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Romain Nith, Jun Rekimoto

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Figure 1: Flying tethered drone with prolonged flight time



Figure 2: Extending User's Vision

Falconer: A Tethered Aerial Companion for Enhancing Personal Space

Romain Nith

McGill University / Sony Computer Science Laboratories, Inc
Montreal, Canada
romain.nith@mail.mcgill.ca

Jun Rekimoto

The University of Tokyo / Sony Computer Science Laboratories, Inc
Tokyo, Japan
rekimoto@acm.org

ABSTRACT

With the growing popularity of drones, we start to see more wearable drone concepts. For the user to carry around a drone, it must be lightweight as well as have a small portable form factor. However, these constraints affect the battery capacity and therefore decrease the flight time of the vehicle. With *Aerial Tethered Companion*, a bigger battery is installed in the user's backpack allowing to extend significantly the flight time. Moreover, without an on-board battery, the quadcopter can carry more payload. Such system can be used in various scenarios for example in sports augmentation where the user would see itself through the drone's camera. Furthermore, *Aerial Tethered Companion* can be applied in telepresence where an external user would be able to see and navigate around the local user.

CCS CONCEPTS

- **Human-centered computing** → **HCI theory, concepts and models.**

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KEYWORDS

Quadcopter, Drone, UAV, Tethered Vehicle, Augmented Perception, Augmented Sports, Telepresence

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INTRODUCTION AND BACKGROUND

Drones are becoming more and more popular these days. Unfortunately, the flight time is limited by the batteries' capacity. Therefore, to extend the flight time, the operators must choose to either change and charge multiple batteries or carry a bigger capacity battery with the cost of decreasing the weight of the payload. To keep the aerial vehicle in the sky without interruption and maximize the payload, companies like *Elistair* and *Powerline* developed tethered solutions. The idea is to decouple the battery from the chassis to have a lighter vehicle but also to increase its flight time significantly compared to current products (around 21min with at DJI Mavic Pro).

Most of the applications are aimed towards professional usage such as filmography, surveillance or exploration. However, Falconer aims to apply the tethered drone technology for human enhancement. DroneNavigator [1] already utilizes tethered drones to guide visually impaired travelers but also to extend the battery life. Whereas Flying Head [7], Drone-Augmented Human Vision [4] and Multi-View Augmented Reality with a Drone [8] show how drones can augment human vision by exploring places where the user could not go or see. Additionally, with tele-operating capabilities, Falconer allows virtual users to explore new locations.

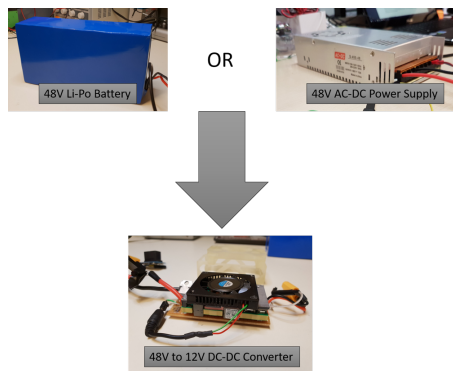


Figure 3: Power Unit of Tethered Drone



Figure 4: HTC Vive Motion Capture Setup

TETHERED DRONE

For a wearable drone, the main criteria are weight and size. The Parrot's Bebop 2 falls into this category as it is small and light enough to be carried around but also delivers enough power to fly outdoors to counter drifts. Additionally, with its GPS and ground-facing camera, the UAV (Unmanned Aerial Vehicle) can maintain its position accurately via Parrot's low-level software.

Power Unit

As designed for outdoor usage, the Bebop 2 can peak up to 480W at full throttle. In this scenario to avoid having a heavy cable disturbing the balance of the drone, we decreased the current by increasing the voltage in the power delivery cable. Therefore, the power system is composed of two elements: a 48V power source and a 48V to 12V DC-DC converter as shown in Figure 3. Since the drone is capable of pulling 10A at 48V, we chose to use 20 AWG wires allowing a maximum of 11A to flow through the cable safely according to the American wire gauge table. Furthermore, for our application we will

only be deploying 5m of cable, but the system can easily be scaled up to 16m (33.31mΩ/m). With the different proposed applications, the power source can vary from a wall outlet through a 48V AC-DC power supply or directly at 48V battery pack. With a capacity of 10Ah, we can expect around 1h15min of flight time if we assume a constant current draw of 8Ah.

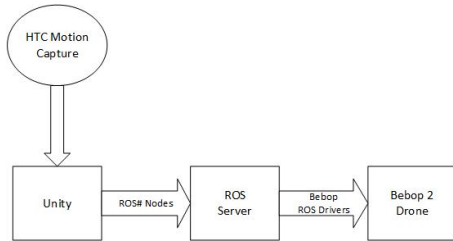


Figure 5: Manual Control System Architecture

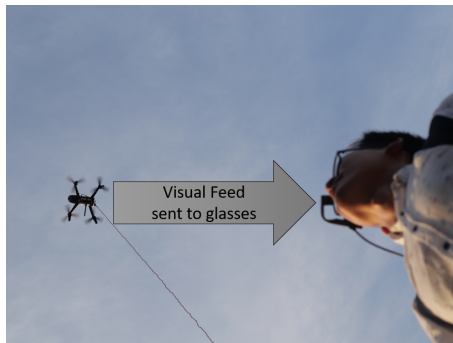


Figure 6: User's Vision Extended by Drone's Camera Through AR Glasses

¹ROS Sharp by Siemens: <https://github.com/siemens/ros-sharp>

²bebop_autonomy - ROS Driver for Parrot Bebop Drone (quadcopter) 1.0 & 2.0: <https://bebop-autonomy.readthedocs.io/en/latest/index.html>

Tracking

We used HTC Vive Trackers mounted on the drone, the user's head and hand to track each other's position. The head tracker is used for user's location and orientation whereas the hand trackers detect gestures to control the drone. As the HTC Vive system needs IR transmitters called Lighthouses, tracking can only be done indoors at the current state.

