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Are Drones Ready for Takeoff?

Reflecting on Challenges and Opportunities in Human-Drone Interfaces

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ABSTRACT

Recent technical advances introduced drones into the consumer market. Thus, past research explored drones as levitating objects that provide in-situ interaction and assistance. While specific use cases and feedback scenarios have been researched extensively, technical and social constraints prevent drones from proliferating into daily life. In this work, we present past research in the area of human-drone interaction we conducted. We present technical boundaries and user-based considerations that arose during our research. We discuss our lessons learned and conclude how to deal with current challenges in the area of human-drone interaction.

KEYWORDS

Human-Drone Interaction; Human-Drone Interface; Tangibles; Object Tracking; In-Situ Interaction

INTRODUCTION

Drones have proliferated into the research domain and consumer market with various selection of use cases. The application of drones ranges from professional and personal aerial videography, delivery services, surveillance, and simple radio-controlled toys. Past research explored how unique properties of drones, such as their fast movement in three-dimensional space without any suspension, can be used to provide flexible just-in-time interfaces. While the use cases are many-fold, the deployment of drones is not always trivial and involves many obstacles and trade-offs which need to be considered. For instance, the use of autonomous drones requires reliable self-localisation mechanisms in the

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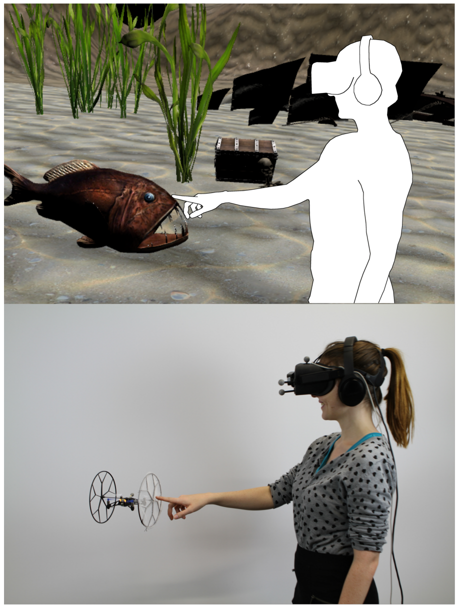

Figure 1: VRHapticDrones is providing haptic feedback for VR by aligning a touchable surface to an virtual object.

interaction space. However, this limits the use of drones to the dedicated tracking space. Further considerations include drone control, user safety, and a suitable interaction design space.

In this work, we first provide an overview of human-drone interaction research we conducted. Followed by the lessons learned throughout the implementation and evaluation of the research prototypes. By presenting our insights, we believe that future human-drone interaction practitioners and researchers benefit from our insights on how to design, model, and conduct research in this area.

BACKGROUND

In the following, we summarise past human-drone research projects we conducted. We give a short project description categorised our work into interaction modalities, haptic feedback, and navigation. Further, we highlight the challenges we encountered during the development, implementation, and evaluation.

Interaction Modalities

We investigated suitable interaction modalities between users and drones. This includes interaction via (a) direct contact and (b) remote controls [6]. We researched how drones can be used as levitating interaction elements that augment the environment of the user. We presented participants with three different interaction modalities for drones. This included two different input modalities (i.e., touch and push to provide input) and one output modality (i.e., drone drags user to a certain position). While users preferred input via touch, output via drag was not well perceived by the participants. Due to the low efficiency of drone motors, output via drones was barely perceived.

Instead of controlling drones with direct body contact, we investigated the efficiency of different remote controllers to steer drones [9]. In a user study, we compared how efficient users interacted with drones using a keyboard and smartphone controls as well as using a pointing remote control. We found that the remote control was preferred by the participants to control a drone. However, participants took more time to complete their task since a customised PID controller [1] regulated the velocity of the drone. Thus, an optimised or adaptive PID controller that is set accordingly to the users’ individual skills or environment can resolve this issue.

