From Zero to Drone Hero

Enhancing Critical Infrastructure Security with User-Centered Drone Interface Considerations

Kristian Bengtson, Christoffer Nielsen, Kristian Thomsen

Software HCI Masters, cs-24-hci-10-01, 2024

Master Project

AALBORG
UNIVERSITY

Software
Aalborg University
https://www.aau.dk/

Title:

From Zero to Drone Hero: Enhancing Critical Infrastructure Security with User-Centered Drone Interface Considerations

Project:

P10-project

Project period:

February 2024 - June 2024

Project group:

cs-24-hci-10-01

Participants:

Kristian Dragsbæk Schmidt Thomsen
Kristian Juel Bengtson
Christoffer Lykke Nielsen

Supervisor:

Timothy Merritt
Page Numbers: 18

Date of Completion:

May 29, 2024

Abstract

The security and safety of critical infrastructure is a critical concern for modern society. Threats to the infrastructure are becoming more sophisticated, traditional monitoring methods are becoming insufficient. Drones are becoming more prevalent and have emerged as a promising answer to the security and surveillance needs, by offering capabilities in rapid response and monitoring. However there has not been a lot of research into what the user wants from a system utilizing drones for security and surveillance, and how those needs translate to designing a user interface for such a system. The goal of this paper will be to find out what operations personnel want from a system using drones, and how an interface should be designed to support those wants. The context used in this paper, is the monitoring of a power plant facility. Here the drones are tasked with monitoring for intruders, and responding to alarms. Stakeholders with experience in being operations personnel and drones were brought on to provide a knowledge base that could be drawn from. This paper has resulted in several design suggestions for designers to use, and researchers to explore.

Summary

This thesis examines the preferences and expectations of operations personnel regarding an interface for a drone surveillance system, focusing on the largely unexplored field of power plant operations. The study involves experienced personnel from HOFOR and select Drone experts.

An initial study was performed identifying potential uses for drones in power plant security and monitoring, focusing the paper on operational scenarios and how drones could assist. Participants discussed various scenarios and the potential role of drones in each.

A second study involved five participants with backgrounds in operations, security, or drones. Using guided interviews, the study explored four categories: "Automatic Response," "Control Methods," "Video Popup," and "Attention direction." Short videos provided context, followed by discussions to understand participants' reasoning.

The results revealed that operations personnel require substantial context for decision-making to ensure safety and proper documentation. Flexible control methods for drones were also deemed essential. These insights led to six design considerations for future studies and interface designs for surveillance drones in critical infrastructure.

This research contributes to the broader understanding of human-drone interaction, offering valuable recommendations for designing user-centric drone systems. The findings suggest considerations for enhancing the usability and adoption of drone technologies in critical infrastructure monitoring.

Resumé

Denne afhandling undersøger driftspersonalets præferencer og forventninger til en brugergrænseflade til et droneovervågningssystem med fokus på det stort set uudforskede felt af kraftværksdrift. Undersøgelsen involverer erfarne medarbejdere fra HOFOR og udvalgte droneeksperter.

En indledende undersøgelse blev udført for at identificere potentielle anvendelser af droner i kraftværkssikkerhed og overvågning, med fokus på operationsscenarier og hvordan droner kunne hjælpe. Deltagerne diskuterede forskellige scenarier og dronernes potentielle rolle i hvert scenarie.

En anden undersøgelse involverede fem deltagere med baggrund i operationer, sikkerhed eller droner. Ved hjælp af guidede interviews udforskede undersøgelsen fire kategorier: "Automatisk respons", "Kontrolmetoder", "Video Popup" og "Opmærksomhedsretning." Korte videoer gav kontekst, efterfulgt af diskussioner for at forstå deltagernes ræsonnement.

Resultaterne afslørede, at driftspersonale kræver væsentlig kontekst for beslutningstagning for at sikre sikkerhed og korrekt dokumentation. Fleksible kontrolmetoder for droner blev også anset for at være afgørende. Disse indsigter førte til seks designovervejelser for fremtidige undersøgelser og grænsefladedesign til overvågningsdroner i kritisk infrastruktur.

Denne forskning bidrager til den bredere forståelse af menneske-drone-interaktion og giver værdifulde anbefalinger til design af brugercentrerede dronesystemer. Resultaterne foreslår overvejelser for at forbedre anvendeligheden og udnyttelsen af droneteknologier i kritisk infrastrukturovervågning.

Contents

I. Introduction

Ensuring the security and resilience of critical infrastructure is a central concern in modern society. With the increasing sophistication of threats, traditional surveillance and monitoring methods are often insufficient. The European Union has recognized this issue, resulting in directives aimed at enhancing the protection and resilience of critical infrastructures[1]. Drones have emerged as a promising technology to address these challenges, offering capabilities for comprehensive monitoring and rapid response.

Drones are becoming more prevalent in society as a whole. Currently, there are a multitude of different fields of usage that have drone research associated with them. These fields cover entertainment, surveillance, emergency services, and more. However, drones are still considered somewhat of a novelty, as researchers are still looking into the best ways to utilize drones. New challenges and research opportunities are still being explored, leaving fields without guidelines, for how systems should function and be interacted with [2], [3].

Despite the EU directive, there has not been a lot of research, within the field of security, in regard to how a human operator would interact with such a system[3]. There is research examining what matters to professional drone pilots[4], however, there is still a lack of the expectations from the operators of critical infrastructure. Through our previous work, we found there was interest in exploring the capabilities and use cases of a drone security and monitoring system within the power plant known as *Amagerværket*[5].

The goal of this paper will be to study what monitoring personnel would prioritize when working with drone systems monitoring critical infrastructure, and present the priorities and insights from personnel focused on monitoring. The recommendations will be created in collaboration with the experienced monitoring personnel from HOFOR, who monitor the power plant known as *Amagerværket*. The research question for this paper is:

> "What do operation personnel on power plants hope to gain from the use of drones for security and surveillance, and how should interfaces be designed to support their security duties?"

The contributions of this paper is two-fold:

- Insights from interviews with operation professionals from a power plant that help build an understanding of requirements for a drone-supported security and surveillance systems
- User studies conducted with operation professionals from a power plant operations team interacting with visual artifacts in order to derive implications for the design of drone based security and surveillance user interfaces.

II. Related work

Drones in industry

From earlier work we know semi-/autonomous drones are becoming more integrated into the industrial sector. Today, a multitude of companies offers advanced drone solutions to both the public and private sector. Drones can be equipped with ocular and metrical sensors which collect data to be analyzed using machine learning tools thereby providing autonomous path routing, volumetric measurements, object detection and tracking. Earlier work also uncovered potential use cases in power plants. Fuel can be stored in piles which are hard to measure. Another use case is grounds security with focus on intruders, personnel hazards

and first response.[5]

Volumetric measurements using drones is a well-studied technology[6] and have found use in the industry for measuring stockpiles[7]. The drone flies around a stockpile at low altitude to create a high quality map of the surface and converts that to a volumetric surface model. Drone research into private security is dominated by the defense sector. The area of research seems to be skewed towards the security of the drone and not the implementation of the operational system in a security setting[8], [9]. Some research have looked at the possibility of having drones track intruding drones as this is a challenge to do from the ground[10], while the industrial defense solutions are more focused on reconnaissance, tracking[11] and active countermeasures[12].

Introducing new technology to a field has the ability to empower workers and make the system work more efficiently, but it also comes with costs that can be a liability in an emerging market. The initial investment is high because most cases will require specialized implementation and subsequent system maintenance. In some cases, drone pilots will need to be staffed or trained, and in others, the available technological capabilities are lacking, leading to lower output than expected. Speed, cutting cost and sustainability are favored traits in already developed industries, where the use cases often require a more technical and customized solutions. In industries such as mining, safety is the main concern as mine and machinery inspections does not require sending a human. The main idea behind drones is they can move fast and through the air and thereby not having to risk the safety of workers by sending them into difficult situations.[13]–[15]

Usability

Research in power plants has mainly focused on how people use technology to make sure things are safe and work well. One important area of study is the design of control rooms. It highlights how the layout of control rooms is key to reducing mistakes by operators and improving how they communicate. A big concern is managing how much work operators have to do. Overloading operators with excessive tasks can lead to fatigue and stress, which could lead to accidents.

Prior research has highlighted a high contribution to accidents in aviation and medical device domains due to design problems, many attributed to human failure. They argue this is due to poor situational awareness (SA)[16]. They build upon earlier work which identifies 8 SA demons and contribute 3 additional. The second SA demon - *Misplaced Salience*, describes how poorly placed warnings and alerts can lead to misunderstandings. The eighth SA demon is *'Out-of-the-Loop-Syndrome'* which presents the increasing lack of awareness in the operator when a system operates autonomously due to over-reliance on automation. A contributed SA demon, *Enigmatic Autonomy* warn how human who are not able to interpret the drones' behavior risks communication problems. The operator must be able to understand what a drone is doing and how and which autonomous decisions have been taken.

Another contribution of theirs is a design solution of a user interface (UI) of an autonomous multi drone system in relation to emergency response scenarios. Their methodology consisted of engaging domain experts over 6 sessions, exposing them to design concepts using visual aid representing SA demons. They also adopted a scenario based approach to achieve higher engagement during discovery. Scenarios was used to understand how

the system should behave under certain conditions and act as a sort of test for the system. Among their findings is when a discovery alert is show the associated video should be full-screen, route markers and drone paths are helpful indicators on a map and displaying coordinates was a bad idea due to the rapid changing numbers.[16]

Another study developed a prototype for a similar system, also with a focus on search and rescue, using semi-structured interviews and Likert scale questions as a way to evaluate specific UI elements on a map. It builds on earlier proposed control tools, *Selection control* and *Beacon control*[17] as a way of manipulating semi-autonomous drones. *Selection control* allows to select drones and order them to search an area and *Beacon control* allows placing a marker to have drones search the area in a given radius. The study contributes an *Area selection tool* where the area to be searched is marked by placing a polygon. They discovered the preference of control tool depended on the situation, furthermore *Beacon control* seemed to be the most user friendly variant.[18]

In a related paper presenting the findings of 3 co-design sessions developing the control UI, they provide further evidence for *Selection control* and *Beacon control* both providing value. They also highlight findings regarding video feed presentation. They put an emphasis on not viewing more than 4 video feeds at a time and differentiating video feeds either via colors or numbers.[19]

Multiple ways of drawing attention by designing visual markers is explored in a study on the display of machine learning detection's to locate cancer tissue. They present various designs including a circle, tight circumference, area segmentation, dimming all non highlighted area and displaying a frame. They presented the study to field experts which rated their perceived performance improvement based on Likert scale and found a higher preference towards designs focusing on highlighting the location and not obscuring any important information in the process.[20]

III. Study design

In order to answer our research question and fulfill our contributions from section I we aimed to identify the possibilities and constraints for a drone system in critical infrastructure as well as inform of the visual needs of such a system. We therefor designed and conducted two exploratory studies on the use of drones in critical infrastructure. The first study was used to characterize the current practices in the industry and establish and ideate the use of drones in these practices. The second part was used to explore the interactive preferences for a drone monitoring system in critical infrastructure.
The participatory design approach has inspired many of the choices made in designing this user study, as it has been shown to not only help explore the usability of a project, but also shown to help sustain the initiatives after the project [21], [22]. This is reflected in the participants, as they have been chosen because they have a personal or at least professional interest in the investigated matter and would gain from any eventual solution that could result from the research. This is further reflected in the visual aids displayed to the participants that were iteratively developed using the information from this study and building on our previous work made using participatory design with the same experts in drone technology and human computer interaction [5].

Thematic analysis is used to identify, analyze, and report patterns, also known as themes, in data. It is an accessible form of qualitative analysis, due to not being locked to any single theoretical

framework, in contrast to other forms of analysis, such as grounded theory. There are multiple different variations of thematic analysis. Inductive thematic analysis, is where themes are identified in a "bottom-up" fashion. This type of analysis is used when the themes do not need to fit into a pre-existing framework, it is well suited to find new knowledge. In contrast to inductive is theoretical thematic analysis. The theoretical thematic analysis usually yields a detailed description of an aspect of the data. It is well suited to answer a specific research question.[23]

The reason for choosing thematic analysis is that it can be used to find themes within individual data items, where other methods find patterns across a data set. Additionally, it can be used both to explore wide and go into deep dives.

Study One: Exploring Security Challenges and Drone Use in Critical Infrastructure Monitoring

This study aims to explore the potential use of drone technology to enhance security and operational efficiency in critical infrastructure settings. The potential is explored by looking into the current security operations within *Amagerværket* and ideating with the personal on how drones could be used to assist their daily work.

