Drones for Remote Collaboration in Wilderness Search and Rescue

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ABSTRACT

Wilderness search and rescue (SAR) is an activity that could potentially be well supported by drones, both as search tools and as devices to help with collaboration between remote helpers and workers on the ground. However, even with this potential, there are still usability challenges that need to be addressed. In our work, we are exploring potential use cases for drones to support wilderness SAR, as well as design solutions for wilderness-SAR drone systems. We discuss these explorations in this position paper, as well as some of our ideas and plans moving forward.

KEYWORDS

Drones, search and rescue, remote collaboration, outdoors, emergency situations

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INTRODUCTION

Search and rescue (SAR) has long been seen as an activity that can be well-supported by drones. Wilderness SAR in particular, which involves searching and scanning large swaths of unpopulated wilderness for a lost person (e.g., a hiker, skier, or mushroom picker) [7], could benefit from the use of drones, as they can provide searchers with a unique overhead perspective and allow them to cover more territory in a shorter amount of time. Drones can also get to hard-to-reach places (e.g., steep mountain tops, deep valleys) and inspect them from both afar and up close.

While this is the case, a number of usability challenges in state-of-the-art drones still act as barriers in their use in most real wilderness-SAR incidents. For example, most drones have to be manually flown by a co-located user, or the user has to define a specified flight path for the drone in advance. Manual piloting is mentally demanding and physically cumbersome to SAR workers, given that they have to use both of their hands to control the drone, and they have to direct all of their attention to it. When a SAR worker pilots a drone in this way, they cannot perform other tasks with their hands, and it becomes more difficult to pay attention to other things. Pre-defining flight paths alleviates these issues, though it takes in-the-moment control of the drone away from the SAR workers, and it makes it less easy for them to change the course of the drone based on new information. Additionally, pre-defined paths often do not take into account the locations of obstacles, other SAR workers, or important details in the field (such as clues and footprints). There are other control strategies between full control and full autonomy to consider that could be beneficial to SAR. We will discuss these later.

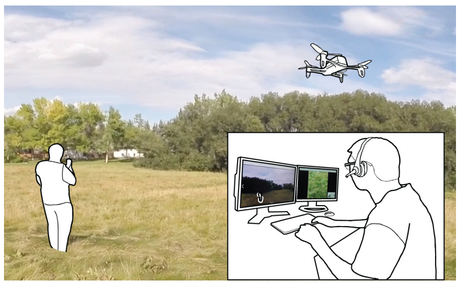

Figure 1: A drone enabling remote collaboration between an outdoor user and a remote (indoor) user. Such a system could be used to support remote collaboration in wilderness SAR. From [6].

In our work, we are exploring various use cases in which drones could support wilderness SAR. From these, we are coming up with a set of recommendations for the design of drone interfaces to support wilderness SAR, as well as implications for both local and remote users. Currently, there are two main purposes in which we see drones being used for wilderness SAR: (1) to allow a single user (remote or local) to search and inspect an area; and (2) to allow a remote user to collaborate with a local user, usually to provide guidance, give instructions, or work together on some task. In this position paper, we discuss examples and ideas from both of these.

DRONES FOR SEARCH AND INSPECTION

Drones provide users with a unique perspective of an environment, allowing them to inspect the space from angle that would otherwise be unachievable [6]. This can be beneficial for SAR, as it can allow searchers to see the environment in a brand new way, either spotting things they may not have seen before (even spotting the lost person) or seeing familiar things at a new angle, thus helping with navigation and spatial problem solving.

With this new perspective though comes challenges. For example, if the drone is high up, depending on the fidelity of the camera it could capture a lot of information. While this is certainly beneficial, it could easily be too much information for a human to comprehend and make good use of. Similarly, since humans are not used to inspecting visual information from up in the air (since we are ground creatures after all), matching this information to what we see on the ground and planning in accordance to it can sometimes be tricky. In a previous study we ran [6], we found that while users collaborating on outdoor activities using a drone (as the remote user's view into the activity space; see Figure 1) find the information visible in the drone view to be useful, they often have a hard time matching the visual information to the frame of reference of the collaborator on the ground (similar to what has been found in [11, 15]). To illustrate a simple example, a remote collaborator viewing through a drone might say "move up" or "move down," but these directions would need to be translated to the frame of reference of the collaborator on the ground (e.g., *up* might be *forward* for the collaborator on the ground). It gets even more complicated when the remote collaborator needs to give directions in relation to landmarks she can see through the drone view, but she is not sure whether or not her partner on the ground can see them from his point of view.

