User Interface Design for UAV Swarms in Search and Rescue

Andreh Bassam Bahodi
Aalborg University
Denmark

Maria-Theresa Oanh Hoang
Aalborg University
Denmark

Rasmus Skov Buchholdt
Aalborg University
Denmark

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Summary

Search and Rescue (SAR) operations are missions where a group of trained professionals forage areas to find and help lost people. Currently in Denmark, SAR operations are conducted by a Danish governmental agency under the Ministry of Defence called the Danish Emergency Management Agency (DEMA)[1]. In traditional SAR operations emergency staff are sent out to search for people who have gone missing, however, in more recent times SAR operations involve the use of drones. The addition of drones to their rescue team ensures that they are able to forage areas quicker as well as reduce risk of endangering the emergency staff by sending the drone to forage high-risk areas.

The master's thesis is called *User Interface Design for UAV swarms in Search and Rescue*, where we explored how to design user interfaces for drone swarms as well as various methods to control the swarm. We developed a prototype in the form of a web application where drone operators are able to control multiple drones simultaneously. There was added support to control physical drones, which added a sense of realism when the study particpants used the prototype. It provided the drone operator with the ability to control the drones using three methods:

- **Selection control**: The user selects one or multiple drones and selects where they should go on the map.
- **Beacon control**: The user defines an area which the drones should avoid or investigate further when close by.
- **Leader drone**: One drone acts as the leader and following drones inherit its behavior.

We conducted a co-design session where we visited DEMA in Tinglev and had prepared scenarios as well as interview questions for two Senior Sergeants from DEMA who participated in our study. The purpose was to gain insights into future design features or changes that could help create a better working prototype for the next iterations, where the project group could test with DEMA in the future.

The two senior sergeants gave comments about how they currently use drones and how they imagined their process could be improved by a new system. Our prototype helped to instigate conversations about planning of a mission, controls of the drones, as well as discussions about functionalities and requirements that could be added. In order for the system to be usable, it would be important that the system continues to be as simple as the prototype we presented. They also explained that while manually commanding the drones to move or behave in a specific way could be useful, they found that automating it in some way would prove more beneficial for them. This meant that the drone operator should only specify the mission with very few actions and the system handles the rest.

We evaluated the different suggestions and requirements taking inspiration from the human-centered AI work of Ben Shneiderman [1] to consider if and how they should be implemented in a future prototype. We aim toward a system that will be reliable and trust worthy. An ideal system would not be overly restrictive, but empower the users to take action when needed and provide benefits of advanced AI algorithms for automating some aspects of the swarm control.

[1] https://www.brs.dk/da/

Contents

1 Introduction

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2 Research Contributions

In [2] seven types of research contribution categories for HCI are described. These are *empirical*, *artifact*, *methodological*, *theoretical*, *dataset*, *survey* and *opinion*. In our thesis, the contributions are primarily related to empirical findings and the developed artifact. In the paper, Wobbrock lists empirical research methods commonly used in HCI. We used one of the most important of these, *interviews*, in a meeting with DEMA drone professionals. For artifact contributions Wobbrock describes them as being dependent on *never-before-seen* inventions which are instantiated by *prototypes*, *sketches*, *mockups*, *demos*, or other *envisionment* and most commonly partially functional.

In terms of the empirical contributions, we provide unique insights into how SAR operations are conducted in Denmark and provide initial understanding of the requirements and vision for a drone swarm SAR system. Our most important contribution is a working prototype for a multi-drone control platform. Based on this prototype we are able establish a clearer understanding of DEMA's needs through the co-design session that we conducted with them. Lastly our contribution also involves the critical feedback on the UI And swarm control mechanisms that we received from DEMA during the co-design sessions interview part.

3 Discussion

In this section we will discuss how it was to work with DEMA and Robotto, and also how our project can directly contribute the HCI research community.

3.1 Working with collaborators

3.1.1 Robotto

Robotto[3] is a private owned company specialized in AI drone software and are also one of the partners involved in the HERD project. Throughout the project we had a total of three meetings with them that contributed to

[2]https://www.brs.dk/da/
[3]https://www.robotto.ai/

our final application. Their role in HERD is to hopefully commercialize the outcome and be able to sell it to end users on the market, which meant that their interest did not align completely with ours.

The first meeting we with had with their CEO made it clear that they were not very interested in UI as their company focused on AI and everything would be autonomous. He did however say if we needed help working with the drone software then they would lend us a hand. When we began to implement our first prototype, we scheduled a meeting with two of their developers and explained our goal and what kind of architecture that would be required to meet our goal - they helped us understand what was possible and recommended the final architecture which we used. While implementing the application, we also had one meeting where they helped us with the DJI Mobile SDK.

3.1.2 Danish Emergency Management Agency

Our cooperation with DEMA has had both pros and cons. What was nice about working with DEMA was that we had a unique opportunity, where it was possible for us to receive feedback from professional end-users who will be using our tool. DEMA was also very cooperative and were open to answer many various types of questions as well as giving us a thorough walkthrough of their current SAR operations and how drones are involved in these.

What troubled us mostly, however, was, that because we lived in Aalborg, and DEMA resided in Tinglev, which was about a three hour car ride aways, we did not have much physical contact with them. It took several months before we were actually able to meet them and conduct our co-design session. This meant that we had developed a prototype before-hand which were based on second-hand information, assumptions as well as using knowledge that we gained through investigating existing papers. Nevertheless, there were some positives gained from this. The first positive was that because of the knowledge gained from the investigations, we were able to really focus on what we believed that they needed. It also made us able to provoke their thoughts so that they would think and question themselves on whether they would for instance need a specific feature, if it could work in some specific scenarios, etc.

3.2 Contribution to the research community

The research that we have contributed with are the prototype, the research on how to design UI For drone swarms and the co-design session. These contributions serve as work in which future research can be built upon by other members of the community.

We argue that the prototype is a crucial contribution because, from the research that we have done on state of the art related works, we have yet to come across some that have creating a functional or partially functional prototype. This means that we are some of the first to have done this type of contribution to the community. Additionally, we noticed during the co-design session that the end-users behavior changed slightly when they were presented with a working prototype. This is because they had a real connection to a drone swarm and they were able to actively control it, which we think has something to do with the fact that, they do not have to imagine a scenario happening, instead they are an active part of that scenario. This is also a contribution, as it is an important factor which we think future researchers should take into consideration.

Lastly, we contribute with qualitative and quantitative feedback received from DEMA. Interestingly, there were quite a few surprises in terms of their opinions on how they wanted the designs of systems for drone swarms to be. We think that these are also going to be very interesting for other researchers to have a look at, and possibly avoid some of the design choices that might not be preferred by end-users.