Participants

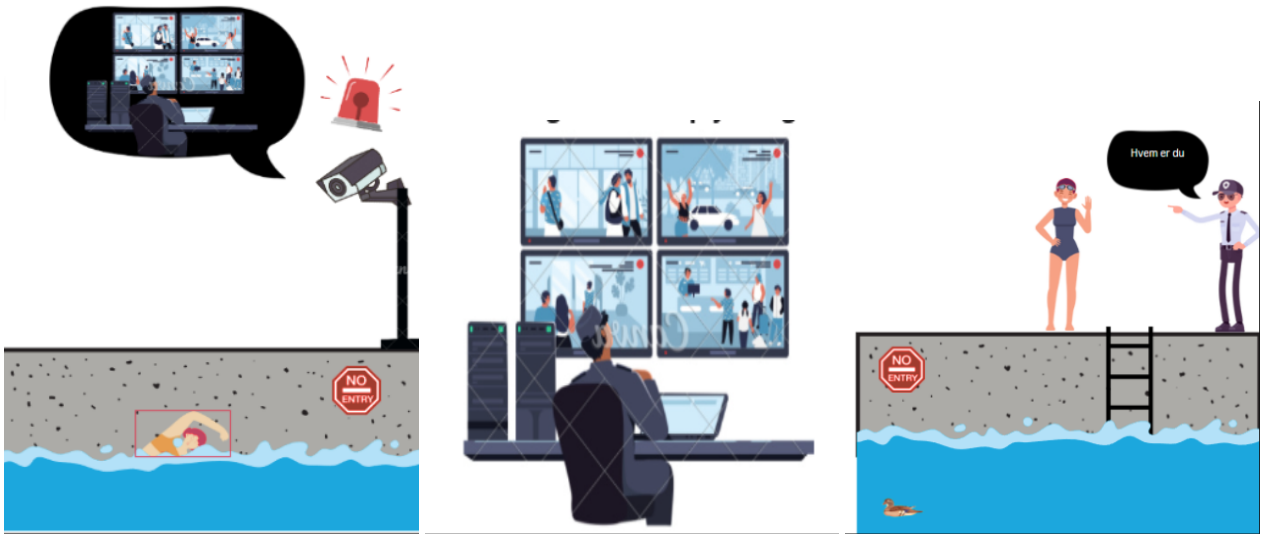
Two selections of participants were used in the study, one for the pilot studies and one for the user study itself. The participants for the first pilot study were selected for their expertise in drone technology and consisted of two industry experts in drone technology from the drone specialist company Robotto and one researcher of Human Computer Interaction(HCI) with a focus on drone technology. The second pilot study were conducted with the head of innovation from HOFOR. The two participants for the user study were selected for their expertise in operation and security on critical infrastructure, and consisted of the head of innovation and the head of operation at HOFOR. All participants were Danish.

Materials

A pilot study was made in order to find what could be explored within security and drones. This pilot was done in two interviews. The first interview with two members from Robotto and an expert in HCI. The second interview with the innovation lead from HOFOR. The first interview focused the interest of research within security on intruders and personal hazards like missing hardhats, security vests and the like. We then created an initial set of scenarios using the second pilot interview conducted as well as the information gained in our previous work [5] mentioned in section II. A series of storyboards showcasing the established scenarios were created along with the questions. These were created as a way to focus the user study as well as a method to allow the participants to further establish the scenarios, explain how the situations are currently solved and ideate the use of drones in the scenarios. [24], [25] An example of the storyboards can be seen in Figure 1. Each storyboard consisted of three simplified abstractions of reality, covering the aspects of security within the focus of this paper:

1) The detection of an issue, either an intrusion or a personal hazard
2) The communication of the problem to relevant parties, including how a drone would be deployed or how security personal currently are being deployed
3) The resolution of the problem, including how the problem was logged

Two sets of storyboards were created for each scenario, one displaying the current way and one displaying a possible future with drones. To allow the participants own imaginations for the



(a) Storyboard part showing CCTV detecting a potential intruder

(b) Storyboard part showing an operator monitoring the surveillance footage

(c) Storyboard part showing an operator sending the intruder away

Figure 1: Swimming Intruder Storyboard

possibilities of the future use of drones, the display of the future was mostly a copy of the current way scenarios with the addition of one or more drones.

Procedure

The study were conducted by the authors through Teams and in the mother language of the participants(Danish). All participants were encouraging to give as much information as possible. The interview were recorded, transcribed, and supplemented with notes taken during the meeting to mitigate possible errors in the recording and transcription. The participants joined through Teams and were presented with the prepared material through Miro to allow them to interact with the provided visual artifacts. The participants were presented with an introduction to the project and our previous work in order to establish the context of the study. After the introduction, the participants were presented with a series of initial questions related to their work and trust in automated systems. Each initial question was presented under the topics: work environment, daily tasks, and automation, in order to initiate an exploring discussion. After each question, further questions were asked dependent on the participant's answers. Each topic had a max time limit of 10 minutes to respect the limited time of participants and as to not exhaust the participants with the initial questions. When the topic was explored or the time limit reached, the next group of questions was presented. After the initial questions, the participants were presented with the storyboards with attached questions for each of the three parts of the storyboards. The scenarios were presented in order, with the current situation storyboard being shown first and then the future storyboard, before moving on to the next scenario. For each storyboard the participants were given an intro and then prompted to discuss the given scenario. For each of the discussion points additional probing questions were used to explore the scenario in depth.

Findings study one

The data provided during the interview was analyzed qualitatively using an inductive approach

with the steps from thematic analysis. This resulted in a number of themes with textual evidence behind each theme. In addition to the found themes, the scenarios were also further described and focused.

Balancing Operations and Security

The analysis revealed the possibility that personnel's primary task is operational management, while security is a secondary responsibility that the operators have on top of their normal tasks. When issues are detected, the response typically involves dispatching one or two operators, often over considerable distances. This operational challenge is compounded by the limitations of static camera monitoring, resulting in a predominantly reactive approach to site security, with each reaction taking time away from the operators' primary tasks.

Inefficiencies in Current Surveillance Systems

Current surveillance systems exhibit inefficiencies, such as frequent false alarms, exemplified by the system mistaking birds for intruders. This misallocates resources and necessitates potentially long and unnecessary verification trips increasing the operational burden on personnel.

Logistical and Financial Constraints

Logistical and financial constraints impact the security. Although there is interest in utilizing drones for various tasks, budget limitations restrict the hiring or training of dedicated drone operators. These constraints impede the adoption of advanced technologies that could enhance site security and operational efficiency.

Potential of Automated Systems

There is interest in the benefits of automated systems. Automatic drone flights for monitoring biomass and deploying drones for security tasks are viewed favorably. Automated CCTV-to-drone communication is also considered valuable, particularly for preliminary assessments of potential threats such as fires or intruders. These systems are believed to substantially improve operational capabilities by enabling timely and efficient responses to incidents.

Drones as first responders

There is an interest in allowing the drones to act as first responders. Personal should be able to have drones inspect areas. This is thought to help reduce personnel workload by functioning as mobile CCTV cameras allowing for further investigation without the need for the personal having to interrupt their tasks. The drones are expected to relay information to the personal, who can decide on further actions, with simple interactions. Further, interest was put forth in allowing the personal to communicate with any potential intruder through the drone, again mainly to avoid having to leave their post.

Anti-Drone Measures and Detailed Logging

The need for anti-drone measures and comprehensive logging emerged as themes. There is an interest in deploying drones that can track and potentially neutralize unauthorized drones, thereby enhancing site security. Detailed logging of drone activities, including timestamps, altitudes, routes, and potential information leak, is considered essential for accountability and operational tracking and is currently a difficult task to perform. Alerts and information on drones approach or in sensitive areas are also deemed important.

Informing study two

Based on these themes, we focus on the studying the usability requirements of automated drone systems for routine monitoring and security tasks, specifically the interaction needed to complete such

actions. The integration of detailed logging and anti-drone capabilities, and the implementation of new technologies in a manner that minimizes disruption to public and recreational activities, is left to future work. Addressing these areas is expected to enhance both security and operational efficiency while maintaining a positive relationship with the public. The chosen scenario in relation to the found context of the operatives in *Amagerværket* can be seen on Figure 2.

Study Two: Analyzing Operator Preferences in Drone Control and Display for Security Monitoring

This is a study of drone control and display of automated drone systems for routine monitoring and security tasks. The study will consist of a number of guided interviews using short videos of interaction methods as visual aid for a set of subjects, with each section ending in the selection of the most preferred and not preferred method and pre-arranged question prompting discussion with the interviewer. The objective is to understand the participants' preferences on various methods of drone control and video display by using their given preferences as talking points for further discussion. The guided interview approach facilitates a deeper exploration of the rationale behind their preferences by posing questions and then prompting them to explain in which situations they preferred a method over another, and why. The study contains 4 sections:

Video and autonomy
To gain a simple understanding of video preferences regarding what is important when capturing video, where to focus and angle the view. It also includes the presumed level of autonomy the drone would operate under during different conditions and alarms. It was clear from earlier study that routine security and emergency alerts require different operating procedure. Each subsequent situation also requires a more specific procedure, due to the dynamic nature of the workplace requiring operator judgement.

Control
Different ways of commanding a drone to an area. *Selection control*, *Beacon control* and *Area selection control* from prior research explored in section II, have been included in the study. We have included 2 versions of the beacon, one with a fixed size area and one with an expandable area. We also included two versions using selection to also have the ability to place multiple waypoints to form a route, in addition to just placing a single target waypoint.

Video display
How to display video in context to a map is an area lacking dedicated study. Other studies earlier found a higher preference for a full-screen video display over a small popup in regards to search and rescue missions[16]. We included both and in addition we present 2 more. One which split the screen vertically to preserve as much relevant data while sacrificing parts of the full available view from both. The second presents the video in full-screen with the map shrunken into the right corner and is called a minimap. This concept is a popular solution in the game development community to similar problems.

Video detection
Exploring different methods of highlighting machine learning detections could provide insight into what information might be relevant for an operator. Based upon earlier research we are including a tight bounding box around the detected object and another using a segmentation layer placed over the object as described in section II. We also included 2 additional. A bounding box

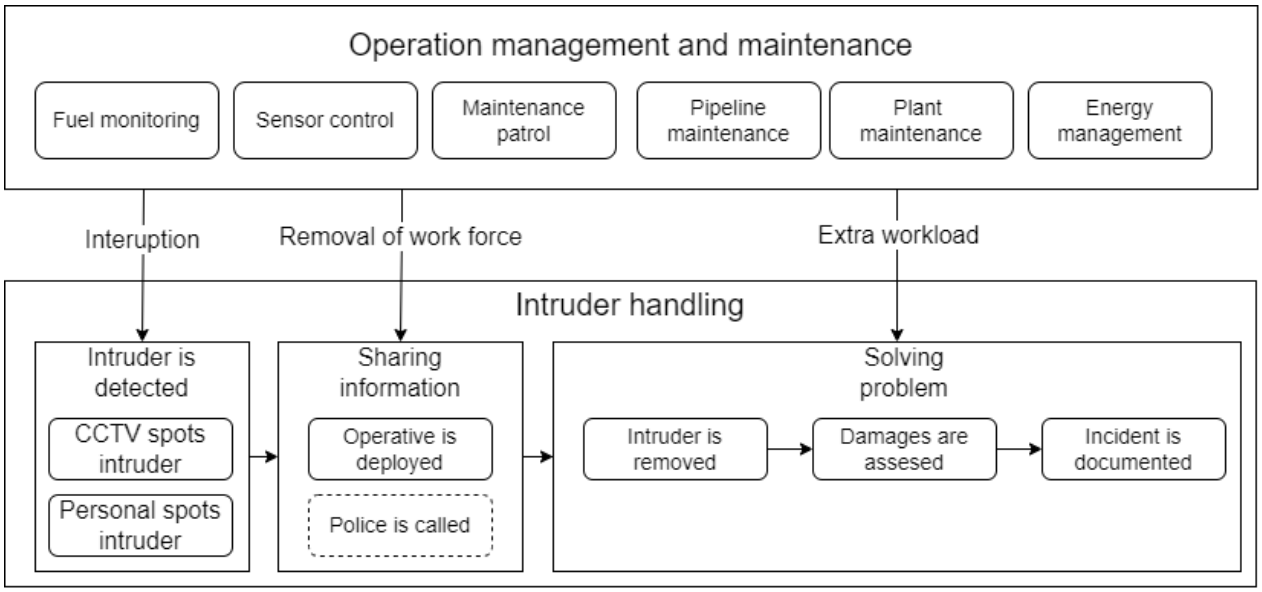


Figure 2: Duality of the operatives tasks

with an appended label and the second with label and a confidence score.

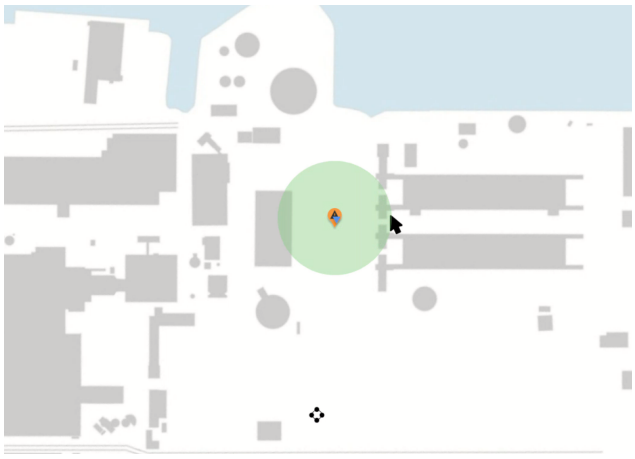


Figure 3: A screenshot of the *Beacon control* video showing the map containing an expanded beacon with its area marked in green.

