International Conference on Artificial Reality and Telexistence
Eurographics Symposium on Virtual Environments (2022)
R. Kondo and T. Teo (Editors)

Poster

HumanCopter: Wearable Drone System for Remote Multi-Directional Teleoperation

Wong Keh Fei[†,1] and Lu Zhou [†,1] and Wang ZiYue[1] and Kouta Minamizawa[1] and Pai Yun Suen[1]

[1]Keio University Graduate School of Media Design

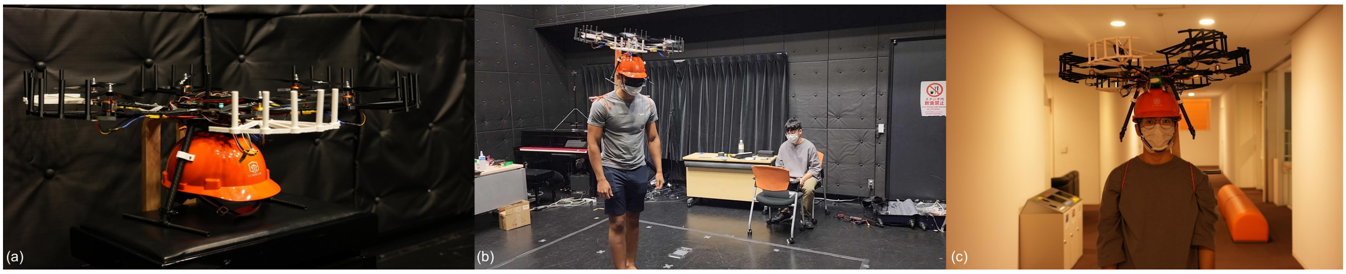

Figure 1: *a) Prototype image of HumanCopter b) Image of navigation experiment c) a front view for HumanCopter*

Abstract

Research on providing teleoperation to remote users for learning, training, or even as an assistive function has been well explored. Yet, most approaches are unable to provide full directional cues to the user. This includes not just front, back, left, and right, but also up, down, turn left, and turn right. Additionally, assuming direct control become more challenging without such freedom of navigation. To achieve this, we propose HumanCopter, a wearable unmanned aerial vehicle (UAV) where a teleoperater can provide six directional cues and 2 rotational cues to the controlled, or avatar user. Our proof-of-concept utilizes an open-source hexacopter drone mounted on the user via a helmet and shoulder supports to accurately navigate users.

CCS Concepts

• ***Computing methodologies*** → *Collision detection;* • ***Hardware*** → *Sensors and actuators; PCB design and layout;*

1. Introduction

Delivering directional cues can be important for a variety of applications, such as remote navigation in unfamiliar territory, remote training and learning, or navigation for the visually impaired. This commonly relies on visual [DBW*12], auditory [SBD*05], or haptic aid [TY04], yet these methods come with drawbacks: they lack the physical sensation of actual movement in space. Teleoperation is a potential solution where a remote user can assume direct control of another on-site. For example, research in telexistence allows teleoperated users to share various sensory feedback [Tac15]. Yet, the user is tethered to a fixed location only. For complete freedom of navigation, aerial systems hold a lot of potential.

UAVs, or drones, have previously been used for a variety of applications. For example, related works explored its application to augment jump sensation [TSM*18], or as a system for immersive sports experience [HFS*15]. These works acknowledge the freedom of locomotion that a drone offers and leverages its movement to assist the user. Yet, there is very little work on making a wearable drone to directly provide directional and rotational cues to the user.

We propose HumanCopter, a wearable drone system that allows a remote user to directly teleoperate another user, thereby treating them as their avatar, to accurately navigate them. A hexacopter is mounted atop the avatar securely using shoulder mounts and a safety helmet. This allows the operator to control the avatar and provide multidirectional and rotational cues, including front, back, left, right, up, down, turn left and turn right, akin to remotely controlling a drone. We performed an initial evaluation on the directional cues and found that users can distinct most directional force and follow the affordance to perform correct movement to reach the goal. Our contributions are the following: 1) we propose a wearable drone system that allows teleoperators to remotely con-

† These two authors contributed equally to this work

DOI: 10.2312/egve.20221296

trol their avatar's position multi-directionally and rotationally, and 2) we found that HumanCopter is capable to navigate user accurately through multiple checkpoints in a simulated environment even when the users' eyes are covered.

2. HumanCopter Design and Implementation

Our open-source hexacopter utilizes Pixhawk4 as the main flight controller. Using Mavproxy as the ground control station to remotely optimize the drone, and Mission Planner as a monitoring windows. As we are using the drone indoors, the GPS function is turned off to remove the negative impact of inaccurate GPS, compass is mainly used to acquire the current drone position. The P gain and Max Accel for each axis are modified to increase the directional force given, we also change the EKF3 settings to disallow resetting on the yaw axis, allowing the drone to work properly while staying mounted. 3D printed safety protectors are installed on the drone for safety. However, when the experiment is carried out, we remove the top layer of the protector as it slightly affects the airflow and balance of the drone. The final weight of the drone is 2.9 kg, and 3.8 kg for the whole wearable structure.