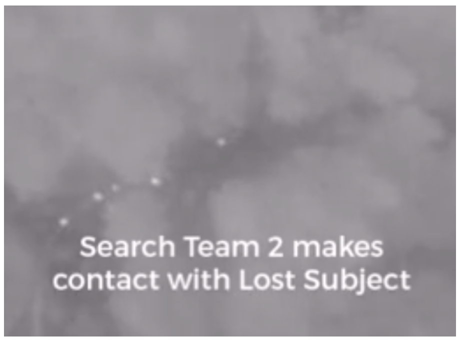

Figure 2: Heat cameras on drones could help SAR workers easily spot lost people in areas dense with trees and vegetation. From Kamloops Search and Rescue [2].

Beyond simple RGB cameras, drones can also fly with other types of cameras and sensors. Infrared (thermal) cameras can be particularly beneficial for wilderness SAR, as searchers can spot people with them easily due to the fact that human bodies produce enough heat to stand out easily on thermal images (see Figure 2). A wilderness-SAR group we are working with has been trialing the use of thermal cameras on drones during training activities. In addition, drones with thermal cameras have been successful at spotting lost subjects in at least one real SAR incident [1]. With this potential though, there are still some challenges. These include (but are not limited to) tree density in some wilderness areas blocking the view of victims, challenging weather conditions such as strong winds, difficulty getting up close while avoiding collisions with trees and other obstacles, avoiding disturbing wildlife, the importance of not distracting SAR workers on the ground, and local drone laws and regulations (e.g., not being allowed to fly a drone out of one's line of sight). In terms of laws and regulations, this is largely dependent on the jurisdiction of operation, and drone laws could potentially become more relaxed (at least for SAR and other emergency-response agencies) as drones themselves become more socially acceptable. Challenges such as obstacle avoidance, weather conditions, and distraction-free flight will likely be addressed through improvements of the technology. For example, newer drones will likely be built to emit minimal noise and fly more stably in difficult weather. In addition, artificial intelligence (AI) and machine perception (e.g., computer vision) could allow drones to more-effectively avoid obstacles, allowing the user to focus more on inspecting the images coming from the drone.

Aside from inspecting live video images from up in the air, drones could also be used to capture imagery of the search area for viewing at a later time. A sequence of images of multiple spots could be taken, of which a SAR manager at a command centre could search and scan through. Furthermore,

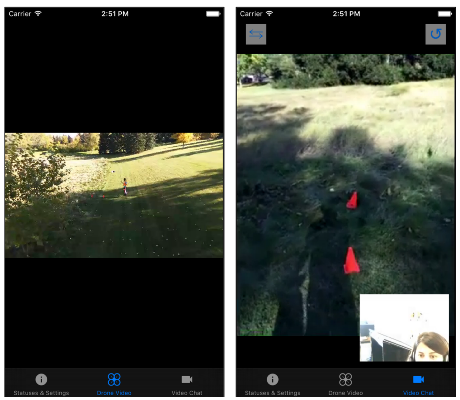

Figure 3: A video-conferencing system utilizing a drone, enabling remote collaboration between a local user on the ground and a remote user providing assistance. From [6].

these images could be stitched together, forming either a 2D overhead representation of the search area (similar to satellite imagery) or a 3D reconstruction of the search area (e.g., similar to [3]).

Beyond assisting users with inspecting wilderness environments, developments in AI and machine perception will likely allow drones to carry out much of the work of searching the space by themselves. Future drones may be able to fly around the wilderness environment autonomously and pick out the missing subject(s) by themselves; or at least help SAR workers narrow down their search from a vast area to one or a few smaller spots.

DRONES FOR COLLABORATION BETWEEN REMOTE AND CO-LOCATED USERS

Drones can also be used to accompany a SAR worker in the field as they communicate with and receive assistance (e.g., navigational instructions) from a remote worker at command. We have explored similar scenarios in previous work [6]. We see a lot of potential for these types of designs in wilderness-SAR scenarios—specifically, designs that allow drones to act as collaboration tools, serving both remote users and users in the field. But when they are used in this way, they should be designed to account for both sets of users, and human-drone interfaces should allow for interactions (e.g., inputs and outputs, communication and feedback) with both remote and co-located users.

In previous work, we designed a drone-video-conferencing interface in which the drone follows the local (outdoor) user (Figure 1) and the remote (indoor) user views through the drone's camera feed (Figure 3). With this system, we gave the remote user slight control of the drone by allowing them to adjust the camera pan/tilt/zoom and define how high up and how far back it flies from the local user. With this system, we studied scenarios between two collaborators, in which one collaborator is in the outdoor environment where the task is taking place and the other is in a remote indoor location such as an office. We ran a study in which participants worked on activities that involve searching, inspecting, and organizing objects around large spaces. These activities require the remote collaborator to give navigational instructions, understand the spatial layout of the environment, and provide search guidance to the outdoor collaborator based on the perspective they have. We found that while the interface allows workers to collaborate on such tasks with greater ease than with a typical mobile-video-conferencing setup (e.g., a FaceTime-like interface), remote collaborators sometimes had difficulty rephrasing navigational directions in the frame of reference of their local counterparts. In addition, when there was a lot in view, the remote collaborators had trouble understanding and contextualizing all of the visual information they could see. On the local side, users were sometimes concerned for their own safety with the drone nearby, and also for the safety of the drone itself. In addition, given that the drone followed the local user, local users often felt a sense of responsibility for the drone, making sure to walk around such that the drone does not fly to unsafe spots. While this study did not specifically look into wilderness-SAR scenarios, we outline below some wilderness-SAR scenarios in which drones could be used in a similar way as tools to support collaboration between remote and local users.

