ProxyDrone: Autonomous Drone Landing on the Human Body

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Interdisciplinary Workshop on Human-Drone Interaction (iHDI 2020)
CHI '20 Extended Abstracts, 26 April 2020, Honolulu, HI, US

Abstract
Launching drones often requires several steps that the operator needs to complete. Yet, in many scenarios, such as search and rescue, saving time is crucial. For instance, rescue personnel might be occupied with safety-critical tasks, while needing to operate drones to get an overview of the environment. We propose the concept of a drone that is located on the human body (e.g., on the back). The drone can take-off and land without human intervention. We plan to build a working prototype and investigate drone maneuvers that are suitable for both taking off and landing operations on the human body. We will further investigate the operator's perception and extract task-related design factors. This work will help derive guidelines for implicit human-drone interaction at close proximity.

Author Keywords
Human-Drone Interaction; On-Body; Drones.

CCS Concepts
•**Human-centered computing** → *Haptic devices;* **Human computer interaction (HCI);** *Haptic devices;*

Introduction
Drones will likely become ubiquitous companions for humans in the near future. They can be used for a range of applications, such as video production and photography, to

guide visually impaired people [4], support artistic performances [11], body movement [15, 16] or sports education [24], and even support search and rescue missions [18]. We expect that this growing range of applications will increase interactions between drones and humans [12]. In addition, drones are now being used as flying interfaces [6, 13] and can serve as haptic proxies to enhance Virtual Reality (VR) experiences [2, 14]. Different aspects of human-drone interaction were investigated by previous research, such as input using drones [3, 7], expressive drone flight behavior [9] and orchestration of drones [17].

The use-cases for drones are versatile, yet we find that the interaction is often centered around the human body. That topic was exposed in prior work designing a drone user interface projected around the user's body [8]. However, we note that the close proximity of the drone to the user is still not yet investigated in the literature. In prior robotics work, researchers had investigated the use of robots on a user's body [10], which inspired our work.

We find examples of body-worn drones like the *Nixie* which is used for photography [1]. This wrist-worn drone can be used on-demand to take selfies of its operator. Similar to the *Nixie* drone, we propose to develop a drone that can land-on and take-off from the human body. Being in close proximity to the user opens new doors to human drone interaction through multiple modalities, from vibrations to pulling or bumping into the user.

To enable this close interaction, we explore how a drone can land-on and take-off from a person's body. We envision several scenarios that would benefit from such functionality. For example, drone operators can seamlessly start and stop operating a drone that might be attached to the back of the operator. In such a situation, rescue personnel can use drones while being engaged in safety-critical tasks.

Such a drone requires two major considerations: 1. the technical capability for the drone to attach and detach itself to the human body, and 2. the user's acceptability of close body interaction. We indeed envision that the design of the drone and its position with regards to the person will affect its acceptability. Prior work highlighted many design factors that influence the perception of a drone user [23, 5], including that current safety mechanisms are perceived negatively in terms of trust.

As such, we plan to prototype different form factors and technical solutions suited for taking-off and landing-on the human body. That includes the design and development of bespoke drones with diverse mechanisms (e.g., electric magnets, hooks, and textile solutions), for the drone to attach itself to its operator. We then propose to develop a framework for close human-drone interaction that will enable us to research and identify suitable flight behavior and design factors to accomplish automated land and take-off procedures on the human body.

Design Space of Body Worn Drones

In the following, we propose a design space for body-worn drones and discuss each of the identified dimension.

Body Location

We want to investigate which parts of the body are suitable to serve as a spot for drones to land and take-off. This can influence the design and size of the drone, as well as its flight behavior (i.e., take-off and landing procedures). An important question to be considered, is how the user perceives the drone while it is approaching various body parts. We consider the following body locations:

Back. The back might offer plenty of space for a drone to land. Possible larger drones might be deployed on the back of a user. Further, functional garments might provide anchoring on the back. The back might be suitable for drones that take-off and land while the operator is engaged in a task. We expect that the posture of the user will present some importance. For example, when the drone is hanging vertically from the back (e.g., like a fly on a wall), it must carry out a specific maneuver to stabilize itself in the air when it takes off. Such a procedure must be done safely to protect the user.

Shoulder. Like a parrot, a drone could rest on the shoulder of a user. Smaller, light-weighted drones might be suitable in this case. Safety means and specific maneuvers should be investigated due to the proximity to the user's face.

Head. Drones that are deployed on the head might have a special design. The proximity to the face will influence both design and maneuvering operations. Drones in close proximity to the head require a small-size and light-weight design, so that the drone does not get in the way of the human body sensory systems. Helmets might serve as a ramp for the drone to land and take off.