Participants

The participants for this study were selected to maintain consistency with our previous research. We intentionally included individuals who had participated in previous studies as well as additional security personal, opting for one-on-one interactions to delve deeper into their personal perspectives and experiences. This approach allowed us to gain a deeper understanding of their viewpoints. The participants consisted of 3 industry experts in operation and security on critical infrastructure from HOFOR with an average experience of 6.17 years(5 year minimum) and a drone expert from Robotto with 15 years of security experience. All participants were Danish.

4 experts

Materials

In the interview, a number of visual artifacts in the form of short videos are used. Each video displays a variation of control or display of drone footage from the point of view of an operative on *Amagerværket* as well as a description of each action taken in the video in the form of subtitles. Each video is an interaction created and animated using Figma, displaying a part of the set scenario in the form of either a control or display of the drone on the map or its footage. Each video contains a static map of *Amagerværket* along with a set of symbols

representing either an alarm, user action or a drone along with a set of geometrical shapes representing interaction artifacts. An example can be seen in Figure 3. The drone footage used in the interview is a video made by the researchers, where a drone sees a person going past in an environment mimicking that of *Amagerværket*. The same video is used for all instances where a footage is required in the videos. A series of Likert-like scales is presented after each video to have participants rate the individual interaction methods. This approach helps us identify participant preferences, such as the desired level of drone autonomy. Unlike traditional Likert scales, these are not used to measure quantitative metrics; instead, they are primarily used to foster qualitative discussions and facilitate further prompting during the interview to understand why a particular interaction is preferred or not.

Procedure

The study were conducted by the authors through Teams and in the mother language of the participants (Danish). All participants were encouraging to give as much information as possible. The interviews were recorded, transcribed, and supplemented with notes taken during the meetings to mitigate possible errors in the recording and transcription. The study was shared with the participant through Google Analytics, and they were prompted to share their screen. This way, the participants were in control and could go the tempo they wanted. The participants were presented with a written introduction to the context of the study, the final scenario as seen in Figure 4, and the context of the videos including the map and icons. This was followed by initial warm up questions and when the participant was ready they could move on to the sections. Each participant was presented with the sections in the same order. Each section started with a short introduction describing the drones' behavior, the task performed in the videos and their task in that section. Before the first video was shown, the participants were instructed to enable subtitles on the videos. When they had seen the video, the participant moved on to answer the Likert-like questions, for that video. The participant was again prompted to think aloud if they did not do so automatically. The final question after each group of Likert-like questions prompted the participant to vocally brainstorm or discuss their choices and the use of drones in the shown videos. The interviewer prompted the participant with additional questions until each of the participant's given preferences had been discussed. After each section, a follow-up section was used to gauge the overall preferred control or display method and present further prompting questions for ideating the use of drones. After the last section the user was given a debriefing section, thanking them for their participation, again showing the scenario and prompting them to answer with any information they thought relevant or felt had been forgotten to be included or mentioned in the study.

IV. Results

The results of the second study were analyzed using inductive thematic analysis. The themes found are concentrated into six design considerations. These considerations capture the essence of the findings, and are intended for designers and researchers alike to use in future works. The considerations will be presented in relation to the four sections presented in Figure III.

Automated response

In this section of the study the participants were introduced to the idea that the drones responding could be autonomous as standard, performing monitoring tasks when not responding to alarms. The answers were focused on what the drone should do, when responding to an intruder.

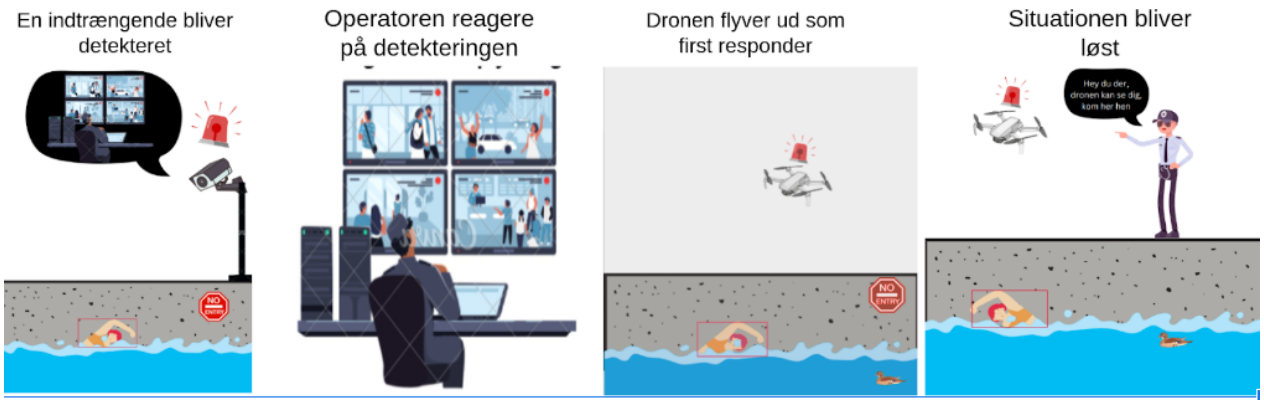


Figure 4: The final shown scenario, text is in danish

Observing surroundings

Observing the intruder is not enough. Not only is it important to observe the intruder from multiple angles, it is also important to observe the surroundings of the intruder. An example given by a participant would be if the intruder placed or dropped something, if this thing were to be hazardous, operators would be aware of it and call in proper personnel. Were it to be something non-hazardous, then personnel can be sent to collect it. As one of the participants said:

> "In case of someone attempts sabotage, and they run away when the drone arrives, it is important to see if something, which was left behind, is a bomb or a toolbox."

Not only does this reduce the risk for monitoring personnel, it also helps in finding the correct response to a situation. Getting multiple angles also helps as documentation, both in case charges have to be made or for training new personnel. It is clear that the context is important.

Design Consideration: Get context to help the operators make decisions and create documentation. The findings show that operators want as much information about a given situation as possible. This is for both decision making and documentation purposes. For the purposes of decision making, knowing whether something dropped is a bomb or not is incredibly important. For documentation purposes the additional context can function as evidence, it could be used for training purposes, and to help in establishing what the norm for such situations is. As such, more context is incredibly valuable during and after intrusion.

Operator permission

The participants were also asked whether the drone should ask for permission before moving to an alarm, and whether the drone should follow the intruder. Here the answers were mixed. The concerns were in regard to who has responsibility in case the drone makes a mistake like flying outside its designated area or fly into something or someone. However participants agreed that some form of human involvement was necessary, the operator doesn't have to give permission, but should be notified. This could also help people on the ground with accepting the drones, because they know there is a human on the other end.

Design Consideration: Have a human operator involved when the drone needs to deviate from the standard. Monitoring personnel is not exclusively focused on intruders. There are multiple key places, and processes that need to be monitored because failure could be dangerous. As

such, requiring the permission of the operator every time there is something could be too intrusive. However the operator should be notified, and in some case made to make a decision.

Direct control

The participants were presented with different ways of controlling the drone, ranging from placing way-points, to marking specific areas. These controls allow for the operator to direct the drone to specific places for investigation. The answers that were received did not differ a lot, between the different methods.

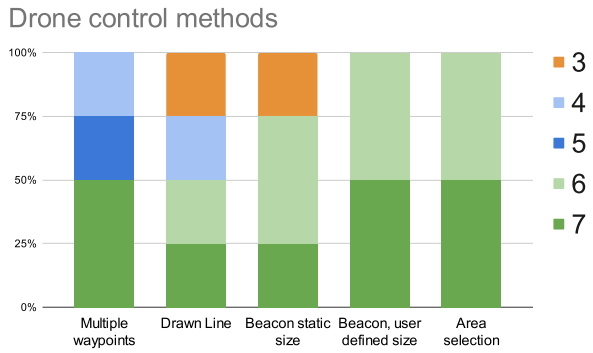


Figure 5: The scale goes from 1 to 7, with 1 being disagrees, and 7 being agrees.

The preference found was for control methods that support marking an area of variable sizes. The ability to mark specific areas as needed was a high priority for the participants, the other methods were also liked, as can be seen in Figure 5, however their lack of area coverage and flexibility meant that the methods that supported marking an area of user controlled size, were preferred. *Beacon control* with user defined size was well received, as it allowed a user to shrink or enlarge the area as needed.

> "It's because then I can set the area and I think it's a good idea because there can be all kinds of gizmos going on out there at the plant where I need to either narrow it down or make it bigger."

It was noted by a participant that it would also translate well to a tablet. The *Area selection tool* was equally well received, especially the flexibility as it could also be used for creating a patrol path. The *Area selection tool* was preferred over *Beacon control* when dealing with more complex mission. However *Beacon Control* was preferred when something needed to be marked quickly. In addition the control methods should be kept simple, as the operators could run into situation where a complicated system would present a hindrance rather than a boon.

Design Consideration: Make the method of directing the drones flexible and easy to use. None of the presented control methods were disliked, each methods were generally liked. However from the interviews a clear preference could be found. Each participant liked having the flexibility of defining an area themselves, with some of them even mentioning the idea before the method was presented to them. Participants also noted that the flexible methods could be used to place more than one task at a time.

Video popups

Part of a system with monitoring drones would be to show video feeds to the operator. This could be to verify what the drone sees, help guide personnel, or take notes for future reference. The participants were presented with different ways for the video to be shown. The answers were varied, with one exception.

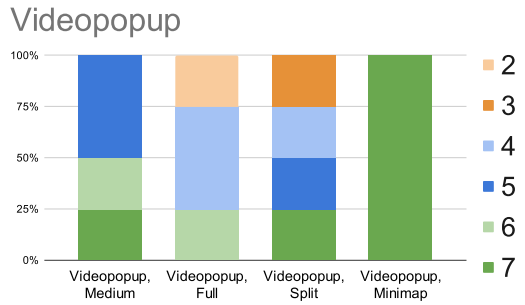


Figure 6: The scale goes from 1 to 7, with 1 being disagrees, and 7 being agrees.

The video popup with the map minimized in the corner was the clear preference for the participants, as can be seen in Figure 6. The map being shown in a non obtrusive way, while also putting the focus on the video feed, made it the favorite.

> "you just feel more confident in your case when you can see, okay that's what I can see and it's on the map. Then it is much easier to explain it if I have to tell it to my colleague who is on his way out to investigate.

The least favored version, was the one where the video feed completely overtook the map. The participants liked the minimap as they where able to use it for referencing the position of the drone and the alarm quickly.

Design Consideration: Do not remove context to show something else. For the video popups, four different options were presented. Out of them, the participants unanimously picked the option were the video popped up, with the map becoming a minimap in the corner. In contrast, the option were the video popped up and completely covered it, was the most disliked. From this it can be surmised that the participants disliked the removal of the map. This indicates that removal of context, even to show other context is not the preference.

Bounding box

Lastly the participants were presented with videos that featured two people. Each video showcased a different form of bounding box, with the bounding box being used to direct attention to what the drone had spotted. This part had the most differing answers from the participants. The participants all liked having a box. However the questions regarding the different labels proved to be divisive.

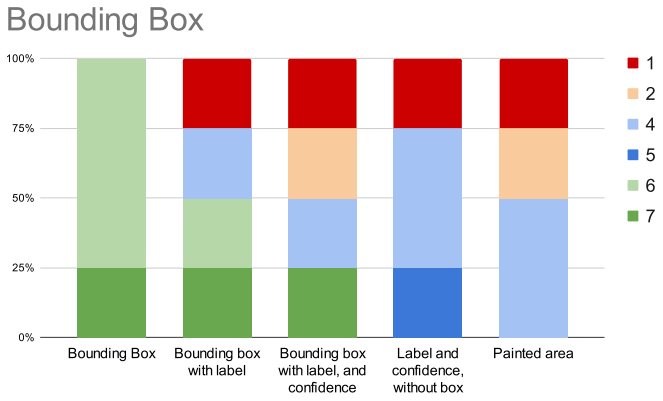


Figure 7: The scale goes from 1 to 7, with 1 being disagrees, and 7 being agrees.

The removal of the box also did not showcase a clear preference, as can be seen in Figure 7, though the majority of participants either disliked or were indifferent to the removal of the box. The segmented area proved to be the only version that was disliked, due to overlapping the object which concealed information.

> "It's a shame that you mostly look at what's there, which gets blurred a bit."

From the answers it is clear that the preference is for there to be something that draws the attention. However what information it should relay in addition to that, would most likely be considered on a case by case basis.

