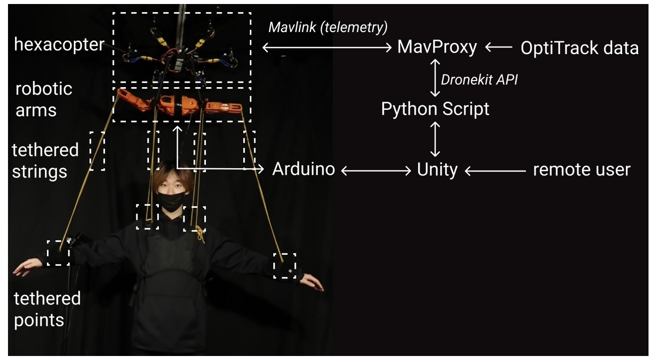

Figure 2: System diagram for AeroNette

We run the ArduPilot[4] software which allows us full control of the drone's parameters via the Mavlink protocol. We used MavProxy, an ArduPilot ground control software that communicates with the drone via Mavlink. Data from OptiTrack is also streamed to MavProxy for the drone's indoor localization. Additionally, it also communicates with our Python script where we program custom flight patterns to the drone using the Dronekit[5] API. For the robot arms, we use the Arduino development environment to stream data. Finally, both the python script and Arduino is connected to Unity, where we can visualize and model the entire setup.

4 DEMO EXPERIENCE

The demo will include a 1) real-time tele-operation from a remote user to perform a task, and a 2) pre-programmed sequence where AeroNette actuates a user to perform activities. The 5 minutes experience will be within a $3mx3mx3m$ netted cage. Our safety protocols are: 1) the drone itself will also be entirely covered in a cage [Abtahi et al. 2019] so that it is impossible for any of the propellers to be in contact with anyone. 2) The drone for the demo will be externally powered by a bench power supply ensuring continuous flight throughout the demo. 3) A safety cord will be physically attached to the drone so that in the unlikely event that it attempts to land unexpectedly, it will simply dangle from the cord.

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[4]https://ardupilot.org/
[5]http://dronekit.io/