3. Initial Evaluation and Results

To determine the accuracy of multi-directional affordance provided by HumanCopter, we propose a user test with N = 5 test subjects (3 males, 2 females) from the age 23 to 39 years (M=27.8 , SD=5.71). A pilot test is conducted to allow participants to gain a brief knowledge of how HumanCopter works. For this purpose, we provide the participants with a total of 8 directional forces in a randomized order. Figure 2 shows the accuracy for each direction, we observed that the participants are confused with directions L and TL, the direction down also seems to be not convincing.

8 Directional Forces

	Fw	Bw	L	TL	R	TR	Up	Down	Can't Tell
Fw	80%	20%							
Bw		100%							
L			0%	40%		20%			40%
TL			40%	60%					
R					100%				
TR					20%	80%			
Up							80%		20%
Down				20%			60%	20%	

Figure 2: *Confusion matrix for the accuracy of all directional force(Fw-Forward, Bw-Backwards, L-Tilt Left, TL-Turn left, R-Tilt Right, TR-Turn Right)*

Next, we explore the capability of HumanCopter in guiding participants around a simulated environment. A total of 35 checkpoints (dimension of 5 x 7) are set up in an equal distance inside a 3.5m x 5m space, 5 random checkpoints were chosen as a route that participants must pass through in sequence. Each participant needs to complete two rounds of navigation study (5 checkpoints x 2 times) with the second round blindfolded. The route in the different rounds are not the same, but they are consistent between subject. 4 minutes is given to complete each route, and once they are done with both the route,they will answer a questionnaire before a short interview.

There is one participant who failed to complete the route while blindfolded. He/she claims it to be extreme insecure while blindfolded, so the participant takes every step slowly and with extra care, resulting in exceeding the time limit. Based on the participants' answer on a 7 scale questionnaire indicating how clear is the directional force, we got an average score of 5 (SD:1.87). For the question: "how comfortable is the experience?", we got a score 3.4 (SD:2.07) that denotes the experience to be slightly uncomfortable.

From the interview, all participants gave a positive feedback on the directional force with one saying: "I was surprised by how well I could follow the directions. Following forward and backward was easiest. However, some directions were a bit ambiguous. For example, sometimes it was difficult to tell if I should turn and continue to walk or just turn in place." Three participants claim that the direction force of tilt and turn is confusing. In a comparison to blindfolded, most participants claim that they can tell the directions better when they were blindfolded: "Easier to follow the directions when blindfolded", "Much better. Makes me less confusing, when I am not blindfolded, I will try to defy the force when I see myself walking towards the border.", said by two of the participants.

4. Conclusion and Future Works

We propose HumanCopter, a wearable drone system that leverages its freedom of movement as a method for teleoperators to deliver multi-directional, and rotational cues to their remote user or avatar. For our future works, we plan to 1) improve the system to be able to provide full upper-body control, and finally control the remote person like an avatar, 2) redesign the system to be more comfortable to the user and 3) investigate alternative methods, such as bladeless drones that are potentially quieter and safer.

References

[DBW*12] DÜNSER, ANDREAS, BILLINGHURST, MARK, WEN, JAMES, et al. "Exploring the use of handheld AR for outdoor navigation". *Computers & Graphics* 36.8 (2012), 1084–1095 1.

[HFS*15] HAYAKAWA, HIROHIKO, FERNANDO, CHARITH LASANTHA, SARAIJI, MHD YAMEN, et al. "Telexistence drone: design of a flight telexistence system for immersive aerial sports experience". *Proceedings of the 6th Augmented Human International Conference*. AH '15: The 6th Augmented Human International Conference. Singapore Singapore: ACM, Mar. 9, 2015, 171–172. ISBN: 978-1-4503-3349-8. DOI: 10.1145/2735711.2735816 1.

[SBD*05] SIMPSON, BRIAN D, BRUNGART, DOUGLAS S, DALLMAN, RONALD C, et al. "Spatial audio as a navigation aid and attitude indicator". *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol. 49. 17. SAGE Publications Sage CA: Los Angeles, CA. 2005, 1602–1606 1.

[Tac15] TACHI, SUSUMU. "Telexistence". *Virtual Realities*. Springer, 2015, 229–259 1.

[TSM*18] TAKAHASHI, TAKUMI, SHIRO, KEISUKE, MATSUDA, AKIRA, et al. "Augmented jump: a backpack multirotor system for jumping ability augmentation". *Proceedings of the 2018 ACM International Symposium on Wearable Computers*. 2018, 230–231 1.

[TY04] TSUKADA, KOJI and YASUMURA, MICHIAKI. "Activebelt: Belt-type wearable tactile display for directional navigation". *international conference on ubiquitous computing*. Springer. 2004, 384–399 1.