Design Consideration: Have something that draws the attention to what has been spotted, visually displaying information tied to it. From

the finding it became clear that drawing attention to what is being spotted is a good idea. However the answers received in regards to the type of labels were inconclusive. it could solicit a study by itself, though the suggestion would be to implement the necessary labels according to their customers wishes. In addition to these findings participants floated the idea of having the attention method highlight intruders only when toggled.

Addendum

The interviews also presented other findings partially related to the questions. One such finding was that the participants appreciated the map. The map was something that the team thought as being essential to display the current location of a drone. In addition to this, multiple participants mentioned that context like a timestamp or location information would be a good thing to have for documentation purposes. From this, we postulate that when dealing with autonomous drones, operators need a lot more context.

Design Consideration: Remember to include all the context needed, even if it might seem trivial. These findings showcased that what might seem like a trivial or sensible change to a designer, might not be something that has been thought of.

V. Discussion

The posed research question was:

> "What do operations personnel on power plants hope to gain from the use of drones for security and surveillance, and how should interfaces be designed to support their security duties?"

We engaged in an exploratory study with drone experts and critical infrastructure operators to discover what opportunities and challenges there would be associated with the implementation of drones in critical infrastructure from a security perspective. We chose to engage using an exploratory interview with multiple participant using visual aids. This was followed by a set of guided interviews with the participants, conducted one-on-one using visual aids. From this we devised 6 design considerations to inform the design of future development of drones and their implementation in industry. We consolidated interaction methods from earlier studies[16], [18], [20] and contributed new methods, such as minimap display, which seems promising but is lacking further study.

Challenges

It is evident from the findings that the implementation is a complex task and requires insight into how specific situations should be handled. The appropriate response to an alert requires input from an operator due to the variety of events. Anything deviating from a plan already in place will at least need confirmation. Even the route a drone should take when responding varies based on the current state of the operational area. What we found align with prior research into industrial implementation presented in section II. Creating an out-of-the-box solution does not seem possible due to the required specialization of such a system. A specialized system which would only do a pre-planned security round was seen as a hindrance due to the cctv system already in place. The value would come from being able to combine it with a system able to quickly and safely respond to a situation. It should be noted this is from a security perspective, as drones can also provide value by supporting the operational task where in the case of *Amagerværket* could be volumetric

measurements of biofuel[5].

Considerations

The design consideration; *Get context to help the operators make decisions and create documentation*, necessitates the ability to go above what a cctv usually can do and capture the surroundings. This relates to general security as the need for small details and documentation does not have prior use in the industrial setting.

Have a human operator involved when the drone needs to deviate from the standard is a consideration which relates to most industrial settings due to general safety. Autonomous machines must have clearly defined parameters because if not then the chance of error is elevated and the operation cannot be seen as safe, especially not in dynamic environments.

Make the method of directing the drones flexible and easy to use relates to all fields which requires mission planning. We consolidated earlier work which used *Beacon control* and *Selection control* to move drones[18]. We discovered that it was not necessarily the specific method which was preferred but rather dynamic tools. Even having multiple different methods available to have the ability to create any kind of shape quickly.

Do not remove context to show something else relates to multi-modal tools. Depending on the amount of drones connected to a single platform the amount of alerts will end up stacking up. If an alert hides information or other alerts from visibility the process of attaining the needed information will slow down.

Have something that draws the attention to what has been spotted, visually displaying information tied to it. Drawing attention to objects have shown promise in situations requiring a high and continues focus[20]. The benefit to grounds security seems to be identification and localization, as it can help the operator make faster decisions.

Remember to include all the context needed, even if it might seem trivial. Adding timestamps, location data, drone id etc. to the frame or adding a map could make identification in the moment and at a later point much less of a hassle. It will depend on the situation what is needed but most could benefit from considering this.

Limitations

This project used a small participant group for all interviews and studies. In addition they all either worked for HOFOR or Robotto. The participants from HOFOR were experts in operating the plant and its internal systems while the participants from Robotto were experts in autonomous drone technology and its implementation. We recognize that this is not a large or diverse enough group of participants to conclude anything definitive without further study.

VI. Conclusion

For this project we wished to find out "What do operations personnel on power plants hope to gain from the use of drones for security and surveillance, and how should interfaces be designed to support their security duties?" The interest was sparked from a previous research project based around using drones for monitoring fuel stacks. This project was designed to be exploratory, due to a lack of easily available research on the topic. To answer the question it was decided to use participatory design, as the field of monitoring and security is foreign to the team. The process resulted

in a number of design considerations. Each of these design considerations helps to understand what operations personnel wants from a system using drones for security and surveillance. Furthermore, the considerations could be used as the starting point for further studies.

To conclude, the research question has been answered with a number of design considerations. Each of them could see potential use both in inspiring more research, as well as giving designers suggestions as to how they should design their system. These considerations should not be viewed as hard rules, they are the result of an exploratory expedition into the field. The considerations have the potential to be further refined, refuted, or tweaked depending on what further studies find.

VII. Future work

The findings of this project are not final, and are certainly not the end of the road. The team has found two potential avenues for findings to be used in.

Research

The design considerations that have been found in this project are not final. While they have supporting evidence, there is a lack of verification, and refinement. For the side of verification, studies could be performed in collaboration with other entities than HOFOR to see if the results are similar. The study could potentially involve other power-plants like, windmill parks, solar arrays, nuclear, etc. This could give an idea of what considerations would be applicable to every plant, and perhaps creating considerations that are more specific to the mentioned types. Verifying these considerations, could turn them into recommendations, making them more useful for designers. Further studies could be performed to refine and improve upon the considerations, making them more specific. Such study could be done by picking a single suggestion and using it as a basis to create prototypes. Then presenting those prototypes to experienced operations personnel for evaluation. This process could involve doing workshops, or semi structured interviews, using the prototypes as a basis for discussion. This could allow the suggestion to become more specific, improving their usefulness for designers. This could also result in more considerations, that could be worth investigating by themselves.

Design

This project has only included experienced operations personnel. As such, no designer has weighed in on the considerations. It could be interesting to presents these considerations to designers to find out how they would use them. Having a couples designers use these in project and then taking a look at their prototypes, could give insight into what the considerations are lacking and excel at. It could also create a basis for discussion on what guidelines the field of infrastructure security needs, when it comes to designing monitoring systems. The insight gained could be very different from the insights gained by working with operations personnel or researchers. Using the practical knowledge of applying guidelines and design theory, designers would be able to find problems that researchers and operations personnel wouldn't, and find ways for the considerations to be improved and applied.

Bibliography

[1] "Critical infrastructure resilience - european commission," *Migration and Home Affairs*, [On-

line]. Available: https://home-affairs.ec.europa.eu/policies/internal-security/counter-terrorism-and-radicalisation/protection/critical-infrastructure-resilience_en.

[2] M. Hoang, K. Grøntved, N. van Berkel, M. Skov, A. Christensen, and T. Merritt, "Drone swarms to support search and rescue operations: Opportunities and challenges," English, in *Cultural Robotics* (Springer Series on Cultural Computing), B. Dunstan, J. Koh, D. Turnbull Tillman, and S. Brown, Eds., Springer Series on Cultural Computing. Switzerland: Springer Nature Switzerland AG, 2023, pp. 163–176, Publisher Copyright: © 2023, The Author(s), under exclusive license to Springer Nature Switzerland AG., ISBN: 978-3-031-28137-2. DOI: 10.1007/978-3-031-28138-9_11.

[3] V. Herdel, L. J. Yamin, and J. R. Cauchard, "Above and beyond: A scoping review of domains and applications for human-drone interaction," in *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*, ser. CHI '22, New York, NY, USA: Association for Computing Machinery, 2022, ISBN: 9781450391573. DOI: 10.1145/3491102.3501881. [Online]. Available: https://doi.org/10.1145/3491102.3501881.

[4] S. Ljungblad, Y. Man, M. A. Baytaş, M. Gamboa, M. Obaid, and M. Fjeld, "What matters in professional drone pilots' practice? an interview study to understand the complexity of their work and inform human-drone interaction research," in *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, ser. CHI '21, <conf-loc> <city>Yokohama</city>, <country>Japan</country>, </conf-loc>: Association for Computing Machinery, 2021, ISBN: 9781450380966. DOI: 10.1145/3411764.3445737. [Online]. Available: https://doi.org/10.1145/3411764.3445737.

[5] K. Thomsen, K. J. Bengtson, and C. L. Nielsen, "Multiview platform: A co-designed user interface for multi-drone systems in biomass monitoring.," p. 14, Jan. 2024.

[6] A. Alsayed, A. Yunusa-Kaltungo, M. K. Quinn, F. Arvin, and M. R. A. Nabawy, "Drone-assisted confined space inspection and stockpile volume estimation," *Remote Sensing*, vol. 13, no. 17, 2021, ISSN: 2072-4292. DOI: 10.3390/rs13173356. [Online]. Available: https://www.mdpi.com/2072-4292/13/17/3356.

[7] JOUAV, *Dronemappingandmining*, https://www.jouav.com/industry/mining-and-aggregates, Accessed: (240515), 2024.

[8] H. J. Hadi, Y. Cao, K. U. Nisa, A. M. Jamil, and Q. Ni, "A comprehensive survey on security, privacy issues and emerging defence technologies for uavs," *Journal of Network and Computer Applications*, vol. 213, p. 103607, 2023, ISSN: 1084-8045. DOI: https://doi.org/10.1016/j.jnca.2023.103607. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1084804523000267.

[9] E. Vattapparamban, Güvenç, A. Yurekli, K. Akkaya, and S. Uluağaç, "Drones for smart cities: Issues in cybersecurity, privacy, and public safety," in *2016 International Wireless Communications and Mobile Computing Conference (IWCMC)*, 2016, pp. 216–221. DOI: 10.1109/IWCMC.2016.7577060.

[10] A. Y. Husodo, G. Jati, N. Alfiany, and W. Jatmiko, "Intruder drone localization based on 2d image and area expansion principle for supporting military defence system," in *2019 IEEE International Conference on Communication, Networks and Satellite (Comnetsat)*, 2019, pp. 35–40. DOI: 10.1109/COMNETSAT.2019.8844103.

[11] deltaquad, *Surveillance drone for security*, https://www.deltaquad.com/vtol-drones-for/security-and-defence/, Accessed: (240515), 2024.

[12] Anduril, *Anduril - anvil*, https://www.anduril.com/hardware/anvil/, Accessed: (240515), 2024.

[13] O. Maghazei, M. A. Lewis, and T. H. Netland, "Emerging technologies and the use case: A multi-year study of drone adoption," *Journal of Operations Management*, vol. 68, no. 6-7, pp. 560–591, 2022. DOI: https://doi.org/10.1002/joom.1196. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/joom.1196. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/joom.1196.

[14] S. J. S. Abderahman Rejeb Karim Rejeb and H. Treiblmaier, "Drones for supply chain management and logistics: A review and research agenda," *International Journal of Logistics Research and Applications*, vol. 26, no. 6, pp. 708–731, 2023. DOI: 10.1080/13675567.2021.1981273. eprint: https://doi.org/10.1080/13675567.2021.1981273. [Online]. Available: https://doi.org/10.1080/13675567.2021.1981273.

[15] R. G. Bhawesh Sah and D. Bani-Hani, "Analysis of barriers to implement drone logistics," *International Journal of Logistics Research and Applications*, vol. 24, no. 6, pp. 531–550, 2021. DOI: 10.1080/13675567.2020.1782862. eprint: https://doi.org/10.1080/13675567.2020.1782862. [Online]. Available: https://doi.org/10.1080/13675567.2020.1782862.

[16] A. Agrawal, S. J. Abraham, B. Burger, *et al.*, "The next generation of human-drone partnerships: Co-designing an emergency response system," in *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ser. CHI '20, New York, NY, USA: Association for Computing Machinery, 2020, 1–13, ISBN: 9781450367080. DOI: 10.1145/3313831.3376825. [Online]. Available: https://doi-org.zorac.aub.aau.dk/10.1145/3313831.3376825.

[17] A. Kolling, K. Sycara, S. Nunnally, and M. Lewis, "Human-swarm interaction: An experimental study of two types of interaction with foraging swarms," *J. Hum.-Robot Interact.*, vol. 2, no. 2, 103–129, 2013. DOI: 10.5898/JHRI.2.2.Kolling. [Online]. Available: https://doi.org/10.5898/JHRI.2.2.Kolling.

[18] R. S. B. Andreh Bassam Bahodi Maria-Theresa Oanh Hoang, "User interface design for uav swarms in search and rescue," 2022, 1–17. [Online]. Available: https://vbn.aau.dk/ws/files/474517368/Master_Thesis.pdf.

[19] M.-T. Oanh Hoang, N. van Berkel, M. Skov, and T. Merritt, "Challenges and requirements in multi-drone interfaces," English, in *CHI EA '23: Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, 2023 ACM CHI Conference on Human Factors in Computing Systems, CHI 23 ; Conference date: 23-04-2023 Through 28-04-2023, United States: Association for Computing Machinery, Apr. 2023, pp. 1–9. DOI: 10.1145/3544549.3585673.

