Drones for Search and Rescue

Figure 1: A traditional search and rescue scenario in a secluded area, without any connection to the outside world.

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ABSTRACT

Natural disasters are increasingly common as climate change becomes more severe. Search and rescue operations become more and more important to societies worldwide. Rescue services are often engaged in missions in rural areas, treating the injured or searching for missing persons. Often, time is an essential factor for a positive outcome of search and rescue missions. Due to their capacity for flexible deployment, drones have a great potential to be deployed in search and rescue scenarios and thus reduce the rescue time. In this work, we discuss how drones can effectively assist rescue crews in their mission to save human life.

iHDI '19 - International workshop on Human-Drone Interaction, CHI '19 Extended Abstracts, May 5, 2019, Glasgow, Scotland, UK, http:// hdi.famnit.upr.si

Figure 2: Drone overfly of a remote path in a forest. Credit: https://www.instagram.com/bongokaiser/

[1]https://youtu.be/6t-hYnWPiFk

CCS CONCEPTS

• **Human-centered computing → Interaction techniques**; **Collaborative and social computing systems and tools**; **Ubiquitous and mobile computing**; Human computer interaction (HCI).

KEYWORDS

Drone, unmanned aerial vehicles, UAV, quadcopter, human-computer interaction

INTRODUCTION

In search and rescue scenarios, time is often the most critical factor as lifes are at risk. Often the time factor is combined with uncertainty as the exact location of the person concerned is not known. Thus, search and rescue services are required to search a vast area within a very short period of time. Emergency services have already started to deploy unmanned aerial vehicle (UAV) in an attempt to search a larger area in a shorter time span (c.f. freewaydrone[1]). Time and the vast space are the most common critical factors in these missions, but natural disasters often cause constraints which cannot be overcome by humans. Avalanches, floods, and wildfire are among the most common natural disasters which make search and rescue missions extremely hard for humans. Moreover, contamination (e.g. nuclear disaster, and biohazards) may occur in the same area [8].

In these search and rescue scenarios, UAVs have a number of advantages over humans. Firstly, UAVs can be sent to any location without the operator knowing the exact conditions in the target area. This reduces the possibility of rescuer injury or death. Moreover, using the latest tracking and communication techniques, UAVs can scan a large area in a short time span. Here RGB, infrared, and thermal cameras combined with state-of-the-art machine learning (ML) can be used for identifying and tracking humans.

However, a number of factors are still hindering the effective deployment of UAVs for rescue operations. While swarm intelligence can be used to control and operate a large number of UAVs at the same time, the general control concept is still unclear. Today, most of the time one UAV is operated by one pilot which makes scalability insufficient as intensive labor is required. Multimodal interaction coupled with ML can support pilots in operating one or multiple UAVs at the same time [3]. Moreover, the to be rescued person could control UAVs and thereby for instance send in formations to the search and rescue troops.

In this work, we first map the possible deployment scenarios for UAV in search and rescue. Then, we outline challenges and opportunities from a human-computer interaction (HCI) perspective but also beyond this scope.

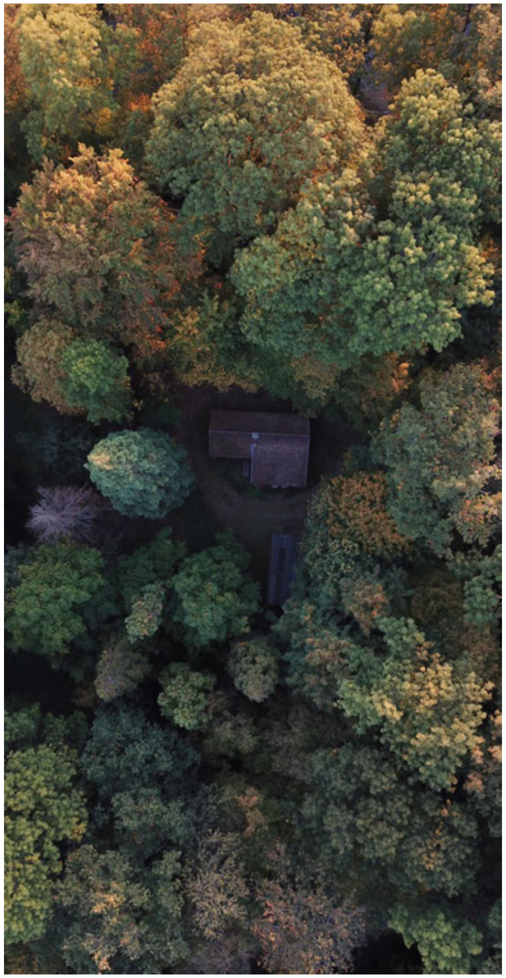

Figure 3: UAV overfly of a remote house in a forest. Credit: https://www.instagram.com/bongokaiser/