(1) Guidance and Navigation: A remote user could use a drone to help a SAR worker on the ground navigate to where they need to go. Previous work has studied the use of drones for providing navigational cues, through positional cues [13, 14] and projections on the ground [4, 9]. Even if the local user has a reliable map and compass, knows where they are, and where they are going, in unpredictable wilderness environments it can sometimes be a challenge to figure out exactly how to navigate to where one needs to go. A remote user flying a drone can inspect the scene from up above to determine where obstacles are and what is the shortest or most feasible path for the local workers to traverse. Once this inspection is done, the drone can then use its physical form and embodiment to communicate the necessary navigational instructions to the field workers.

(2) Collaborative Search and Inspection: Similar to our previous work [6], drones in wilderness SAR can be used for collaborative search and inspection. A SAR worker on the ground could inspect an area of wilderness while a remote worker viewing through a drone inspects the same area from a different perspective—one that is unreachable to the worker on the ground—and offers advice to the ground worker based on what they see through the drone.

(3) Physically Handling Materials: Finally, a drone can be used to physically move or handle materials in the wilderness environment. Depending on the weight and size of the objects that need to be moved and the power of the drone, a drone could help SAR workers move materials to hard-to-reach places. For example, if workers need to move one end of a rope to the top of a cliff or the bottom of a steep valley, they could have the drone fly that end of the rope to where it needs to go.

DESIGN CONSIDERATIONS

While drones certainly have potential to serve wilderness-SAR workers, some considerations need to be taken into account.

First, it is important that the workers on the ground do not become too distracted by the drone. SAR workers need to remain focused on listening for the subject, watching for hazards, and using their hands to handle equipment (such as ropes, pulleys, and bags) and climb through difficult terrain. Thus, it is important that any awareness of the drone, whether it is through hearing or seeing it, provides a utilitarian purpose for the SAR workers on the ground. For the most part, it is ideal for the drone to be either unnoticeable to field workers (while they are providing some use to a remote user) or to have the sight and sound of the drone provide some use to them—for example, using the embodiment of the drone to guide the workers, or having the presence of the drone assure the workers that they are being looked after by command.

Second, the level of control given to users should take into account the user's goals, abilities, and any other responsibilities they have. If the user has other responsibilities to attend to beyond operating the drone (e.g., the user is a field worker paying attention to immediate surroundings, or a manager with other responsibilities in the command centre), it may be beneficial to give the user more indirect control of the drone, so that she can affect what the drone does, but without being too mentally invested in the act of operating it. The Human-Robot-Interaction concept of *shared control* [5, 8, 10, 12], both between the user and the drone [8, 12] as well as between two or more human operators [5, 10] would be worth exploring in SAR. Automation is preferable wherever possible, while still allowing higher levels of control to be passed on to the necessary user during critical moments (e.g., where the lost person may have been spotted, or the drone is in danger). In addition, the ability to pass total or partial control to another user may be beneficial in situations where, for example, a field team no longer needs the drone and wants to pass it on to another team that needs it.

Finally, we also see the benefit of coupling drones with other technologies and interfaces (rather than just using them on their own) to leverage their benefit. As a simple example for remote workers in a command centre, an interface that contextualizes the visual information in the drone's camera feed with information that the SAR agency already has about the search might be useful. Displaying annotations and overlays on the drone video feed showing the locations of SAR workers, clues found in the field, and other important information would help the viewer put what is in view into context, rather than just seeing a set of trees, mountains, and rivers, without meaning. As an example for local workers on the ground, an augmented-reality (AR) interface that displays an overlay over a drone in the sky, showing the worker who is controlling the drone, what the drone is doing, and where it is flying to might provide some use to them.

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

For future work, we plan to work closely with wilderness-SAR workers in western Canada to iteratively design, through a participatory-design process, remote-collaboration systems for wilderness SAR utilizing drones. We also plan to evaluate the more-refined iterations of our prototypes through two stages: (1) field trails, in which pairs of participants use the prototypes to complete search and inspection tasks designed to mimic wilderness-SAR scenarios (to the extent which they are safe), and (2) long-term deployments with SAR teams for training activities and mock searches. Our work will lead to a further understanding of how drones can be used to assist wilderness-SAR volunteers, as well as potentially an early understanding of how they can better support other emergency responders.

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