[20] N. van Berkel, O. Ahmad, D. Stoyanov, L. Lovat, and A. Blandford, "Designing visual markers for continuous artificial intelligence support: A colonoscopy case study," English, *ACM Transactions on Computing for Healthcare*, vol. 2, no. 1, pp. 1–24, 2021. DOI: 10.1145/3422156.

[21] C. Bossen, C. Dindler, and O. Iversen, "User gains and pd aims: Assessment from a participatory design project," eng, in *ACM International Conference Proceeding Series*, ACM, 2010, pp. 141–150, ISBN: 9781450301312.

[22] S. Bødker and M. Kyng, "Participatory design that matters-facing the big issues," eng,

ACM transactions on computer-human interaction, vol. 25, no. 1, pp. 1–31, 2018, ISSN: 1073-0516.

[23] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, pp. 77–101, Jan. 2006. DOI: 10.1191/1478088706qp063oa.

[24] K. Baxter, C. Courage, and K. Caine, *Understanding your users : a practical guide to user research methods* (Interactive Technologies), eng, Second edition. Amsterdam, Netherlands: Morgan Kaufmann, 2015 - 2015, ISBN: 0-12-800609-9.

[25] K. Holtzblatt and H. Beyer, "13 - storyboards," in *Contextual Design (Second Edition)*, ser. Interactive Technologies, K. Holtzblatt and H. Beyer, Eds., Second Edition, Boston: Morgan Kaufmann, 2017, pp. 315–329, ISBN: 978-0-12-800894-2. DOI: https://doi.org/10.1016/B978-0-12-800894-2.00013-2. [Online]. Available: https://www.sciencedirect.com/science/article/pii/B9780128008942000132.

Appendix A
Study One Miro Interview Content

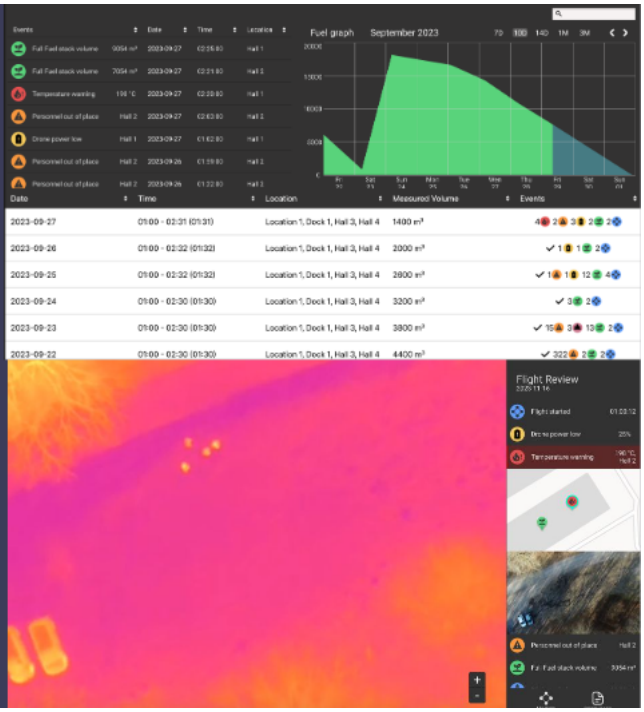
Agenda

1. Intro
2. Prototype ideering
3. Initielle spørgsmål
4. Scenarie walktrough
5. outro

AALBORG UNIVERSITY

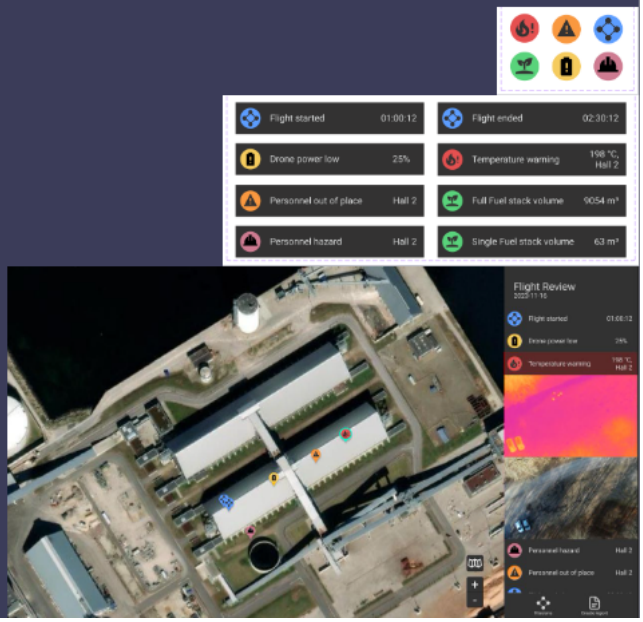
Intro

- Vi har lavet en række prototyper til monitoring af biomass
- Nu vil vi have fokus på monitoring at kraftvarmeværker og andet kritisk infrastruktur
- Undersøgelse af de gængse sikkerhedsscenarier - nutid og fremtid
- Undersøgelse af brugerflade forbedringer til fremtidig brug af droner i monitoring



Prototype ideering
- Event markører

- Undersøgelse af forskellige versioner af event markører
- Deres påvirkning af en operators evne til at finde problemet



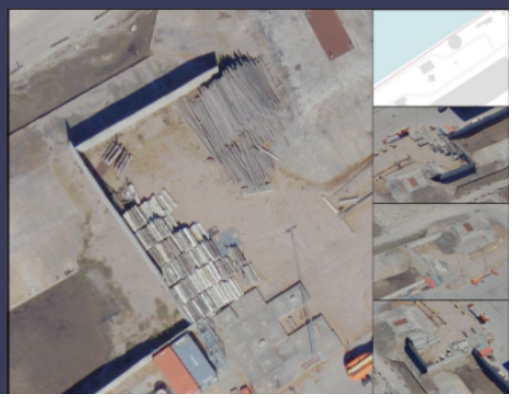
Arbejdsmiljø

- Beskriv dit arbejdsmiljø
- Beskriv det område du overvåger
- Hvilke værktøjer bruger du på arbejdet?

AALBORG UNIVERSITY

Prototype ideering - Drone visuelt framework

- Hvilke informationer skal være til stede
- Hvilke handlinger skal være tilgængelige
- Hvordan vil brugeren tro de kan bruge systemet



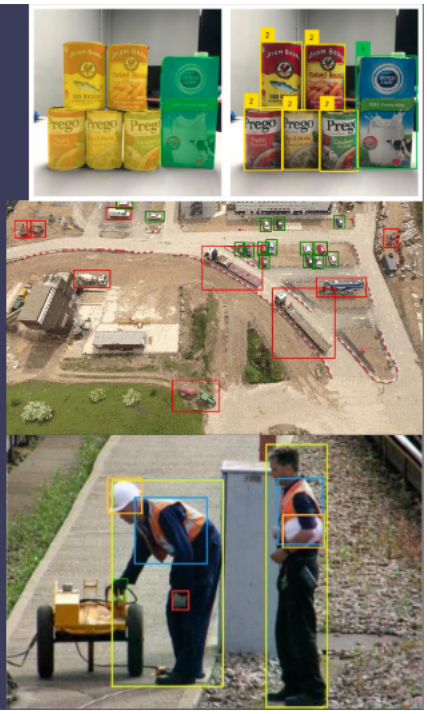
Dagligdag

- Beskriv dine daglige opgaver
- Hvilke opgaver kan blive gjort samtidig med andre opgaver?
- Beskriv handover processen
- Hvilke regler og regulativer, relateret til overvågning skal i overholde?(Rapporter til Beredskabsstyrelsen,rapporter til politiet, etc?)

AALBORG UNIVERSITY

Prototype ideering: Bounding boxes

- Eksempel undersøgelse af bounding boxes
- Segmentering, boks eller markør
- Farvervalg
- Hvad er mest intuitivt



Automatisering

- Hvad er din mening om brugen af automatiserede systemer til overvågning?
- Hvad er din mening om brugen af kunstig intelligens til overvågning?
- Hvad er din mening om brugen af droner til overvågning?

AALBORG UNIVERSITY

Scenarie: Person uden hjelm - Nuværende løsning

Intro

I denne situation er en person blevet spottet uden hjelm

Task prompt

Step 1: Beskriv hvilke opgaver du har i denne situation
Step 2: Træk de enkelte post-it notes til det relevante billede
Step 3: Lav eventuelt manglende post-it notes

Problem detektion

Hvordan bliver det opdaget?

Hvor stor er sikkerhedsrisikoen?

Hvor ofte sker det?

- En hvilket somehelst medarbejder kan opdage situationen
- Runderingsvagten spotter problemet
- CCTV systemet detektere automatisk problemet
- Kontrolvagten spotter problemet
- Kontrolvagten modtager en alarm
- Situationen ignoreres
- Vurderet til et kritisk problem
- Antaget som en potentielt indtrængende som standard

Videregivelse af oplysninger

Hvem bliver kontaktet?

Hvem overtager opgaven?

Hvordan bliver incidentet opsporet?

- Den enkelte medarbejder bliver kontaktet
- Medarbejders kontaktperson vil blive kontaktet
- Medarbejderens leder bliver kontaktet
- Kontrolvagten udsender en sikkerhedsvagt
- Flere kontrolvagter overvåger situationen
- Problemets lokalitet bliver delt
- Sikkerheds vagternes leder bliver kontaktet

Problemet løses

Hvordan bliver problemet løst?

- Personen bliver escorteret af grunden eller til en låsehjelm
- Sikkerhedsvagten har en hjelm med
- Personen bliver givet en advarsel
- Sikkerhedsvagten sørger for at få personens information
- Sikkerhedsvagten sender personen direkte væk
- Medarbejderen sørger selv for at få en hjelm på
- Politiet involveres
- Hændelsen skrives i en rapport
- Hændelsen logges

Scenarie: Person uden hjelm - Drone fremtid

Intro

I denne del undersøger vi hvordan en person der bliver spottet uden hjelm kunne løses i fremtiden med støtte fra droner

Task prompt

Step 1: Beskriv ideer til hvordan man fremadrettet kunne bruge droner til at håndtere de opgaver der er i denne situation
Step 2: Træk de enkelte post-it notes til det relevante billede
Step 3: Lav eventuelt manglende post-it notes

Problem detektion

System detektere automatisk en person uden hjelm

Hvordan kunne det blive opdaget?

Hvilke typer kameraer/sensorer kunne være brugbare?

Kontrolvagten modtager en alarm

Dronen afspiller en lyd

Videregivelse af oplysninger

Droner følger situationen

Systemet selv videregiver informationen til kontroltårnet

Hvem/hvad kunne overtage opgaven?

Hvordan kunne incidentet blive opsporet?

Hvad har operatoren brug for at vide?

Problemets lokalitet videregives

Kontrolvagten udsender en sikkerhedsvagt

Lokationen af hændelsen bliver opdateret på et kort

Flere kontrolvagter overvåger situationen

Problemet løses

Hændelsen logges

Hvordan kunne problemet blive løst?

Hvordan kunne den nuværende løsning blive assisteret eller erstattet af en eller flere droner?

Hvilke værktøjer kunne ellers assistere løsningen?

Kontrolvagten fortsætter med at overvåge situationen

Systemet overvåger fortsat situationen

Systemet giver en alert når situationen er løst

Dronen afspiller en lyd

Systemet skriver incidentet i en rapport

Scenarie: Person set i vandet nær forbudt område - Nuværende løsninger

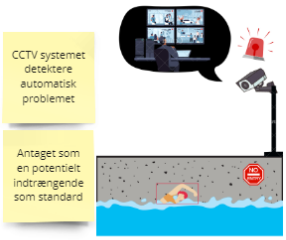
Intro

I denne situation er en person blevet spottet svømmende i eller tæt ved forbudt område

Task prompt

Step 1: Beskriv hvilke opgaver du har i denne situation
Step 2: Træk de enkelte post-it notes til det relevante billede
Step 3: Lav eventuelt manglende post-it notes

Problem detektion



Hvordan bliver det opdaget?

Hvor stor er sikkerhedsrisikoen?

Hvor ofte sker det?

Sikkerhedsvagten spotter problemet

Kontrolvagten spotter problemet

Situationen ignoreres

Vurderet til et kritisk problem

Videregivelse af oplysninger

Driftsmedhjælper eller udemesteren bliver kontaktet 0

Teamlederen kan være nødt til selv at udsendes

Hvem bliver kontaktet?

Hvem overtager opgaven?

Hvordan bliver incidentet opsporet?

Den enkelte medarbejder bliver kontaktet

Medarbejderens leder bliver kontaktet

Kontrolvagten udsender en sikkerhedsvagt

Flere kontrolvagter overvåger situationen

Problemets lokalitet bliver delt

Sikkerheds vagternes leder bliver kontaktet

Problemet løses

Hvordan bliver problemet løst?