Haptic Feedback

VRHapticDrones and Tactile Drones [5, 7] utilises drones to provide haptic feedback in Virtual Reality (VR). VRHapticDrones are equipped with a touchable surface, that the drone automatically aligns with the surface of a virtual object. VR users can reach out to touch a virtual object while feeling the touchable surface as the drone serves as a haptic proxy (see Figure 1). Tactile Drones uses an

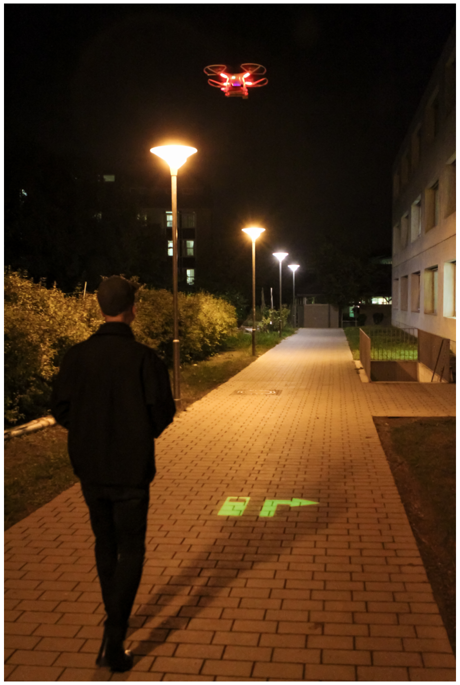

Figure 2: A pedestrian receives navigational instructions by a projector attached to a drone.

attached actuator to nudge the users and therefore simulate feedback for bumblebees, arrows, and other objects hitting the user, while the user is visually and acoustically immersed in VR.

Navigation

Providing navigation through drones has been researched in various contexts [4, 8, 10]. For example, navigation through visual projections by a mobile levitating projector was proposed recently (see Figure 2). The projections were controlled by a microcontroller unit. The user study revealed that the users were compelled by projected in-situ navigation. While GPS was used to track the drone, it does only provide a low level of accuracy, as current outdoor tracking systems do not provide the same positioning accuracy compared to sophisticated indoor tracking.

Auditory and haptic properties of drones have been used to support people with visual impairments. Thereby, the ability to process visual elements is significantly affected. By providing auditory cues, visually impaired people were able to follow the sound that is emitted by a drone [2] (see Figure 3). Follow up studies showed that this approach is socially accepted among visually impaired people [3].

In loud environments, haptic impulses of drones can be used to support navigation for visually impaired. By mounting a leash on a drone, visually impaired people were able to follow a route similar when using a blind mans dog [2]. However, the study took place in a Wizard-of-Oz setting and that does not use automatic drone positioning to provide an autonomous user experience.

LESSONS LEARNED

While drones offer a wide variety of application scenarios their usage can be quite challenging and many aspects have to be considered depending on what they are used for. There is a wide availability of consumer drones from various manufacturers that can be used right out of the box. While they are easy to use, they often do not offer properties needed for a human-drone interaction project. In the following, we provide the lessons we learned throughout our research.

Physical Limitations

While the size of drones is constantly decreasing, characteristics such as noise production, short flight times, and low payload capacities are still limiting factors. For human-drone interaction that needs a certain amount of payload, small off-the-shelf drones are usually not suited. Therefore, they have to be modified and mounted with additional hardware. This is limited to a certain weight and again impacts the battery run time, increases noise production, and impacts the flying abilities and maneuverability of the drone.

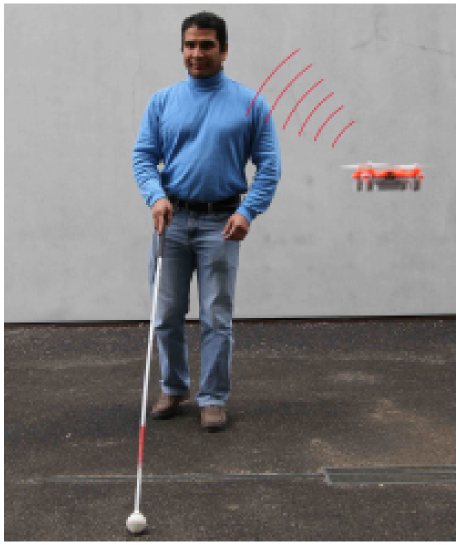

Figure 3: The sound of a drone is capable of guiding visually impaired.