Arm. Like a falcon a drone could land on the arm [19, 20]. The falcon metaphor implies certain behaviors, such as flying to a location and coming back to the user. We imagine the user could hold up their arm to indicate to the drone that it can take-off or land. On the one hand, triggering such interactions might become intuitive to the user and require little cognitive load. On the other hand, take-off and landing sequences might be difficult if the user's hands are busy (e.g., carrying a device or performing a task). Small and medium-sized drones might be suitable for this body part.

Body Adhesion Method

Since the drone should remain on the human body after landing, we will investigate materials and techniques to attach drones to the body. We are considering different hardware solutions, from electric magnets to velcro tape. Specially designed clothing might provide docking capabilities for easier landing and take-off, although we prefer ad-hoc solutions that do not require the user to wear specific equipment. We will investigate how a drone can rest on a person's body, while not falling off while he/she is moving. We propose that the drone may use its own force to stabilize itself on the human body.

Level of Automation

Triggering take-off and landing sequences can be done in various ways. It can be automated with no hands used or triggered explicitly by the user (e.g., the drone can be grabbed and put into place). The drone might detect gestures, speech commands, or context to initiate take-off and landing. It will therefore be important to communicate the intent of the drone to the user and vice versa. If a drone approaches the user to land, the user should understand the next steps of the drone's landing process. This can be achieved by wearing smart glasses that display the flight plan or even Augmented Reality (AR) to visualize the planned trajectory of the drone. We expect that lights might be used to communicate intent, [22] as planes do. Also, the user might intervene with an autonomous operating drone. Therefore, the drone should provide an intervention interface [21]. Implicit and explicit interactions might vary depending on the use case. However, detected commands triggered by false positives can lead to dangerous situations. In that case, it is very important to use appropriate context aware controls and triggering mechanisms that can adapt to the situation of the operator (e.g., occupied hands).

Drone Shape and Function

The size of a drone will most likely determine its use cases. A small drone with a camera can be used for scouting and overview, while a larger drone can enable physical interaction with the user and other objects (e.g., carrying a payload). These factors will influence the drone design and determine the interaction space.

Application Scenarios

We outline three different application scenarios in which we envision close-to-body drones to be applicable.

Search and Rescue

Rescue personnel can benefit from drones that take-off automatically while being engaged in primary tasks. The drone could be used as a scout for planning a mission, while critical tasks can be fulfilled without the interruption, that is currently required, to start operating the drone. For example, in firefighting missions, the firefighters have to pay attention to their environment and protect their own life while trying to rescue survivors. A drone could be of great help to sense the surrounding environment, but should however do so without interrupting the firefighters or adding to their cognitive load.

On-demand 3rd Eye

Climbers might need an overview of their surroundings while being suspended at great heights. For example, they may want to check for changing weather conditions or map out their climbing path. Getting a drone to take off from one's hand or from the ground while climbing might be complicated, if not dangerous, or impossible. We propose that a drone, attached to the back of a climber, could take-off and gather information before landing back on its operator. The action of take-off or landing could be done without requiring the use of the climbers hands. In addition, the drone could directly support the climber, such as by lifting and securing a carabiner. Such scenarios would increase the safety of the climber, especially when the climber is exhausted or can not reach the next spot to secure him/herself.

Personal Assistant

Close proximity to the user enables more intimate relationships between drones and humans. We expect such drones will be understood like a pet sitting on its owner's shoulder, rather than as a piece of technology. As such, we envision that the drone could become a personal assistant. The drone can use the operator's body as a base station (e.g., when charging) and take-off to perform off-body tasks, such as taking a photo (as in [1]), navigating the user to a destination, and transporting small objects. This exceeds the capabilities of today's body-worn robots [10].

Research Plan

We plan the following steps to build and evaluate our prototype and to extract guidelines for close proximity human-drone interaction. In the initial step, we will gather literature on drones and on-body interaction to derive a suitable concept. Afterwards, we will implement the system (i.e., drone and the control application), so that the drone should be directed towards its target automatically. Once being in proximity to the target, it should initiate a suitable landing maneuver and attach itself to a person. Once attached, the drone should be able to identify opportune moments to take-off based on its role. After the implementation phase, we evaluate our prototype in a user study and derive guidelines from the study results.

Conclusion

We proposed to investigate close proximity drones that can land and take-off from the human body. First, we identified requirements to span an initial design space. We then discussed various aspects that must be considered for body-worn drones, including body location, level of automation, drone shape and functionality. Finally, we introduced application scenarios and presented a research plan.

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