Hændelsen logges

Personen bliver escorteret af grunden

Kun meget kritiske situationer Politiet involveres

Sikkerhedsvagten sørger for at få personens information

Sikkerhedsvagten sender personen direkte væk

Hændelsen skrives i en rapport

Personen bliver givet en advarsel

Scenarie: Person set i vandet nær forbudt område - Drone fremtid

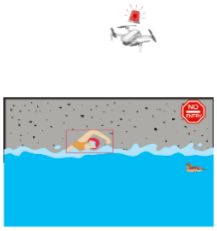
Intro

I denne del undersøger vi hvordan en person der er blevet spottet svømmende i eller tæt ved forbudt område kunne løses i fremtiden med støtte fra droner

Task prompt

Step 1: Beskriv ideer til hvordan man fremadrettet kunne bruge droner til at håndtere de opgaver der er i denne situation
Step 2: Træk de enkelte post-it notes til det relevante billede
Step 3: Lav eventuelt manglende post-it notes

Problem detektion



Mere fleksibelt CCTV

Automatisk overvågning

Hvordan kunne det blive opdaget?

Kontrolvagten ser en person uden hjelm igennem Drone

System detektere automatisk en person uden hjelm

Kontrolvagten modtager en alarm

Videregivelse af oplysninger

CCTV kunne selv sende dronen til videre overvågning

Hvem/hvad kunne overtage opgaven?

Hvordan kunne incidentet blive opsporet?

Systemet selv videregiver informationen

Dronen følger situationen

Dronen afspiller en lyd

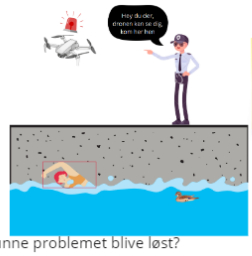
Lokationen af hændelsen bliver opdateret på et kort

Giver information om personen lokalitet videre

Kontrolvagten udsender en sikkerhedsvagt

Flere kontrolvagter overvåger situationen

Problemet løses



Vagtchefen kan kommunikere med indtrængende igennem dronen

Dronen kan flge indtrængende

Hvordan kunne problemet blive løst?

Hvordan kunne den nuværende løsning blive assisteret eller erstattet af en eller flere droner?

Hvilke værktøjer kunne ellers assistere løsningen?

Systemet skriver incidentet i en rapport

Systemet overvåger fortsat situationen

Kontrolvagten fortsætter med at overvåge situationen

Systemet giver en alert når situationen er løst

Hændelsen logges

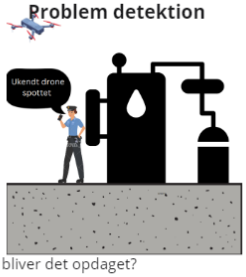
Scenarie: Drone tager billeder af kritisk infrastruktur - Nuværende løsninger

Intro

I denne situation er en person ved at tage billeder af kritisk infrastruktur

Task prompt
Step 1: Beskriv hvilke opgaver du har i denne situation
Step 2: Træk de enkelte post-it notes til det relevante billede
Step 3: Lav eventuelt manglende post-it notes

Problem detektion



Hvordan bliver det opdaget?

Hvor stor er sikkerhedsrisikoen?

Hvor ofte sker det?

Sikkerhedsvagten spotter problemet

CCTV systemet detektere automatisk problemet

Kontrolvagten spotter problemet

Kontrolvagten modtager en alarm

Situationen ignoreres

Vurderet til et kritisk problem

Antaget som en potentielt indtrængende som standard

Videregivelse af oplysninger

Hvem bliver kontaktet?

Hvem overtager opgaven?

Hvordan bliver incidentet opsporet?

Den enkelte medarbejder bliver kontaktet

Medarbejderens leder bliver kontaktet

Kontrolvagten udsender en sikkerhedsvagt

Flere kontrolvagter overvåger situationen

Problemets lokalitet bliver delt

Sikkerheds vagternes leder bliver kontaktet

Problemet løses

Hvordan bliver problemet løst?

Sikkerhedsvagten sørger for at få personens information

Sikkerhedsvagten sender personen direkte væk

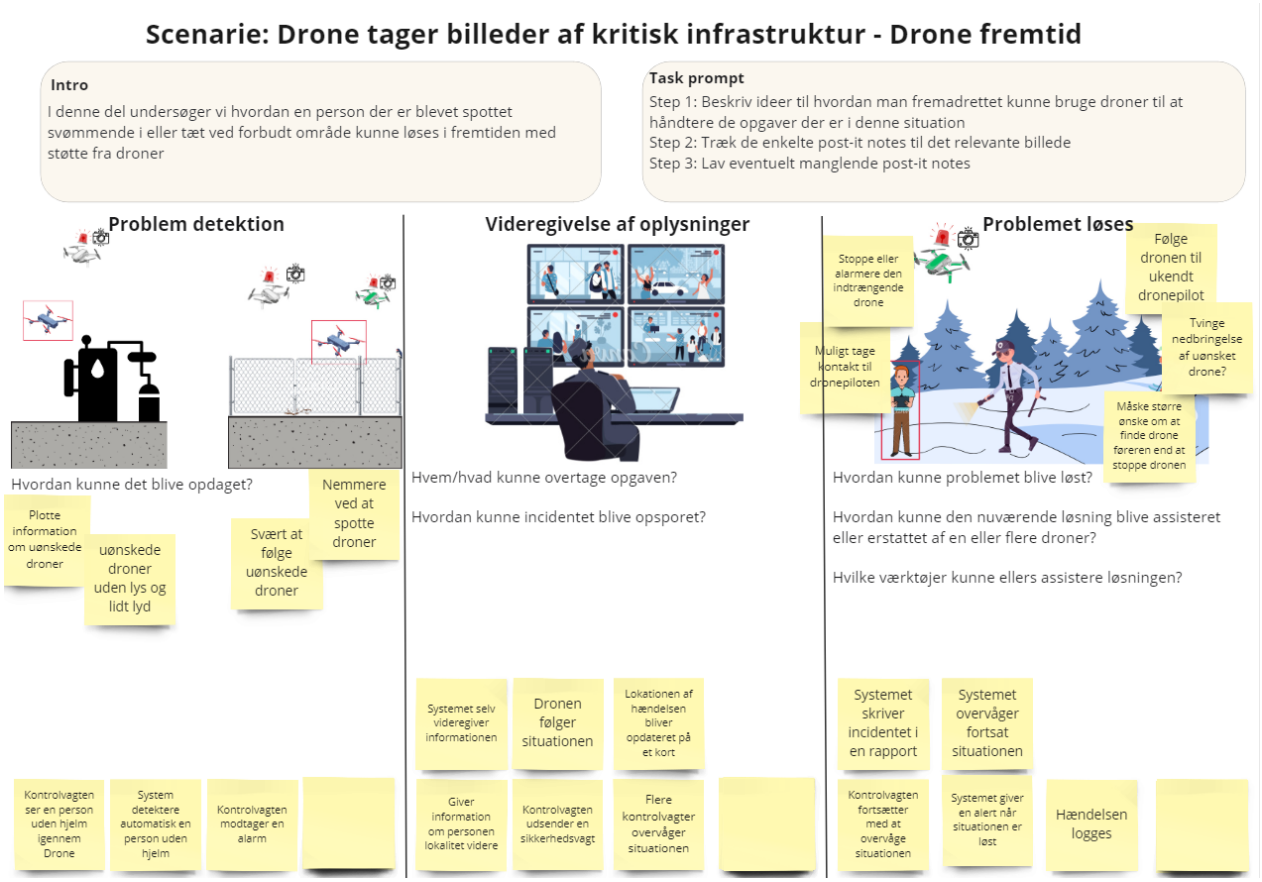
Personen bliver escorteret af grunden

Personen bliver givet en advarsel

Politiet involveres

Hændelsen skrives i en rapport

Hændelsen logges



Appendix B

Study Two Google Analyze Interview Content

Selvstyrende droner på Amagerværket

Dette er en undersøgelse af præferencerne for brugen af autonome droner på Amagerværket med det formål at indsamle viden til udviklingen og potentielle anvendelse af sådanne systemer.
I denne undersøgelse ønsker vi svar på præferencerne til måder man kan interagere med en drone der skal reagere på at systemet eller personalet er blevet alarmeret om en indtrængende på området.

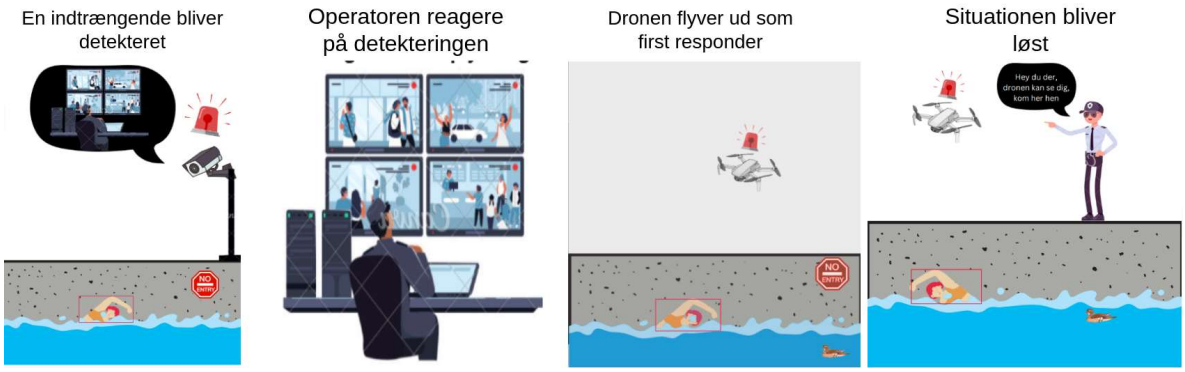
Denne undersøgelse er delt i 4 dele:

1. Automatisk respons med drone
2. Styring af en autonom drone
3. Præsentation af videoer fra en autonom drone
4. Muligheder for tilknyttet ekstra information til drone videoerne

For hver del vil blive præsenteret for opgaven og det brugte scenarie. Efter at have sat dig ind i opgaven skal du se de enkelte videoer og besvare tilknyttede spørgsmål. Dette efterfølges af et diskussions segment med enkelte spørgsmål herunder en åben brainstorm af potentielle forbedringer til designet og funktionaliteten af systemet. Derefter videre til næste del af undersøgelsen.

* Spørgsmålet er obligatorisk

Det antagede scenarie



Video kontekst

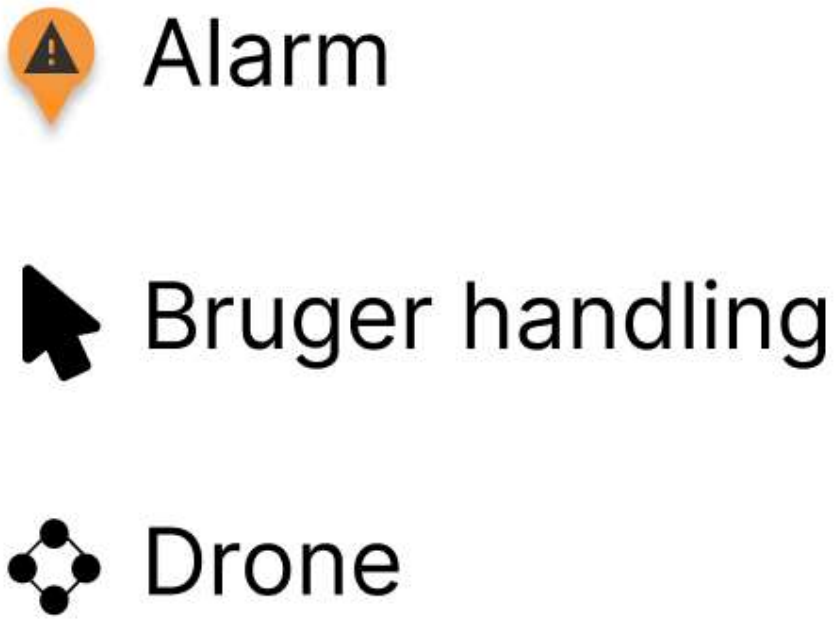
De videoer, vi viser, er forenklede skitser af, hvordan brugeren kan se og interagere med systemet. De er ikke endelige designs, men blot brugt som grundlag for dette studie. Vi har forberedt interaktionerne på forhånd, og din opgave er at se om de svarer til hvad du ville forvente at gøre. Vi opfordrer dig til at give din ærlige mening om, hvad der fungerer godt, hvad der kan forbedres, og ideer til det endelige system.