The power potential of the motors limits the payload and can negatively impact the quality of force feedback. This can affect that a user cannot feel the drone dragging their hand [6] or that the level of resistance the drone can provide is not enough to stop the pushing of the users' hand [5].

Safety

When working in human-drone interaction, the safety of the user is an important factor. Regular consumer drones are not secured in a way that there is no danger of harming users during an interaction. Providing protection for users reduces the hesitation from interacting with the drone. For instance, users that wear an HMD and cannot observe the drone visually may get distracted and cannot perceive a potential danger. Therefore, off-the-shelf drones often have to be modified with security cages. However, this may increase the payload and impact the maneuverability by blocking the propeller airflow. To prevent collisions of the user with the drone, no-fly zones are recommended. Manoeuvres, such as fast acceleration towards the user, have to be limited and the position of the needs to be detected (e.g., position of VR HMD). All of this demands the implementation of a framework that enables more than the use of basic functions, such as positioning of a drone.

Drone Tracking

For indoor tracking, we used a dedicated tracking system and facilitated reflective markers on the drone. This restricts the use of automated drones and limits the use of autonomous drones to a tracking space that is often constrained to a single room. During VRHapticDrones [5] and Tactile Drones [7] we experience issues with the tracking and controlling as the drones internal camera stabilisation system cannot be turned off. The simulations application of the internal stabilisation and the external tracking system sometimes led to positioning issues while hovering, as both systems tried to correct the positioning of the drone. This again is caused by the fact that the used drones are consumer products that are not meant to be automated. Several studies employed a Wizard-of-Oz approach as outdoor tracking systems were not accurate enough [8]. Furthermore, inside-out-tracking were not sophisticated enough for indoor applications which were not restricted to a single room [3].

Data Connection

Bluetooth and WiFi pose the major connection modality for drones. This vastly expands the variety of remote controllers for drones. While this also allows the use of computers as a controlling unit for automated steering, it also inflicts issues and creates overheads

Development Framework

Controlling and automating drones is complex since many factors have to be considered. Among these are the adjustment of the Proportional–Integral–Derivative (PID) controller [11]. A PID controller communicates the next movements between drones and computing units. Depending on the use case and environmental factors, adjusting the PID controller poses a major overhead.

While there are libraries [12], they only work with proprietary drone models and do not allow full control over the firmware of the drone. Further, we experienced Bluetooth connection issues, where several attempts were needed to connect to a drone. Connectivity is even more complicated if more than one drone is used. When connected, sending commands to the drone sometimes led to delayed movements or commands that were not executed at all. Therefore, connectivity and controls that are handled via Bluetooth, by our experience often lead to various issues and make the system less responsive.

In general, frameworks need to be developed from scratch, are not standardised, and are highly heterogeneous. This is a challenging obstacle for interested developers and users. Furthermore, this makes it difficult to reproduce research since similar programming parameter needs to be used.

CONCLUSION

In this work, we summarise our work regarding human-drone interaction. We describe the challenges we encountered throughout the implementation and evaluation of human-drone interfaces. These issues are partly responsible that drone implementations need to be adjusted for specific use cases and thus extensively increase the effort of research projects. This is often due to the large overhead which is generated by implementing drone projects from scratch. We provide lessons learned regarding the aspects *Physical Limitations*, *Safety*, *Tracking Drones*, *Data Connection*, and the *Development Framework*. We expect that the human-drone community benefits from our insights and experiences usher the creation of a standardised drone framework to enable rapid prototyping of human-drone interfaces.

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