3.3 Results

The two senior sergeants had the opportunity to use our prototype while we were at Tinglev. We quickly explained them what the prototype was capable of and also introduced them to the Wizard-of-Oz study approach. This was to be transparent that the behavior of the drones were simulated by having two project members controlling them manually. This did contribute to some confusion when the prototype did not respond to a command, because it was unknown whether it was due to the prototype or because of the person controlling the drone. While they used it, they often also switched their attention from the tablet to the sky. This was due to them checking if the drones were in an appropriate altitude and did not risk flying into buildings or poles in the area as this was not displayed properly on the prototype.

From our co-design session, the two senior sergeants gave a deep insight to how a multi-robot application could be used to enhance the work they do. However, one concern was that having multiple drones flying at once would introduce too much visual feedback for the SAR team to process. In order for the project to work, the system would need to support visual computation and only notify the team when something of significance is shown. They also said that when something is found, it should be marked on the map and not be displayed on the tablet screen as it would be too small to properly analyse the images.

To our surprise, the participants expressed that they were much more interested in the drones being able to decide what to do in a given situation and only require interaction from the drone operator if needed. This meant there were some assumptions we had taken which were not as relevant as we thought they were. The most significant were the need for the control methods. Based on exisiting work [3], we assumed that the drone operators would like to have as much control as possible, but the opposite were the case and they should only be used occasioanlly. Their want for automation also lead them to the opinion that even if there were a lot of drones in the map, they did not think they cluttered as were not interested in knowing the drones' immediate positions at all times.

Instead, their vision of the application was more as a tool for planning a mission. Even here they were interested in automating the processes associated with planning such as auto suggestion the search paths of the drones, but still have the option to change it to their needs. Interestingly, the beacon control showed to be more beneficial as a planning tool rather one that should be used amidst a search. This would require some changes to the current behavior of the beacon, as a circular beacon would not be suffiecient. Instead, it would be more relevant if it was similar to the area selection tool, where one could select an area with a polygon tool and have more fine grained controls to how the drones should behave in these areas.

3.4 Limitations

In the beginning of the thesis there was one major issue which limited caused us a little inconvenience when approaching the project. The project hosted by DIREC included Aalborg University, other universities as well as other stakeholders. This led to us having to wait during the time of our thesis for meetings to be conducted between these multiple parties before we could really begin with our project. Additionally, we also felt that on some occassions we were not able to be fully creative as it seemed like we resided in a box with pre-set constraints.

We were also limited by the fact that we only had access to two DJI enterprise 2 drones. This limited us in the first sense because we were a group of three, meaning that only two people at a time could work on developing the prototype simultaneously with using the drones. But more importantly, this limited us in the sense that for our testing and co-design session we used only two drones instead of many more, which could have better represented a drone swarm.

4 Future Work

The application itself is a prototype and some of the features had to be left out or mocked up for us to have something ready for the meeting with DEMA. The prototype should include a database in the future enabling users to save data so that it is preserved longer than their client session. This data could also be used to understand their missions and bring further improvements to planned missions in the future.

We used Wizard-of-Oz for parts of our study. For some of the features we did not have time to implement, and in other cases, we simulated features that were not within the scope of our project. In the future we want to integrate with an actual swarm algorithm so the drones become autonomous, meaning features like beacon and leader will also be functional and not just mocked up by us. We also want to get access to the live feed from the drone, so the operator can see the drone feed on the client for a quick look. However, we also need to implement a feature which allows the user to upload or stream the images to a larger screen as a tablet screen would be too small for inspecting them.

The HERD project aims to span over 3 years with multiple stages, therefore, it has been expected that there was going to be a lot of future work that might build from our study. This project served as the initial study with the end users to get an idea on where the long-term project should go. In the future, researchers in the HERD project may implement the feedback DEMA gave us. Likely there will be additional meetings and iterations of prototypes in order to arrive at effective user interfaces for drone swarm-supported SAR missions.

There are also some topics we want to focus on more in our user interface. Most importantly, studying situational awareness when operating these complex systems would be obvious next steps. The first interview with DEMA gave us good insights into how we could incorporate a focus on situational awareness. For an effective system, we learned that we should make sure the operator's workload is optimized providing the appropriate level of control, yet not overwhelming with too much information or need for moment-by-moment interventions.

5 Conclusion

In our thesis we developed a prototype, which focused on mission planning and various drone control methods for drone swarms. We added a sense of realism by creating a functioning communication to multiple physical drones.

In collaboration with two senior sergeants from the Danish Emergency Management Agency, we conducted a small pilot study, where they used the prototype which was then followed by a co-design session. Here they gave great insights to the limitations they experience at the moment and how a multi-drone system could be beneficial in the future. They also gave comments to the current prototype and which functions worked well and which could be improved.

We found that extensive control was not needed, and they were more interested in the system deciding what should be done, and the drone operator would have the option to change the automatic suggestion. This means that it is still relevant to develop functionalities where the drone operator is enabled to control and plan a mission as they deem appropriate, but they should not have to.

References

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[2] Jacob O. Wobbrock and Julie A. Kientz. Research contributions in human-computer interaction. *Interactions*, 23(3):38–44, April 2016.

[3] Andreas Kolling, Katia Sycara, Steve Nunnally, and Michael Lewis. Human Swarm Interaction: An Experimental Study of Two Types of Interaction with Foraging Swarms. *Journal of Human-Robot Interaction*, 2(2):103–128, June 2013. More focused on the algorithm, but does incoorporate some more user-centric ideas.

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ANDREH BASSAM BAHODI, Aalborg University, Denmark
MARIA-THERESA OANH HOANG, Aalborg University, Denmark
RASMUS SKOV BUCHHOLDT, Aalborg University, Denmark

ABSTRACT

Using unmanned aerial vehicles (UAVs) has become integral to supporting professionals in critical situations such as search and rescue (SAR). UAVs are most commonly used in SAR missions to optimize the search process for people in distress and to obtain video/still images of dangerous situations. While research has been conducted to develop the algorithms for more efficient UAV behavior, they are often treated as single autonomous entities with minimal human interaction. The drone operators in SAR come to the situation with intuition and past experience and must be able to guide the drone movements to optimize their search. However, it is still unknown how user interfaces can be designed to support the shared control in a complex interaction. Few existing works show how it could be done, focusing on giving the right amount of information without decreasing situational awareness. Most relevant studies have been conducted in a lab setting, often with virtual drones. These studies usually do not take place in the realistic environment with physical drones flying in the same space.

We created a tablet-based prototype that controlled the real-time flight of two physical drones to provide increased sense of realism for the SAR professionals. The main features focused on mission planning and three drone control methods including: **selection** control, **beacon** control and **leader drone**.

We conducted a pilot study in the form of a co-design session, where we had the study participants complete simple tasks with a focus on their interactions with the control methods. Afterward, we interviewed them about their experience with the application and how it could be improved. Here we found out that although the different control methods were useful in specific situations, the participants thought there was room for additional automation. They also found that the tool would be more useful as a planning tool where they could define which area should be searched. Still, there was also a higher interest in having this automated, again to minimize the amount of interaction that would be required of them. We discuss our findings in relation to human-centered AI research and current UAV research.