For at kontrollere dronen antages der i videoerne, at brugeren har adgang til at interagere med et kort via en tablet, computer eller lignende enhed. Det anvendte kort er en simpel repræsentation af Amagerværket, og for simpelhedens skyld antages det, at dette er det eneste område, der skal overvåges.
Derudover er der 3 vigtige ikoner tilstede på kortene i scenarierne:

1. **Alarm ikonet**: Dette ikon repræsentere den mistænkte lokation af en indtrængende enten givet automatisk af statisk overvågning eller telefonisk fra en medarbejder.
2. **Bruger handlings ikonet:** Dette ikon repræsentere den forestillede interaktion med brugerfladen og er der for at gøre opmærksom på at det er dig som bruger der udfører en handling i systemet.
3. **Drone ikonet:** Dette ikon repræsentere dronens position. I systemet her er det antaget at dronen selv er istand til at lave basal navigation som at udtænke og flyve en rute uden om forhindringer

Kortet og ikonerne kan ses på de følgende to billeder

Kort ikoner



Amagerværket kort

1. Hvad er din alder? *

2. Hvad er dit køn?

3. Hvor mange års erfaring har du med droner, operative processer eller sikkerhed? *

4. Klar til at begynde *

Markér kun ét felt.

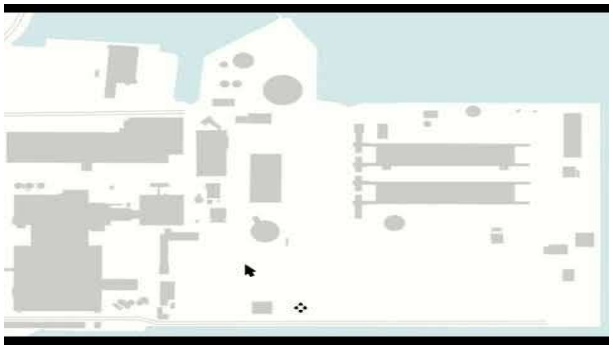
- ◯ Nej
- ◯ Ja

Droner på Amagerværket: Automatisk respons

I denne sektion er en indtrængende blevet detekteret på kræftværket markeret med en alarm på kortet.

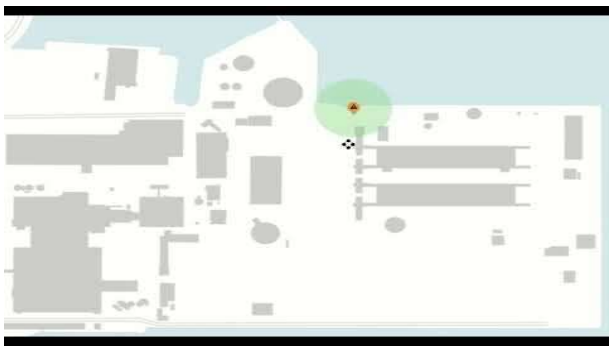
- Din opgave er at observer dronens opførsel i forhold til at skulle filme den indtrængende
- Dronens opgave er automatisk at flyve til alarmen og observere den indtrængende.

Dronen reagerer automatisk - fokuseret



http://youtube.com/watch?v=nB2yF7h2tAE

Dronen reagerer automatisk - cirkulering



http://youtube.com/watch?v=GbeODorWLy4

5. Det er vigtigt at observere området omkring den indtrængende.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

6. Det er ikke nødvendigt at observere indtrængende fra flere vinkler.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

7. Dronen bør flyve hen til området uden at operatøren giver tilladelse.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

8. Dronen bør følge efter det den har opfanget uden operatørens input.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

9. Diskuter: Hvordan mener du den automatiske reaktion fra dronen burde foregå? *

Markér alle, du er enig i.

- [ ] Jeg har diskuteret med interviewer

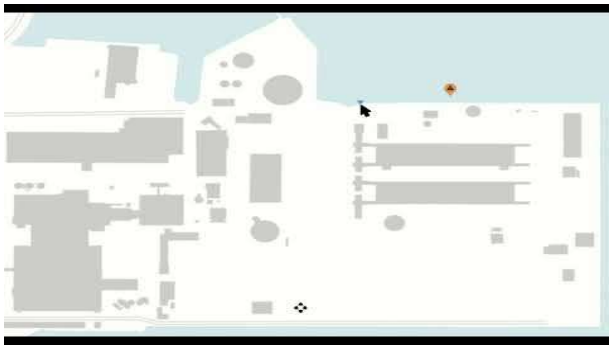
Gå til spørgsmål 10

Droner på Amagerværket: Styring

I denne sektion er en indtrængende blevet detekteret på kræftværket markeret med en alarm på kortet.

- Dronens opgave er at afsøge området omkring den indtrængende efter skader på værket eller andre indtrængende.
- Din opgave er at vurdere de forskellige muligheder brugeren har for at markerer et afsøgningsområde.

Dronen følger markerede pejlemærker sat af en operatør



http://youtube.com/watch?v=lS5R3lcHVM8

10. Dette føles som en intuitiv måde at kontrollere dronen på.

Markér kun ét felt.

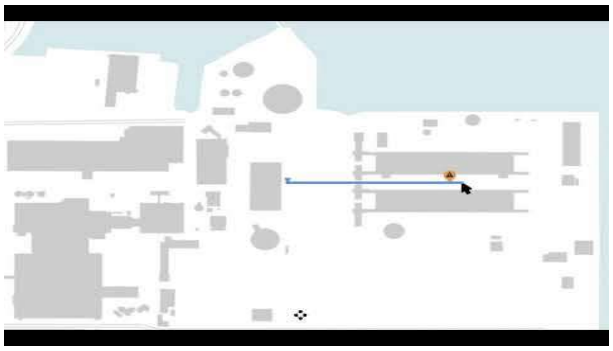
	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

11. Diskution: Hvilke fordele/ulemper kunne der være i at styre dronen ved placering af pejlemærker?

Markér alle, du er enig i.

☐ Jeg har diskuteret med interviewer

Dronen følger en tegnet linje lavet af operatøren



http://youtube.com/watch?v=aco-J4cDaHM

12. Dette føles som en intuitiv måde at kontrollere dronen på.

Markér kun ét felt.

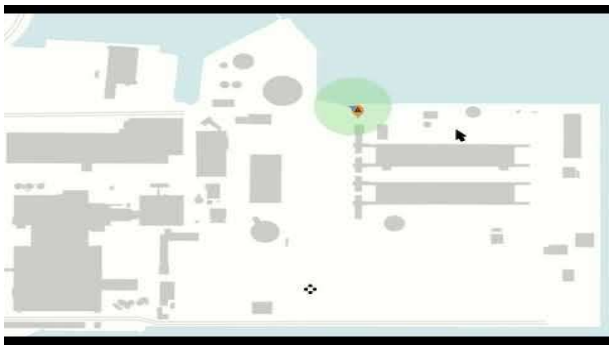
	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

13. Diskuter: Hvilke fordele/ulemper kunne der være i at styre dronen ved at tegne musen/fingeren?

Markér alle, du er enig i.

☐ Jeg har diskuteret med interviewer

Dronen undersøger et cirkulært område med forudbestemt størrelse sat af operatøren



http://youtube.com/watch?v=bc4FFPWuZpg

14. Dette føles som en intuitiv måde at kontrollere dronen på.

Markér kun ét felt.

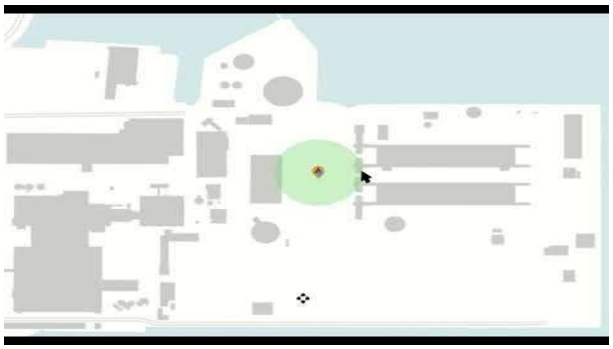
	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

15. Hvilke fordele/ulemper kunne der være i at styre dronen ved at sætte en markør med et markeret område?

Markér alle, du er enig i.

- [ ] Jeg har diskuteret med interviewer

Dronen undersøger et cirkulært område med brugerdefineret størrelse omkring en brugerbestemt lokation



http://youtube.com/watch?v=ITFDRLv003I

16. Dette føles som en intuitiv måde at kontrollere dronen på.

Markér kun ét felt.

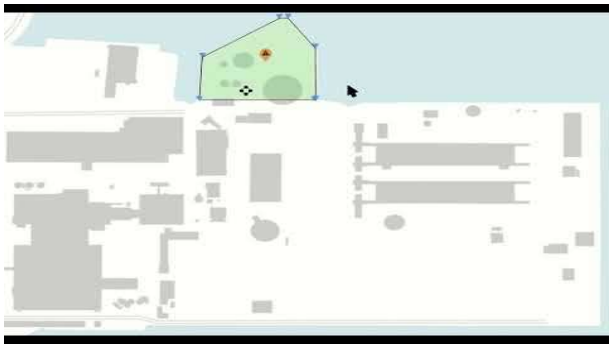
	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

17. Hvilke fordele/ulemper kunne der være i selv at bestemme det markerede områdes størrelse?

Markér alle, du er enig i.

- [ ] Jeg har diskuteret med interviewer

Dronene undersøger et område markeret af brugeren



http://youtube.com/watch?v=DqfaI_9mW3g

18. Dette føles som en intuitiv måde at kontrollere dronen på.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

19. Hvilke fordele/ulemper kunne der være i at markere området med et polygon?

Markér alle, du er enig i.

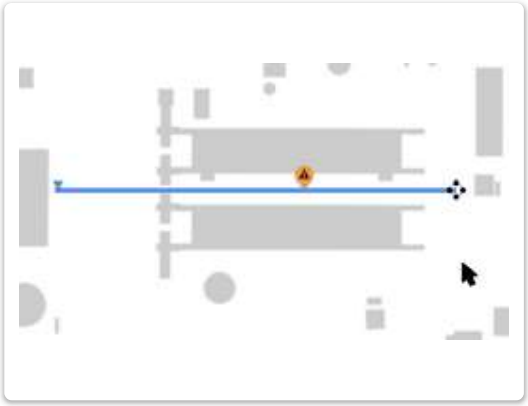
- [ ] Jeg har diskuteret med interviewer

Diskussion af styring af droner på amagerværket

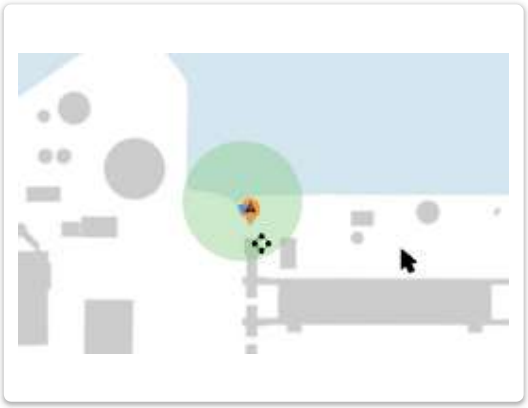
20. Hvilken styrings metode fortrækker du?

Markér kun ét felt.

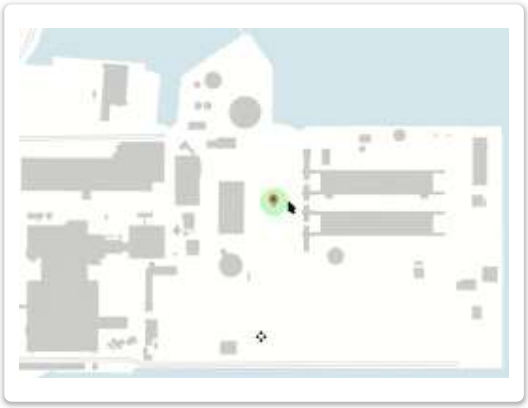
Markerede pejlemærker



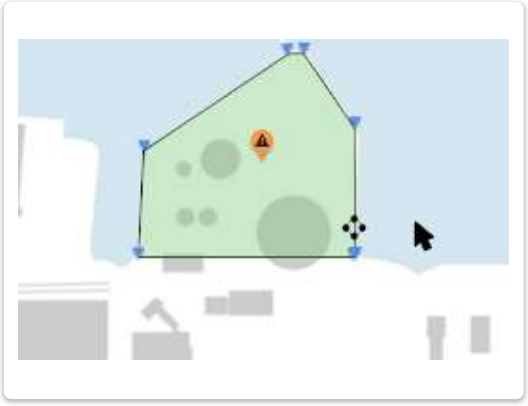
Tegnet linje



Statisk cirkulær område



Dynamisk cirkulær område



Bruger markeret område

21. I hvilke situationer ville det være relevant at dronen dirigeres af en operatør?

Markér alle, du er enig i.

☐ Jeg har diskuteret med interviewer

22. Er det mere relevant at styre området, eller ruten som dronen undersøger?

Markér alle, du er enig i.

☐ Jeg har diskuteret med interviewer

23. Hvis du kunne styre dronen på en hvilken som helst måde, hvordan ville du gerne styre den?

Markér alle, du er enig i.