SEARCH AND RESCUE SCENARIOS

For the design space of search and rescue we identified four axes: 1) Outdoor - Indoor; 2) Urgency; 3) Remote action; 4) Subjects. In the following, we will explain the four axis and describe their interplay.

Outdoor - Indoor

UAVs have extensive abilities to overview large and remote areas, see Figures 2, 3 and 5. They can transmit image and sensor data from remote locations faster than conventional means and without the risk of injury to the person monitoring the situation, see Figure 4. In all kinds of natural disasters, UAVs can help emergency forces understand the situation and identify injured persons or persons requiring support. This is particularly relevant when the area is hard to access or accessing it would endanger the rescuers. Such tasks include avalanche rescue, wildfires, floods or contamination (e.g. nuclear disaster). In these situations, UAVs can transmit not only visual information, but also other sensor data such as temperature, air quality or radioactivity. Further, UAVs can provide a communication connection to inaccessible people or even deliver urgently needed tools.

Even without natural disasters, people require remote assistance. When people involved in outdoor sports, such as running [11] or hiking, health conditions can change quickly and finding the injured or proving remote assistance can be required [7]. Furthermore, people can get lost while performing outdoor sports and have to be brought back home. This can be supported by UAVs. This is also the case when children get lost while playing outside or pets elope. In amusement parks or during large events, people lose their companions or their children. Here, UAVs coupled with computer vision can help find the required people in crowds.

This challenge of relocating other people is not only relevant for outdoor scenarios but also for fairs, shopping malls, and even in smaller houses UAVs could be used in case of a fire. Firefighters can use UAVs to analyze the situation in a house without entering the building. Here, missing people could be located before sending in firefighters. Additionally, through thermal imaging [1] and air quality sensors collected information would help firefighter to act faster and safer.

Urgency

Rescuing and locating people is not always time critical. For instance, finding one's friends in an amusement park might increase the happiness of people, but is not urgent. On the other hand, the more common scenarios for search and rescue missions are time critical. Such as in natural disasters, fire, or critical health conditions have a high urgency. Here UAVs offer the means to capture first impressions even before the troops are ready to work and provide them with the necessary information when they arrive. This can improve coordination and limit the risks associated with rescue.

Figure 4: Search and rescue at a beach with communication by gestures.

Remote Action

In many cases, it is advantages to obtain an overview of a situation remotely to be able to react to emergencies quickly, see Figure 5. Also, transmitting the geo-position of a lost or insured person speeds up the rescue process significantly. In the next step, it might be required to communicate with a person remotely, see Figure 4. When a quick rescue is not possible, tools, medicine or nutrition could be delivered by an UAV even before emergency responders arrive. In the worst case, the person could also be transported by an UAV.

Subject

The search and rescue of humans are definitively the main target. However, as already indicated, not only humans might be rescued by UAVs, but also pets. UAVs can assist in emergencies in farming where the farmer can search and monitor animals remotely and securely.

OPPORTUNITIES

Traditional UAV deployments often suffer from risks like e.g. polluted airspace [14], privacy concerns and a negative effects of the UAV sound [4]. However, we argue that while theses challenges exist, they are, in search and rescue scenarios not as important.

Common challenges in UAV control are navigating, with Global Positioning System (GPS) often not providing enough precision. However, recent advantages in optimization problems a swarm search strategy [5] would help operating multiple UAVs this will improve current drawbacks as easy pathfinding and easy navigation using UAVs is still an open research challenge.Another common challenge is the limited communication range. Here, WLAN [9] or 4G [13] (and future 5G networks) can be explored to extend the range. We envision that UAVs could either deploy repeater on the fly, act as repeater themselves, or even fly back to transmit information.

Finally, beyond technical challenges which currently exits, we identify a number of challenges within our design space which should be addressed by HCI research.