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1 INTRODUCTION

In the sudden life critical missions of first-responders, time is of the essence — teams must coordinate efficiently and understand the situation at hand. Tools and equipment to support search and rescue (SAR) missions often include unmanned aerial vehicles (UAVs) because they offer a visual vantage point for establishing situational awareness and they are much easier to deploy than manned aircraft. The current research space of Human-drone-interaction (HDI) also see the usefulness of drones in emergency settings, as it is the most mentioned topics in HDI research [11]. The benefits of deploying UAVs, rather than having people forage the area of interest, is not only the speed of the UAVs but also safety it brings to the staff. This is due to the fact that drones can reach remote and tough areas very quickly without a person having to physically go in and scout the area [16]. Maritime SAR operations can benefit from using drones due to their fast deployment time and speed as every minute immersed in cold water reduces the likelihood of survival for victims. For example, an average person without any protective clothing can only last a few hours before entering a critical state if the water temperatures are less than 15 °C which is the case for most of the year in Denmark [7].

Currently, the efforts to use UAVs in SAR in Denmark is at its infancy, and there is a high interest in researching how UAVs can be incorporated into the workflow and optimize the execution of the missions. Although interesting to research how a singular UAV can be used in SAR missions, a topic that is quite unexplored is how one can incorporate multiple UAVs into a mission as it could allow for faster area coverage. However, controlling multiple UAVs in parallel is not possible using the standard controller that is intended for a single operator flying one drone. With a single drone, an operator can focus continuously on the video feed from the drone and would know the immediate consequences of their actions. With multi-robot systems, or drone swarms, which consist of many interacting components, it can be difficult for the operator to fully apprehend what is happening moment to moment [19]. This is a highly critical matter in SAR as it is important that the SAR workers are made fully aware when a drone potentially finds the missing person. Sometimes, areas have landmarks which the victim are more likely to be in and should have higher priority to be searched. Given these scenarios, the workers should be given all the possibilities to control the drones in a way that allows them to optimize their search whether that is a larger swarm command or controlling the drones individually as needed while minimizing mental workload.

Therefore, we ask the question: ***How can we design effective user interfaces for drone swarm control to support SAR operations?***

In collaboration with the Danish Emergency Management Agency (DEMA)[1] and Robotto[2], we gained first-hand knowledge of how the emergency services currently conduct their SAR operations and how the deployment of single drones support critical missions. This allows us to understand how current SAR missions are conducted and which troubles they experience in their workflow. We use this information to develop prototypes which contain alternative representations of key functionalities to facilitate the SAR operations. We conducted the evaluations with two senior sergeants who are responsible for all drone SAR missions in Denmark and for their team of 60+ drone operators. The findings from the evaluation and follow up interviews provide insights into refinements to the research platform. Further insights were gained into the challenges of user interfaces to support drone swarm control.

2 RELATED WORK

In this section we present related research on the possible usages of UAVs in SAR contexts. We also shed light on existing research in Human swarm interaction (HSI) for control of drone swarms, but most importantly, work which studies the user interfaces and interactions between humans and the UAV swarm.

2.1 UAVs for Emergency Situations

Using UAVs for emergency situations often aims to benefit from minimizing the time and number of people needed to visually inspect an area of interest or to scout an area to find a safe path for people to traverse through in a mission

[1] https://www.brs.dk/en/
[2] https://www.robotto.ai/

[16, 18]. There have been tragic cases where first responders have lost their lives due to the uncontrolled and dangerous environments which only intensifies the need to separate the emergency personnel from high-risk areas. Examples where first responders have lost their lives are shown in a report on firefighter fatalities in the US in 2020 by the National Fire Protection Association (NFPA). It is not uncommon for firefighters to be killed while searching for victims during active firefighting missions because they must rush into a situation and rescue trapped survivors. By providing visual surveillance of the active situation, often a single drone hovers above the scene and captures video directing the personnel [8]. Another benefit of using UAVs for emergency settings is the fact that drones are very quick to deploy and are not limited by the terrain. This means that, for example in SAR cases where time is of the essence, the UAVs fast area foraging will allow for quicker missions and thereby a higher success rate of the individual's survival. However, manually controlling the UAVs requires the full concentration of the operator and might not be sufficient in a large scale operation. Researchers have therefore conducted studies to automate drones by for example equipping them with sensors for detecting a person from the video feed [10, 17, 21, 23]. Furthermore, Silvagni et al. [23] incorporated a planning phase prior to take-off where the operator, for example, could adjust parameters of a pre-programmed mission so the operator did not need an extensive interaction and planning phase with the swarm.

2.2 UAV Swarm Control

Traditionally, UAVs have been piloted individually with one remote operator controlling one UAV. Recently, there is a rising interest in UAV swarms inspired by swarm behavior from animals such as bees, birds and fish [12]. There exist many application areas in which UAV swarms could be beneficial such as delivery services [2], exploration and surveillance, SAR [1], forest firefighting [3], etc.

In comparison to a single drone, a drone swarm has increased efficiency, such as being able to carry higher payloads during delivery service, thus increasing delivery speed. Multiple drones working in unison are able to forage an area more quickly, increasing the chances of spotting survivors and saving lives during search and rescue missions. Albeit there are clear advantages of drone swarms, there also exist disadvantages which in extreme cases can be detrimental. Among the most serious challenges, maintaining Situational Awareness (SA) [1] is more difficult when an operator needs to be aware of and control more resources in the mission. It is easy for a drone operator to maintain SA when controlling one drone, however, this becomes more difficult when controlling many drones.

There are some examples of research that has examined methods and techniques that are designed to simplify interacting and controlling UAV swarms. In Kolling et al. [15] we are introduced to two control methods, *selection* control and *beacon* control. While selection control is labeled as an *intermittent* interaction, beacon control is labeled as an *environmental* interaction. The difference between these two types of interactions is that, for the selection control an operator can influence the behavior of a selected subgroup of a swarm into a new behavior, while for the beacon control an operator will not directly influence the swarm, but instead manipulate the environment which in turn will cause the swarm to react. In addition to these two methods of controlling a swarm, they identified two additional general types of interactions with swarms. They coin them as *persistent* and *parameter setting* interactions, where for the persistent interaction, an operator provides continuous input to the swarm or members of it. This is seen in *haptic control* of large robot formations and control via a leader. For the parameter setting, changing the parameters can enable a wider or narrower range of possible emergent behaviors. Kerman et al. [13] also had a similar control method to haptic control, where instead of calling it a leader drone, they called it *stakeholders*.