CONTROLS

System

The main tools used are Unity and ROS. Unity takes care of all the controls using the tracking information gathered by the HTC Vive Trackers and sends it to a ROS server through nodes using Siemens' ROS# ¹ Unity plugin. Finally, the server communicates to the Bebop 2 drone through *bebop_autonomy's* ² ROS driver.

Gesture Control

Human tend to interact with drones like the would with another individual or a pet[2]. A combination of both gesture and voice commands could add various type of control over the drone. However, voice recognition might be hard to detect in an outdoor environment, especially with the loudness of the current generation of drones. Therefore, a simple User Interface illustrates how the user can interact with the drone using only gestures. When the drone is grounded, the user flips its tracked hand, palm facing up, to takeoff the vehicle. The latter will make its way to the front of the operator by circling around him/her depending on where it is located. He/she can then move in any direction, the drone will follow by maintaining the same distance and orientation according to the user. To trigger gesture control, the operator raises its tracked hand above hip level and can then move the drone similarly to a joystick approach. By bringing the hand back below hip level, the UAV will remain in its the last known position relative to the user, even when the latter is moving. Finally, to land the drone, the operator keeps his/her hand with the palm pointing the sky but brings it behind his/her back.

Follow Me

Ideally, we would use solely the drone's camera to track and follow the user. Flying Eyes [6] proposed a system using computer vision but distance estimation was inaccurate. By combining accurate GPS



Figure 7: User equipped with AR glasses and battery backpack



Figure 8: Telepresence video conference with external user

coordinates from the two points of interest, we can increase the estimation but only on a 2D plane. Therefore we added a barometer alongside the GPS sensor to extract the altitude. Using a simple projection, we can find the respective distance between the drone and the user. However, the proposed solution is greatly limited by the accuracy of the sensors and did not output reliable data. However, DroneTrack [10] uses acoustic sounds to locate and track the user. Unfortunately, this solution is only ideal for close environments usage as there are too many noise disturbance in the outdoors.

APPLICATIONS

Perception Augmentation

Falconer is a personal companion that augments the user's abilities, more specifically in this scenario, its vision. Since the Parrot drone is equipped with an on-board camera, the live feed can be easily extracted. With an extra pair of eyes in the skies, the quadcopter provides information of the surrounding through a pair of augmented reality glasses to maximize the user's visibility. Figure 6 illustrates how the user can use Falconer to see the horizon from a higher point of view.

Sports Augmentation

The Flying Eyes [6] research showcases an innovative method of training for a sport where the user see itself in a third person view. Being able to see one 's self when practicing an activity helps highlight body motions and optimize each movement. In a similar fashion, dancers already apply the technique in front of a mirror. Furthermore, a third person view training appears to have no diminishing results compared to the normal perspective [3, 12]. On the contrary, a third person perspective does enhance one 's performance when the activity involves the need for surrounding knowledge. In rock climbing, the climber has a restricted view to what is above him/her. With an out-of-body view, Falconer can aid choosing the most optimized path. Therefore, through Falconer's eyes, an out-of-body experience helps athlete with various training as well as act as a tool to help athlete make better choices to improve performance.

Engaging Telepresence

Not having the battery on the drone permits to carry a heavier payload. Attaching a screen or a phone onto the Bebop 2 opens many possibilities for telepresence. Scalable Body [11] attaches a camera on a scalable pole to a movable robotized base. This allows to reflect more accurately the remote operator 's height while also piloting the robot. Falconer reproduces the same effect but with a drone. The remote user can operate the drone to explore and experience the same landscape as the local users. For indoor usage, the grounded power source can either be directly connected to an outlet, providing

unlimited flight time but limited mobility within the range of the wire. Whereas for outdoors, like previously mentioned, the battery pack can be stored in the user's backpack.

DISCUSSION

The current state of Falconer is quite limited at the moment. The different topics outlined throughout the paper shows how versatile a tethered drone can be.

With the current prototype, the cable linking the drone to the power supply can not vary its length, meaning as the vehicle flies closer to the user, unnecessary wires are left on the floor. In the near future, we would like to implement a system that would wind back the cable to minimize the tension as well as the length of the wire left between the drone and the battery.

As we want to implement a relative position control [5] to be able to control the UAV precisely without hindering the experience, other type of tracking should be considered such depth sensing cameras or SLAM. Additionally, by knowing how much wire has been released, we could calculate the distance separating the drone and the user. It would therefore give us more information to help maneuvering the vehicle autonomously around the user. With a decent localization system, the wearable drone would be able to self-takeoff and self-park onto the user's backpack with great accuracy.

Without a battery on-board, the system completely relies on the connection from the power source to the quadcopter. Adding a small capacity battery can prevent disastrous crashes if the main power system fails. If the capacity allows it, implementing a similar design as Evercopter [9] could widen the possibilities of Falconer. The drone would connect to the power source through a magnetic link and would be able to disconnect itself and fly-out independently for a short amount of time.

CONCLUSIONS

Tethering a drone greatly opens new applications for professional uses. However, in this paper, we explored how such system can be beneficial to an individual. Falconer is a prototype of a platform for a personal aerial companion. We dived into how it can enhance one's personal space by augmenting the human vision as well as bringing closer humans with more engaging interactions through telepresence. In the next iteration, we will be addressing the different key components discussed in the discussion section along with refining the design of the current system.

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