Control and UAV ownership

In not safety critical search scenarios, like searching for friends during sport events, UAVs could be provided by organizer of the event. Thereby the number of UAVs in the airspace could be controlled and reduced. However, when possible users would need access to the UAV control. Here, bring-your-own-device [2] as UAV controllers need to be explored. While direct control of a UAV is one challenge, even getting direct live video footage and other information from a UAV to the observer is challenging itself [11]. Thus, it remains a challenge to HCI to understand the design requirement for UAV sharing interfaces.

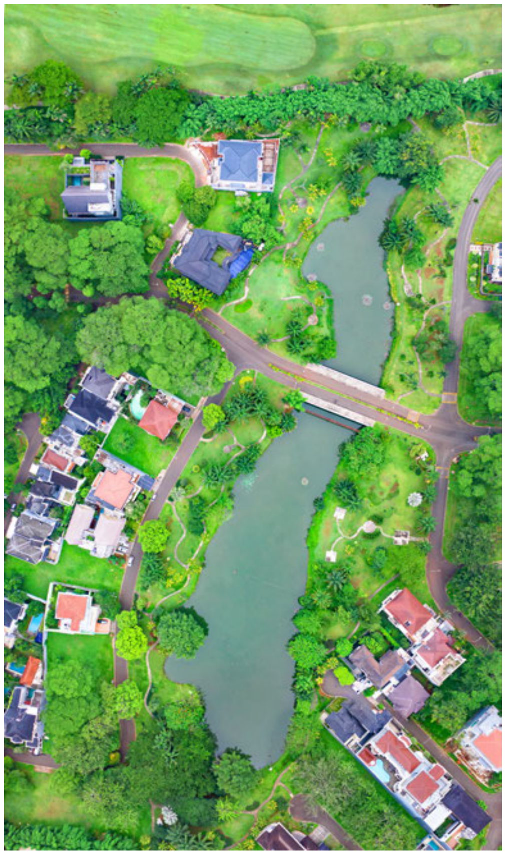

Figure 5: Drone flyby of an village to get an overview.

Today, UAV pilots control one UAV at most. Sometimes, even multiple operators are needed to perform flight maneuvers. In safety-critical search scenarios, the demand for operators needs to be minimized to ensure effcient operations. Thus, new interfaces for the control of one UAV or UAV swarms are necessary.

Here, we see opportunities to transfer solutions from common HCI interface control system to help the direct UAV operator. For example, easy drag-and-drop WYSIWYG implementations will help also novice users to operate UAVs. On the other hand, gesture control will help personnel in the field to redirect UAVs to support them in-situ with new upcoming challenges.

Privacy

UAVs will collect large amounts of personal data in search scenarios. Thereby, the UAV will not only collect data about the missing person or object, but also from all other persons within the field of view of the UAV. Furthermore, in most cases, the missing person will have no chance to agree or disagree to the data collection. HCI research should identify possibilities to minimize the affect on privacy. Furthermore, HCI faces the challenge of being transparent, explainable UAV interfaces that ensure the society's privacy.

Data Analysis, Observation, and Decision-Making

UAVs can provide large amounts of data at a high speed. Particularly, when the UAV is equipped with more sensors than a regular RGB-camera (e.g. thermal cameras) this data will be multidimensional. In urgent situations, rescuers will analyze large live stream data sets (e.g. object tracking [10], and face recognition [12]) from multiple UAVs at the same time. Here, HCI research needs to develop new techniques for monitoring and observation tasks. These techniques will include attention management, interactive data visualizations and interaction with multidisplay environments [6].

Range, and Goods Delivery

Today, UAVs are very limited in payload capacity and flying distance. However, we argue that solving the path planning and controlling issue solves these limitations, as the UAVs will then fly multiple times. Therefore, the UAV can autonomously deliver multiple smaller packages and get a new battery.

FUTURE WORK

UAVs offer extensive opportunities in search and rescue scenarios. We outlined a number of scenarios where we envision UAVs being deployed to help emergency services in their tasks. Nevertheless, making UAVs successful for search and rescue tasks requires research in multiple domains, such as battery technology or sensor fusion. However, we see that the biggest development gap is in interacting, operating, and controlling a large number of UAVs, but also even controlling single UAVs.

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