In Zhou et al. [27], they study swarm of micro flying robots in the wild. Here they argue that drones are widely deployed, however, in highly cluttered environments such as forests still remain inaccessible to drones, even more so to drone swarms. Therefore, they research how to enable swarm navigation in the wild, by developing miniature, fully autonomous drones with a trajectory planner. What this trajectory planner does is that it helps various task requirements such as flight efficiency, obstacle avoidance, and inter-robot collision avoidance, dynamical feasibility and swarm coordination.

2.3 User Interfaces for HDI and HSI

In this subsection we will present related work in Human-Drone Interaction and Human-Swarm interaction, as these are the two main types of interactions which will primarily occur during most uses of UAV swarms.

2.3.1 Human-Drone Interaction. In this section, we investigate papers that have studied methods for humans to interact with drones. In the past years HDI research has seen a rise in popularity, which has lead to an increase of methods in which humans can interact with drones. In Tezza et al. [24] they identify four major fields of HDI research. One of these fields is called *control modalities* which is methods of how a person can interact with a drone. They introduce five control modalities: gesture, speech, brain-computer interfaces, multimodal and touch. The use of some of these control modalities can be seen in for instance [5, 14] where they make us of gestures for interacting with drones and [1] where they use touch.

In a paper that focuses on user interfaces for robot swarms in emergency settings [18], they develop a light array visor prototype, which makes use of a swarm of robots to determine the safest path for a firefighter to follow, by taking into consideration the firefighters position and any obstacles they need to avoid on their way to the destination. The prototype has two variations, one with a *analogical view* and another with *logical view*. The difference is that the analogical view, the firefighter has to simply follow a light that is illuminated in his visor, while for the logical view, the light array is used to encode commands to the firefighter which he has to interpret. Albeit at face value the analogical view seemed most fitting, it was shown that the participants preferred the logical view. This was because the analogical view could be ambiguous as they did not know if they should follow the light or avoid it, while the logical view was less ambiguous and easier to understand.

2.3.2 Human-Swarm Interaction. When designing User Interfaces for HSI, the design needs to be done very carefully. According to Agrawal et al. [1], prior studies show that design problems contribute to 60% to 85% of accidents in aviation and medical devices, where many of these accidents happens because of human failures. They argue that common UI problems in Socio-Technical Cyber-Physical systems are often related to poor SA. SA is defined as the ability for users to perceive, understand, and to make effective decisions. There exist three levels of SA; *Perception* (1), *Comprehension* (2) and *Projection* (3). In these three levels the higher SA levels build on the lower leveled ones and add more complex to the design. Agrawal et al.'s implementation of SA follows Endsley's eight SA demons which are eight common design errors that occur frequently in UI which inhibit SA. Furthermore, they identify three additional SA demons on their own experiences working with UAVs.

Another paper which investigates how designing interfaces that support human-swarm interaction is Rule and Forlizzi [20]. In this case they focus on Multi-User Multi-Robot systems (MURS) where they argue that the number of challenges and their complexity drastically increased compared to single-user, single-robot systems. They also highlight the importance of SA when dealing with HSI. In their paper they argue that when designing interfaces for MURS the following factors must be taken into consideration: collaboration, information presentation, SA and salience of information. From the literature that they had studied they found that minimizing complexity on visual display is very important, and that bottom-up search happens within 100ms of attending a visual display. Because of this, they argue that designs with high visual salience should employ contrast in size and color as design variables. They talk about two very relevant concepts. The first concept is level of autonomy in which they describe as it ranging from level 1 where a human does the whole job and the computer just implements it to level 10 where the computer does everything and only includes the human if it deems it necessary. The second concept is salience of information which ranges from level 1 where the computer does not offer any assistance, where the human must call for all information explicitly to level 7 where the computer selects and displays information it believes is important.

3 RESEARCH PROBLEM

From the few works addressing the subject of user interfaces to control multiple drones, it is apparent that the research topic is still at its beginnings. There have been made some initial studies to explore how first-responders can be empowered through a user interface [1, 18, 20] and different drone control methods[15, 27]. However, the current works seemed to be conceptual and often had not been used in a practical setting. Though useful for initial thoughts, designs that work in an enclosed environment might not work as well when used in the field. Therefore we seek to explore the research problem: ***How can we design a practical drone swarm user interface to support SAR mission for the Danish emergency services?***

We want to extend the current research by developing a prototype which has the capabilities of being used in a practical setting. The prototype will be able to communicate directly with an arbitrary number of drones, and give the drone operators a realistic view of how it would be to use the prototype while being in the same space as the flying drones. While we recognize that designing such a complex system will take many iterations, we take inspiration from known examples in the commercial drone platforms and recent research. In this initial investigation we would like to understand how the operators respond to various ways to select drones, select a search area, as well as more advanced interactions with the swarm such as beacon and leader/follower patterns.

4 INITIAL INTERVIEWS

We began our investigation by gathering information from related partners in the HERD project. This included an interview with Robotto to get a sense of their vision for drones in SAR missions and to begin ideation for scenarios, features, and functions in swarm interfaces. We also reviewed publicly available documents from DEMA describing their use of drones and three of the researchers on the project conducted an online interview with a senior sergeant in DEMA and then shared the meeting notes with our group.

From our initial conversations with DEMA, we understood that the people we would be in close contact with already had a lot of technical experience with the drones and specifically the drones made by DJI[3]. As we have access to the same drones as DEMA's backup drones, we could safely assume which functionalities they were already familiar with. This allowed us to be less constrained with how we could speak to them without considering if the talk became too technical. Moreover, knowing that they already had experience with DJI, we thought that creating paper prototypes or wireframes would not give as much interesting information as a slightly more refined prototype. We, therefore, found it appropriate to develop a prototype with functionalities, which are inspired by the DJI functions they currently use. This would provide a basis for how the designs could look and allow the drone operators to adjust to our interface more easily.

[3]https://www.dji.com/uk

5 DESIGN

In this section, we present an overview of the features and technical details of our prototype for studying drone swarm user interfaces. While the platform was developed to enable expansion and exploration of more complex features later, we developed three control methods for initial exploration: ***selection, beacon***, and ***leader drone***, each taking inspiration from existing research on multi-robot interactions. Our main goal for the prototype is to elicit further requirements from the drone experts in DEMA to inform the development of drone swarm interfaces. They have yet to consider potential interactions and scenarios when collaborating with a swarm of semi-autonomous drone swarm, thus we made attempts to provide the simple features that are relevant for the SAR context and related to the scenarios discussed in the initial discussions.

5.1 Control methods

The three controls methods implemented in our prototype were carefully selected based on their relevancy and alignment to existing SAR missions procedures done by DEMA. This means they should at least be able to perform missions as they already do, just in a swarm manner through these controls.

5.1.1 Selection control. As mentioned in section 2.2, Kolling et al. [15] presents the *selection* control as their implementation of an intermittent interaction with a drone swarm. Here, it is expected that the drone operator is always aware of the drones' current positions to command them in an appropriate manner. In the case where the drones do not have the possibility to transmit data about their whereabouts due to connectivity issues, the drone operator has to make decisions based on old information.

5.1.2 Beacon control. Kolling et al. also presents the *beacon* control which is an implementation of an *environmental* control. How it differs from selection control is instead of directly manipulating the drones, the operator has to place beacons in the map, and nearby drones will act according to the settings the beacons have been programmed to do. At the moment, we have designed the beacon to have two modes: *attract* and *repel.* As their name implies, attract refers to a beacon which "attracts" drones in range and prompt the drones to inspect the area more thoroughly. Repel is the opposite and deters the drones, which can be necessary in situations where the area is of high-risk.

Compared to selection control, it is not necessary for the operator to be immediately aware of the drones' positions. However, not having direct control over the drones also means that one is reliant on the fact that the drones' flying path has to pass the beacon range. This technically means that even though an area is of high interest, if no drone decides to go inside the beacon range, this command can potentially get ignored.

5.1.3 Leader drone. In the work of Kerman et al. [13], they take inspiration from Couzin et al. [6] and they study how a special agent called a **stakeholder** can allow an operator to control whether a robot swarm should act in a *flock* or in a *torus.* Even with a limited amount of stakeholders, the operator still had full control over the swarms behavior and using this knowledge, we have decided to take this control method into consideration in our prototype, however we call the stakeholders *leader drones* in our context. Instead of the operator having to observe, control and decide the actions of every drone in the swarm, they only have to keep an eye out for the leader drones as the following drones will adhere to the instruction given to the leader drone.

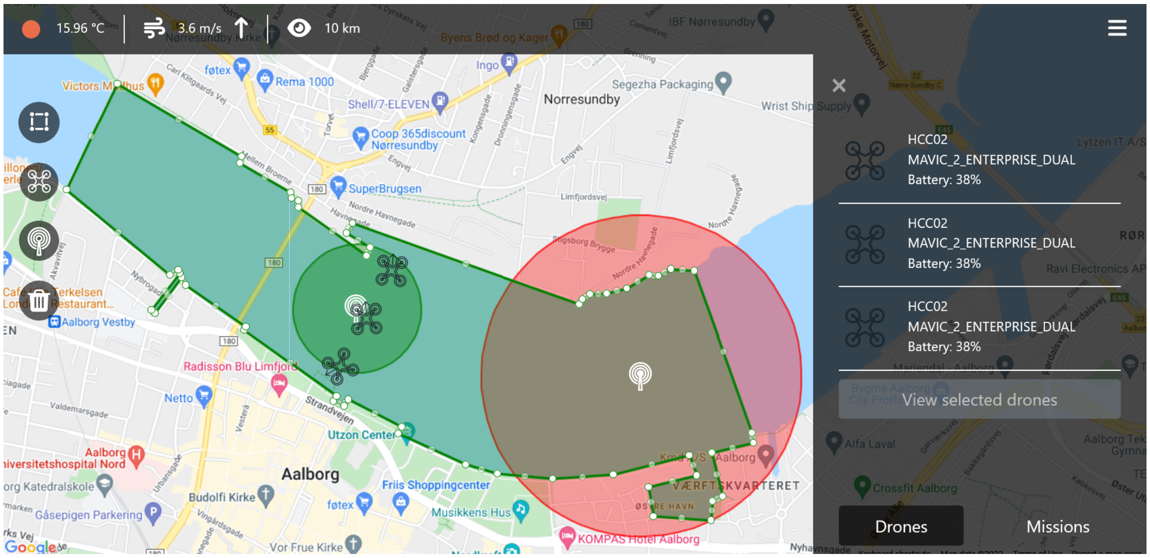

Fig. 1. The user interface of the client with an active mission in Limfjorden Aalborg, that has two placed beacons and three active drones.

5.2 User interface

The user interface was first prototyped in Figma, where it implemented the control methods in a map view, sharing a lot of similarities with the DJI user interface. The main focus of the interface is the map itself which gives the user a quick overview over the drones and their locations. The map supports drawing polygons which serves as the mission area which is very similar to the DJI mission interface. These mission areas can be saved and used as predefined missions in the future, where the user can create, edit and delete them. The motivation for this feature is that in some cities a lot of SAR missions takes place in the same location, like the Limfjorden in Aalborg, where people fall in every year [9]. The map also implements the other control methods, like placing beacons and adjusting these. The user interface also contains a navigation bar that informs the user of the weather and gives access to the hamburger menu with the drone and mission information. The drones can individually be selected where the user can inspect their location, battery level, see their camera feed, appoint them as leader and send various commands to them. The final user interface was then implemented directly in our application based on the prototype as seen in figure 1.

5.3 Implementation

Our implementation consists of three main parts that are separated to support scalability and flexibility in the future. We have a client that works as the user interface for the end user, where they can control and see everything related to a mission. This client communicates with a server that serves as middleware for communication with all the drones. This communication is achieved through the use of WebSockets. The server is also connected to n drone controllers that are able to communicate directly with the drones through the integrated API using the DJI Mobile SDK. The architecture can be seen on figure 2, where both the web client and server are hosted at cloud providers.

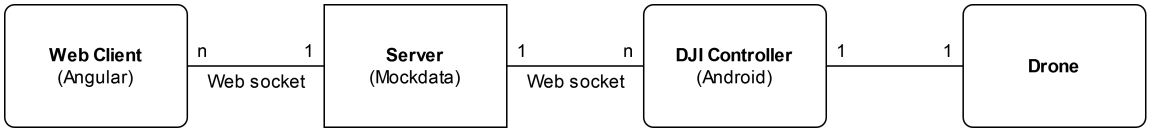

Fig. 2. Architecture of our system

5.3.1 Client. The client is implemented in Angular 13 to make it platform independent thus allowing it to be utilized through any given device that is large enough and has access to a browser. The main part of the client is the map, that is implemented with the Google Maps JavaScript API[4]. Alongside the map, we also have various menus that show drone and mission related data. This data is directly from the server, where the client connects through WebSockets, more specifically Socket.IO[5]. This implementation allows us to visualize the on-going missions in a very responsive manner as the sockets are event driven and automatically refreshes the content on the screen. Any amount of clients can be connected to the server, they will all see the same thing, which means if you interact with the mission on one client then all the connected clients will see this.

5.3.2 Server. The server is the center of the system that allows communication between the drones and clients. The server is implemented in Express[6] which is a Node.js web application framework. The server is hosted on Heroku which is a cloud platform that allows seamlessly deployment and integration with various systems. The server handles all communication between clients and drones, where it makes sure that the commands sent from the client are passed along to the correct drones. All the controllers connected to the server continuously emit their drone information to the server, the server then broadcasts this information to all the connected clients so they can see the drone information displayed in real time. Additionally, it also broadcasts the current weather to the clients, as this can be crucial for a given SAR mission. This server implementation means that any client can be connected to the server, whether it being another server controlling the drones with an algorithm or just another application with an actual user interface.

5.3.3 Controller. The controller is a piece of hardware that is capable of communicating directly with the drone. In our case the controller works as a slave, as we simply use it to bridge the server and drone. This is achieved by installing our own APK that implements the the DJI Mobile SDK on the controller. The SDK allows us to read and send data directly to the drone through an environment we control. The environment is connected to our server through Websockets, that gives us the full link between end-client and drone. This implementation has some hardware limitations as we need one DJI Controller per drone, but this also means that an operator always will be able to manually override control by simply using the real controller. The current controller implementation serves as a foundation for the future, as it still does not support broadcasting live feed of the drone camera to the server. The following features are currently implemented: sending various drone information, go to a given coordinate, and return to home.

6 STUDY DESIGN

We conducted a co-design session with drone experts at DEMA in the emergency services college campus in Tinglev, Denmark. Before the demonstrations and task-based user study session, we were first introduced to DEMA's current SAR operations by the officer who is responsible for all drone-related teaching activities in the organization. Following

[4]https://developers.google.com/maps/documentation/javascript
[5]https://socket.io/
[6]https://expressjs.com/

this discussion, the DEMA team provided a walk through of the typical drone support vehicle that is outfitted with drone equipment as well as large video screens and color printer to support real-time communication among the emergency response teams. They conducted a short mission flight to demonstrate a typical mission and then packed up the equipment. We then demonstrated our prototype and asked the DEMA professionals to test our prototype by guiding them through short tasks. The focal point of this session was to establish a clearer understanding of their needs, visions as well as receive critical feedback on the UI, and the swarm control mechanisms provided by the prototype. We consider this a co-design session [4, 26], which is made of two parts: the first entails that participants explore the prototype through a series of scenarios, while the second revolved around a *qualitative data collection* (semi-structured interview) and *quantitative data collection* (five-point Likert scale) method.

6.1 Participants

The participants of the co-design sessions were two Senior sergeants from DEMA. The first (32M) had 10 years of SAR experience and 9 years of drone experience, while the second (42M) had 23 years of SAR experience and 6 years of drone experience. Both participants are highly technical and familiar with DJI's drone products.

6.2 Scenarios

We used scenarios to guide the participants through the various functionalities that the prototype offers. The pros of using scenarios in our case was that it brought forth a sense of realism when experiencing the features and functions, thus giving them a greater understanding of the prototype, and encouragement to provide valuable, and detailed feedback related to their previous SAR mission experiences and DEMA expertise.

We split the scenario experiments into three phases. We first provided a walkthrough of the general concept and framing they need to understand when considering the application. Secondly, and more importantly is knowledge about the UI that we have designed. Here we gave a walkthrough of how the participants can make use of the UI features such as selecting pre-made missions or marking an area for search as mentioned previously, in the design section 5.2. Lastly, after the participants had time to explore the UI, they were guided through launching a mission by selecting an area that they want to search. We also had them try out the three control techniques including: ***selection control, leader drone and beacon control***.

For the selection control all features were fully implemented in the system, while the others were implemented through a Wizard-of-Oz [25] technique so that we could simulate the features as if they were real.

In terms of the activities for each of the control techniques, for the selection control we had them do the followings things:

(1) Select one or multiple drones,
(2) Direct the drones to search an area.

And for the leader drone:

(1) Select a drone and appoint it as leader
(2) Send the leader drone to a location
(3) Imagine that the non-leader drone controlled by the drone operator is following the leader drone without any manual control.

And lastly for the beacon control we had them

(1) place an attracting beacon

(2) then place a repelling beacon
(3) lastly the drone operators control the drones manually and either go to the attracting beacon or avoid the repelling beacon.

6.3 Interview

Following the task-based study, we conducted an interview with both participants together including semi-structured questions as well as a number of Likert scale questions. The interview was video recorded, where we handed the participants the questions such that there would be a lower risk of misunderstanding them. For each of the questions asked, the interviewees were provided with a written copy of the questions and space in which they could write notes if they felt the need to do so. Both interviews with the participants were conducted simultaneously by the same interviewer, because the two interviewees at DEMA worked closely together and therefore during the interview they could possibly spark ideas between each other. The questions presented in the document were chronologically ordered in terms of the phases that the participants went through during the scenarios.

6.3.1 Semi-Structured Interview. A semi-structured interview was chosen because of two reasons. The first reason was the amount of participants in our study and the second was, that the participants have many years of domain knowledge, as well as experience being part of SAR operations, and using drones in this context. The semi-structured interviews allowed us to ask questions which are open ended and serve as conversation starters as well as thought provoking which could potentially draw out additional, important information.

6.3.2 Likert Scale Questions. We chose to include Likert scale questions which ranges from strongly disagreeing to strongly agreeing in the interview, as it can help indicate the participants level of agreement towards various statements. We realize that a quantitative method is suboptimal for a small number of participants, nevertheless, we chose to include it, as it adds value in terms of making the answers given easier to interpret. E.g. our aim with a question is to understand the level of likeness the participants had, towards a specific UI design element, or a way of interacting with the UI. If we asked an open-ended question we would risk that the participants would continue on an unnecessary tangent, which may have cost time, and might make it a bit more difficult to interpret their answers. However, if we use a Likert scale we can easily interpret the degree of likeness, as there is a laid down constraint, in which their answer can only be one of the options provided in the Likert scale.

7 RESULTS

In the pilot study, both participants were able to successfully complete all the practical tasks with the prototype including launching a mission, moving the drone swarm, etc. with only minor difficulties. The following co-design session started out to be both as a written and oral interview to lessen the risk of misunderstanding. However, halfway through the session, we decided that it would be best to focus predominantly on the oral interview with some written input using Likert scales. This helped the interview as the discussion would not be interrupted with intermittent writing pauses.

This section will provide more detailed findings from our pilot study with the two Senior sergeants from DEMA. First, we will cover how the experience with the Wizard-of-Oz procedure worked and how the two participants reacted to it. Secondly, we will present the different statements and opinions about the various control methods and the general user interface.

Fig. 3. The two participants using the application.

7.1 Practical usage of the prototype

As mentioned in section 6.2, the participants had to go through a couple of different scenarios to let them get a first-person view of what is possible with the current prototype as seen on figure 3. We were transparent that some of the functionalities were not fully implemented. A lot of the drone automation was simulated by having two project members manually control the two drones using the Wizard-of-Oz procedure. It cleared some confusion as to when the drones did not act as expected (for example, when the drones stood still and did not search the area). However, it did also cause some slight confusion when things did not work. For example, the selection control method was implemented such that the drone operator had complete control over it through the user interface, but due to a connection error, the drone did not react to their commands. This caused some uncertainties, whether the drone had not manually been moved or there was an error in the software. Although there was this slight obstacle, the participants quickly ignored that the drones were controlled manually.

Another interesting point we observed when the participants used the prototype was that they often switched their attention between the tablet and the drones flying in the air. We assume this behavior was caused by them confirming that the drones were at a suitable altitude that would not risk the drones flying into each other or any buildings or poles surrounding the area. It was also done to confirm whether the drones behaved as commanded through the application.

7.1.1 Usage of tablet. While using the prototype, the participants used a 11" iPad Pro as a device. We asked them if it made sense to use a tablet device for the application, and they both agreed that the "right tablet" would be useful due to its portability and ease of use. What they meant by the "right tablet" was that it had to be a military grade tablet. This meant that it should be able to withstand harsher weather conditions like hotter and colder weather, as these can have an effect on the battery life and responsiveness of the device. It should also be robust enough that it could withstand some accidents. They also pointed out that while the screen of a tablet would be big enough for missions planning and navigation, it would be too small for any image processing. Usually, when viewing images, they would scale it up to a 50" TV as it would be easier to see if something of interest was displayed.

7.2 Evaluation of mission planning

The interview focused mainly on the area selection functionality and mission selection when addressing mission planning. The participants thought both functionalities were easy to use (answered agree and strongly agree on the Likert scales).

7.2.1 Area selection tool. As the area selection tool was designed to be similar to the selection tool provided by DJI, they both quickly understood how the tool worked. We presented them with an alternative way of selecting an area, where they would select an area with a continuous motion (lasso tool) instead of tapping to define each vertex of the area. However, in general, they were not very fond of having a lot of swiping gesture controls due to multiple reasons. They suspected that they could accidentally trigger other functionalities (e.g., map panning), especially in harsher weather conditions where the tablet screen would be less responsive. Another concern was that it would be harder to see where they would be drawing the area if one had larger fingers.

There was a functionality they found was missing from the application. One of them suggested that there should be the possibility to see the no-fly zones in Denmark by syncing the data from Naviair[7] to the application. Even though DEMA has the authority to fly in no-fly zones, they still found it helpful to have a visual indicator if they were residing in or approaching such a zone.

7.2.2 Pre-planned missions. When designing the prototype, we had the assumption that there might be specific landmarks that were known to be sites where people would go missing (e.g., harbors or rivers). However, when asked if the participants would plan a mission on-site or were able to plan beforehand, they both said that a mission would always be tailored to the specific situation. They had never experienced a case where they could pre-plan a mission, and the relevancy of the functionality was not apparent to them.

7.3 Evaluation of drone controls

When questioned about how it was to control the drones, they provided some feedback on how the drones are displayed in the application and the three different control methods.

They both informed that it was difficult to differentiate the drones in the application, and there was a need for other indicators to know which drones they had correctly selected. One suggestion was to show the altitude beside the drone icons flying on the map. Another suggestion was to have a strobe light emitting from the physical drones. Regardless of the suggestions, they pointed out that it was not highly relevant to be able to differentiate the drones. They were very clear that they would leave the drones to handle when they should return home for a battery exchange and how to keep a safe distance from other flying vehicles. If they ended up in a situation where they would want to inspect an area more closely, it would not matter which drone should do the task. The only situation where they might find it interesting to select a specific drone would be if the drone had found something relevant.

7.3.1 Leader drone. Out of the three different control methods, the participants said they preferred the leader drone control scheme. It seemed to be the control method that would allow them for most automation and minimal interaction as you only had to program the behavior of one drone. They found it difficult in the UI to see which drone was following

[7] https://www.naviair.dk/

the leader and what it meant when another drone was following. They suggested that there should be a clear signifier to show which drone was following the leader by having a line going from the follower drone icons to the leader icon.

7.3.2 Selection control. As mentioned earlier, one of the participants thought the selection control method was somewhat challenging to use. One reason was because of the bug in our prototype, where the participant did not know why the drone did not adhere to their command. Another thing that led to this opinion was that when the participant tried to select another drone, they accidentally made an already selected drone fly towards it. This caused a slight panic as the participants had no control over the altitude, and it looked like the drones were about to collide on the application.

Selecting the drones themselves could also be a challenge, especially if the drones were moving. We gave them an alternative layout, where instead of clicking the individual drones one by one either on the map or in the side-menu, they could instead mark an area with a lasso tool, and the drones inside the area would be the ones to be selected. While they thought the lasso approach was suitable if they had to choose many drones at once, if they only had to select a few, they still preferred the tap to select approach.

Outside of a couple of difficulties with the selection controls, they agreed that when they had selected the point they wanted the drones to go to, it was quite clear if the drones were doing as they had commanded. A situation where this control method could be relevant would be when they found an area of high interest and would need one or more drones to inspect it more thoroughly. Still, again, they were very clear that they were more interested in the drones automatically handling most things. They pointed out that the drones should not go to the exact same point but instead go to the same area while keeping an appropriate distance (5 meters).

7.3.3 Beacon control. The beacon control was the method that seemed to be the easiest to use out of the three, and even with multiple beacons, it did not seem to clutter the screen. As the beacon tool would only place a circle onto the map, we asked if a circular beacon would be sufficient for SAR missions. While it would be sufficient if they wanted to place a beacon quickly, it was more interesting if the beacon tool was similar to the area selection tool. An example they gave was when they should search a forest area; the drones should not go into the forest but instead fly around the circumference of the forest. Here a beacon could be created in the shape of the forest and signal to the drones how they should search the area.

8 DISCUSSION

Current SAR missions rely on two DJI Smart Controllers when controlling a single drone: one for controlling the drone and one to provide streaming of video to a large 50" monitor residing in their van. Our prototype presented a shift because it can be used on any screen device with a browser as it is a web-application. After using the prototype, they articulated various features that would be needed for a controller to fit within the typical environment of SAR missions.

This section discusses the most salient concerns based on the findings from the task-based interactions and the statements given by the two Senior sergeants who acted as participants in our pilot study. Here we highlight the surprising statements and discuss the participants' responses towards the prototype. Most of their comments and suggestions for improvements were related to the tablet as a controller (section 8.1) and the amount of automation needed both for planning a mission and the drone control (section 8.2 and 8.3). They told us the importance of having a device which could handle the conditions the SAR missions would be performed in, as well as having an application which was simple enough for anyone to use that does not require a lot of manual control.

We find it pertinent to relate the statements to the "human-centered AI" work of Ben Shneiderman [22] as he argues for how one can develop AI to support the human rather than replace them and thereby maintain a reliable and safe system. SAR is a critical context because it is a race against time and the missions rely on the safe, yet quick use of various equipment and tools including drones. From the pilot study, it was visible that the participants had to check whether the drones were behaving as expected, indicating a slight mistrust or uncertainty in the system. Using Shneiderman's work, we can see which functionalities can be automated while not reducing the user's capabilities. Specifically, we refer to the two-dimensional framework representing the balance where high levels of automation and high level of human control can be designed into a system to ensure that it is *reliable*, *safe* and *trustworthy*.

8.1 Critical features of tablet controller

The two participants were quite satisfied with using a tablet as their device while using the application, assuming that it would be mainly used for planning and navigation. The tablet screen would be too small if it should be used for processing images, and it would be required that the application could connect to their larger screen. This is different from the work of Agrawal et al. [1] where their prototype used video feedback from the drones as a significant part. We were also informed that while they already used different electronic devices, they often preferred to use physical prints on SAR missions. This was due to the fact that they did not want to be affected by possible events that could potentially slow down the operation (e.g., no battery, software updates, etc.). It would therefore be relevant for our application to add functionalities that upload relevant information to a nearby printer, like the one inside their van, or to the cloud, so if the device is out of commission, they can quickly start a new device and pick up from where they left off. If we relate it to Shneiderman's two dimensional framework, the system would need to automatically handle which images it should upload for later print, which the user can always decide to analyse further later on.

8.2 Tensions between manual control and automation of drones

When developing the prototype, we had an assumption that the SAR personnel required extensive control over the drones. This was due to the rules and legislation surrounding drones in Denmark, and the operator should always be in total control over the drones. However, when showing them the prototype, we found out it was the opposite. To our surprise, the two participants were very clear that they wanted to minimize the amount of interaction they had with the drones. This was because they were more engaged in the idea of having multiple drones flying independently and automatically figuring out what would be the best course of action. While it was requested that the drones should be as automized as possible, the participants still agreed that all control methods were relevant to a SAR mission. Following the two-dimensional framework presented by Shneiderman, in order for a system to be reliable, safe, and trustworthy, we should allow the drones to be fully automized, but the drone operator should always have the capability of taking manual control if they deem it necessary.

Their request of a more automized system also directly affected their opinions on what was necessary to display on the application. Critical moments such as when the drones found a person, there should be a very attention seeking UI element which alarms the SAR people immediately. Oppositely, information like the drones' current status were less relevant and did not seem to be as important to display clearly on the screen. These findings are similar to what Rule and Forlizzi [20] found in their study, where critical situations required high visual display salience, and elements like idle drones required less display salience.

8.3 Semi-automatic mission planning

Many functionalities they suggested that could be added were related to the map and seeing what could be areas that should be prioritized higher and which should be avoided. Here the example with the forest came into the conversation, where they informed that the beacon tool could be used to define where the forest was and how the drones should act when close by. Interestingly, the beacon control seemed more relevant in the planning phase of the mission rather than being a control method that should be used while the drones are up in the air. However, when asked, they also thought the system could automate the mission planning, similarly to how DJI's map mission function could automatically create a route inside the selected area. For example, it could suggest which areas to search first because it automatically detects a river on the map. This would significantly help them as one of the first things they would do, would be scouting targets of value. If we follow the work of Shneiderman, if such functionality should be added, we have to ensure that the user always has the option to reject and edit the system's suggestion if they disagree with the result.

Throughout the interview, the participants explained that the drones often worked in tangent with people on the ground because drones were not as useful in certain areas as people and search dogs. An example they gave was a forest, where the crowns of the tree would make it almost impossible to view the ground from above, and its density would also make it hard to control the drones. Based on this, they thought that the beacon tool could be more useful as a planning tool rather than a control method, and it would be relevant in future designs to redesign the beacon function to accommodate this suggestion. From section 2, it is already being explored how drones can safely navigate around in a forest and dodge trees on their path[27]. However, even when the algorithms mature, keeping the suggested beacon tool would still be relevant. This ensures that the user can always define a mission to their liking, for example, if the mission operator finds it more useful to use people rather than drones in a certain situation.

Pre-planned missions seemed less relevant. We had an assumption that for some SAR missions, it would be possible to pre-plan a mission, especially if it is a known area where people go missing. An example we had in mind was if someone fell into a harbor or anything similar. But the two participants informed us that they had never been able to pre-plan a mission themselves in their whole career, so the functionality seemed irrelevant to them. Still, we believe that this functionality could have relevant usages if the area of interest is a well-known spot for disappearances. For example, *Rådet for Større Bade- & Vandsikkerhed* shows that in 2020 there were specific places where people fell into the water, for example Limfjorden in Aalborg[9], and the work of Silvagni et al. [23] also showed there was some relevance to this functionality.

9 CONCLUSION

In this study, we sought to answer the question: ***How can we design a practical drone swarm user interface to support SAR mission for the Danish emergency services?***. The research question has been partially answered, yet the main contribution of this work is that we elaborated the research problem so that future design and development efforts can focus on more narrowly focused aspects of the larger challenge.

We developed a prototype which was used to facilitate a discussion with the Danish Emergency Management Agency (DEMA) to envision how an application could help them planning a SAR mission and controlling a drone swarm. The prototype was also able to control and communicate with physical drones, which gave the study participants a sense of how it would be to use such a system in a realistic setting.

We had two senior sergeants from DEMA as our study participants, both having years of experience with SAR and drone usage. We had them use the prototype and had a co-design session afterwards. They explained the importance of having a system which could be used in the physical environment of a SAR mission as well as being simple enough that anyone could easily use it in their current SAR workflow. To facilitate the simplicity, they found it necessary that the system would be able to take autonomous decisions both in control and mission planning with minimal human interaction. Future research would seek to further research how the suggested functionality could be implemented in a user interface, and, again, evaluate the usage in a realistic setting.

We believe that this study can be used to further the current research of user interfaces of swarm control with showing the benefits of developing a prototype which can be used in a realistic setting. Although focused on SAR, the findings can be useful in other contexts which requires human interaction with robot swarms such as in agricultural robotics.

10 FUTURE WORK

We only had one opportunity to show DEMA what we developed and receive feedback, meaning that a continuous feedback loop was not possible, so a lot of assumptions were made beforehand and the feedback we were given has not been implemented yet. In the future we want to implement the new features and make adjustments based on their feedback and then have another meeting with them.

The prototype is not connected to a real database, where the server just mocks the same missions and data. In the future we want to integrate a database on the Heroku platform, so the user actually is able to save their own missions and so that we can store data that can be used for mission debriefing.

Wizard-of-Oz was used for parts of our study, as we did not have enough time to implement these features or they were not within the scope of the project. So in the future, we would want to integrate actual swarm algorithms into the system, so the drones have real swarm behaviour and controls like the beacon and leader would be functional. Additionally, we also plan to implement live feed from the drones, as we currently only show a static generic image.

Long term as the platform gets improved and we get closer to a fully functional platform, it would also be interesting to see DEMA use the application for an actual training mission.

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