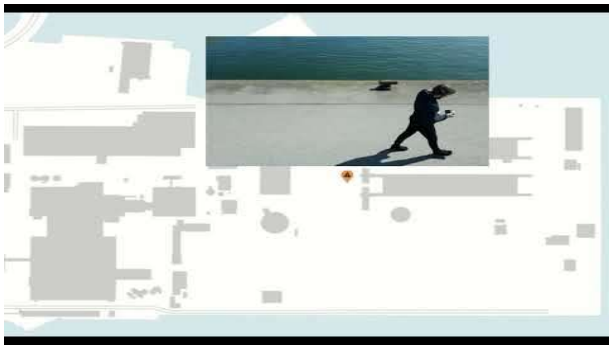
☐ Jeg har diskuteret med interviewer

Droner på Hofor: Video popup

I denne sektion er dronen ankommet og filmer et bestemt område med forbigående på kræftværket.

- En video af et filmet område vises på kortet
- Dronens opgave er at filme et bestemt markeret område med forbigående
- Din opgave er at vurdere visningen af videoen i relation til kortet

Video popup, mellem



http://youtube.com/watch?v=y9X7TjbwggE

24. Jeg kan godt lide hvordan videoen er præsenteret.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Popup, fuld størrelse

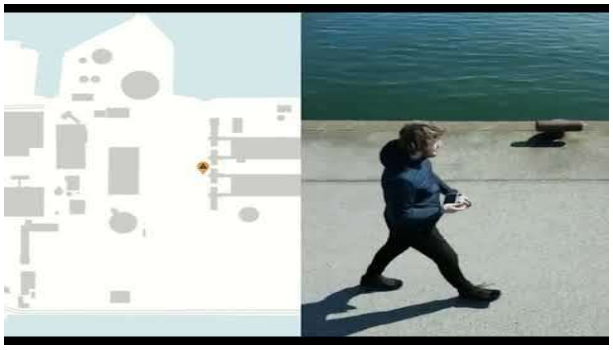
http://youtube.com/watch?v=PEr4odzsLNA

25. Jeg kan godt lide hvordan videon er præsenteret.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Popup split



http://youtube.com/watch?v=4VJ7nuvKdJo

26. Jeg kan godt lide hvordan videon er præsenteret.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Popup med mini map

http://youtube.com/watch?v=dbJOskoMv0c

27. Jeg kan godt lide hvordan videon er præsenteret.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Video popup diskussion

28. Hvilken af de viste muligheder ville du foretrække at arbejde med?

Markér kun ét felt.

◯ Videopopup, mellem

◯ Videopopup, Fuldskærm

◯ Videopopup med split

◯ Videopopup med minimap

29. Hvorfor foretrækker du den mulighed?

Markér alle, du er enig i.

☐ Jeg har diskuteret med interviewer

30. Hvilken af de viste muligheder ville du foretrække ikke at arbejde med?

Markér kun ét felt.

◯ Videopopup, mellem

◯ Videopopup, Fuldskærm

◯ Videopopup med split

◯ Videopopup med minimap

31. Hvorfor foretrækker du ikke den/disse metode?

Markér alle, du er enig i.

☐ Jeg har diskuteret med interviewer

32. Hvilke funktionaliteter kunne være inkluderet i video popupet?

Markér alle, du er enig i.

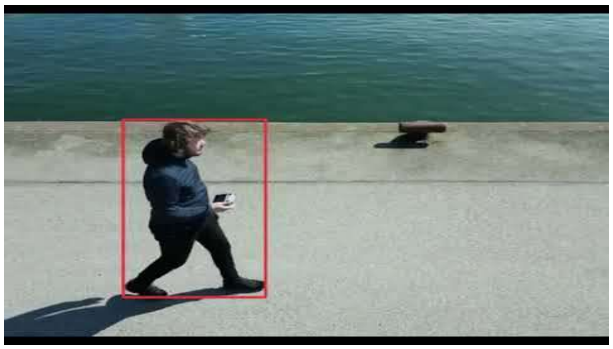
- [ ] Jeg har diskuteret med interviewer

Droner på Hofor: Visuel opdeling

Denne sektion vil vise forskellige metoder at drage opmærksomhed på. Metoderne bruges til at markerer objekter af interesse, såsom personer, flammer, eller droner.

- Dronens opgave er at filme et bestemt område med forbigående
- Din opgave er at se videoerne med de forskellige muligheder for dig at se de markerede personer og efter hver video give din mening omkring de forskellige metoder.
- Farverne der er blevet valgt er vejledende, og bør ikke forstås som endelige.

Boks



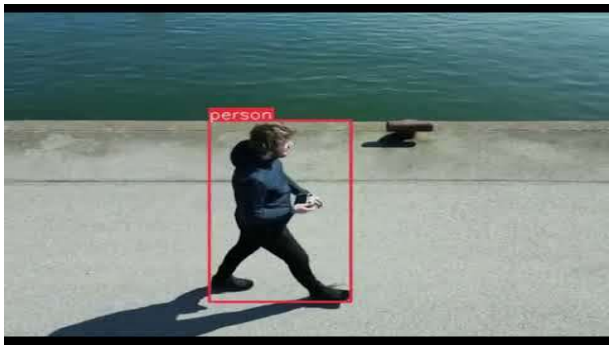
http://youtube.com/watch?v=AeW_Mt-0swY

33. Boksen hjælper med at fokusere min opmærksomhed.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Boks med mærkat



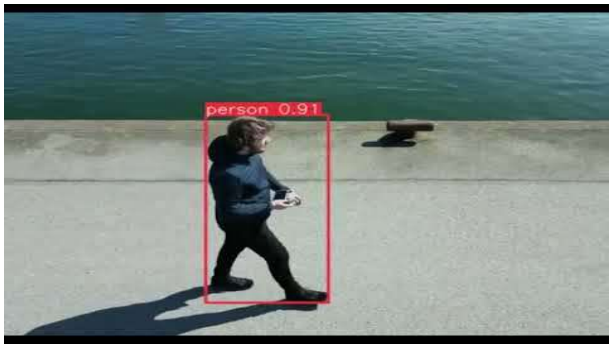
http://youtube.com/watch?v=bvVgDT_Rpno

34. Mærkatet er hjælpsomt for min opgave.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Boks med mærkat og sandsynlighed



http://youtube.com/watch?v=HOEed2__Wrg

35. Sandsynligheden er brugbar for min opgave.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

36. Kombinationen af mærkat og sandsynlighed er brugbar.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Svævende mærkat og sandsynlighed

http://youtube.com/watch?v=tV3HFXn0vmk

37. Fjernelse af boksen hjælper med overblik.

Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

Malet område

http://youtube.com/watch?v=QzuGEnDZ55o

38. Det malede område hjælper med at identificere hvad dronen har spottet.

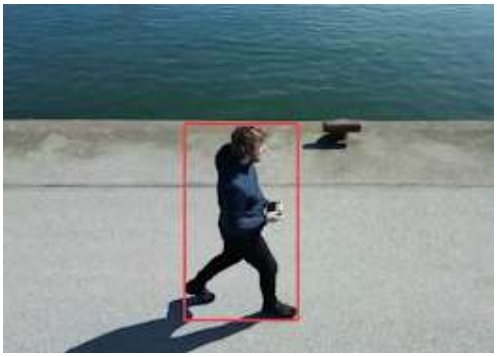
Markér kun ét felt.

	1	2	3	4	5	6	7	
Meg	◯	◯	◯	◯	◯	◯	◯	Meget enig

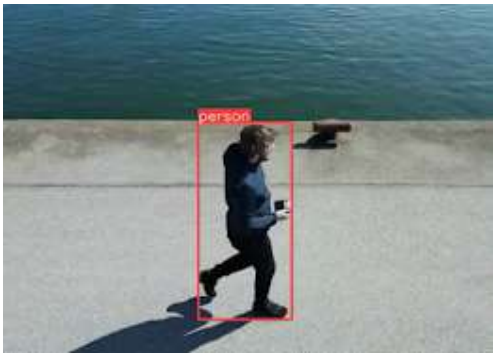
Video segmentering diskussion

39. Hvilken af segmenteringer ville du foretrække at arbejde med?

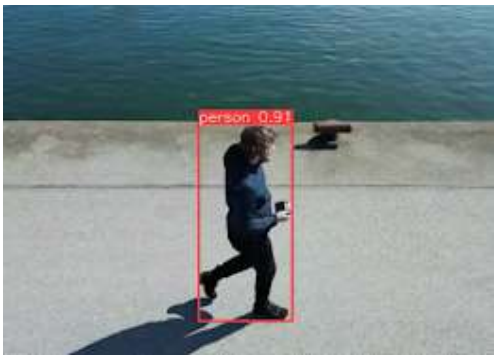
Markér kun ét felt.



Boks



Boks med Mærkat



Boks med Mærkat og Sikkerhed

Mærkat og sikkerhed, uden boks

Malet område

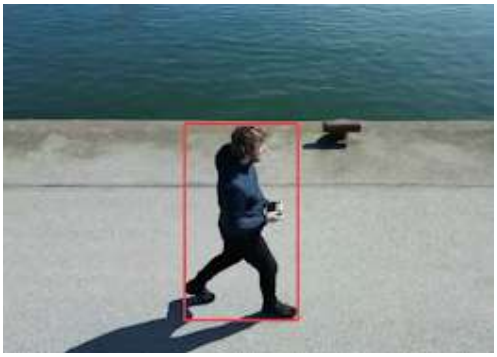
40. Hvorfor ville du foretrække at arbejde med denne?

Markér alle, du er enig i.

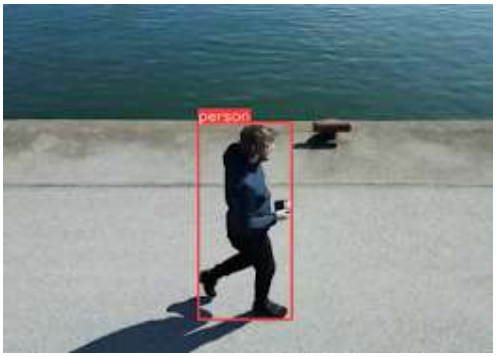
- [ ] Jeg har diskuteret med interviewer

41. Hvilken segmentering ville du foretrække ikke at arbejde med?

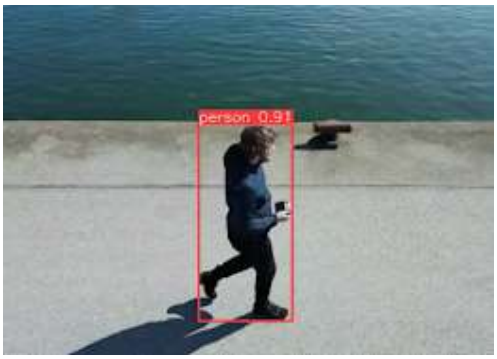
Markér kun ét felt.



Boks



Boks med Mærkat



Boks med Mærkat og Sikkerhed

Mærkat og sikkerhed, uden boks

Malet område

42. Hvorfor ville du foretrække ikke at arbejde med denne? *

Markér alle, du er enig i.

- [ ] Jeg har diskuteret det med interviewer

43. Hvis du skulle arbejde med dette, hvilke funktionaliteter ville du så gerne have implementeret?

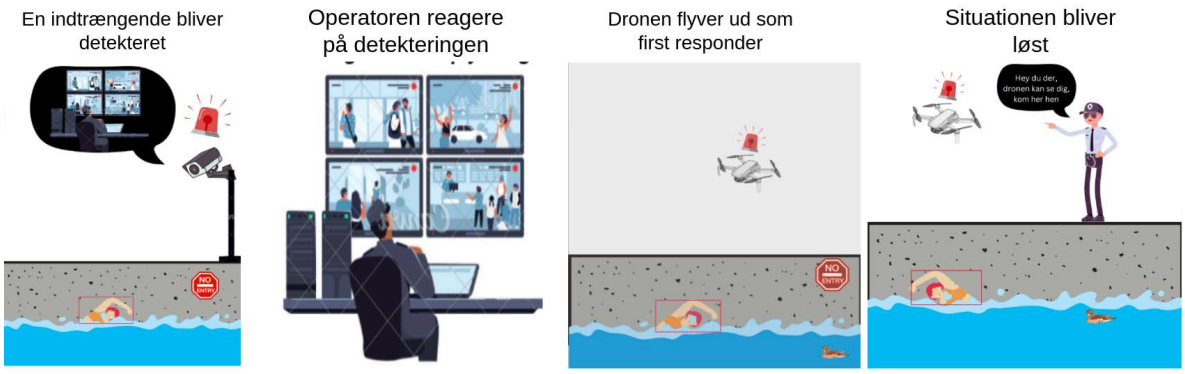
Markér alle, du er enig i.

- [ ] Jeg har diskuteret det med interviewer

Droner på amagerværket: Debriefing

Her til sidst vil vi gerne takke dig for at deltage i denne undersøgelse. Dine svar har været hjælpsomme i at finde ud af hvordan droner bør bruges. Vi har kun et enkelt spørgsmål tilbage inden vi afslutter.

Det antagede scenarie

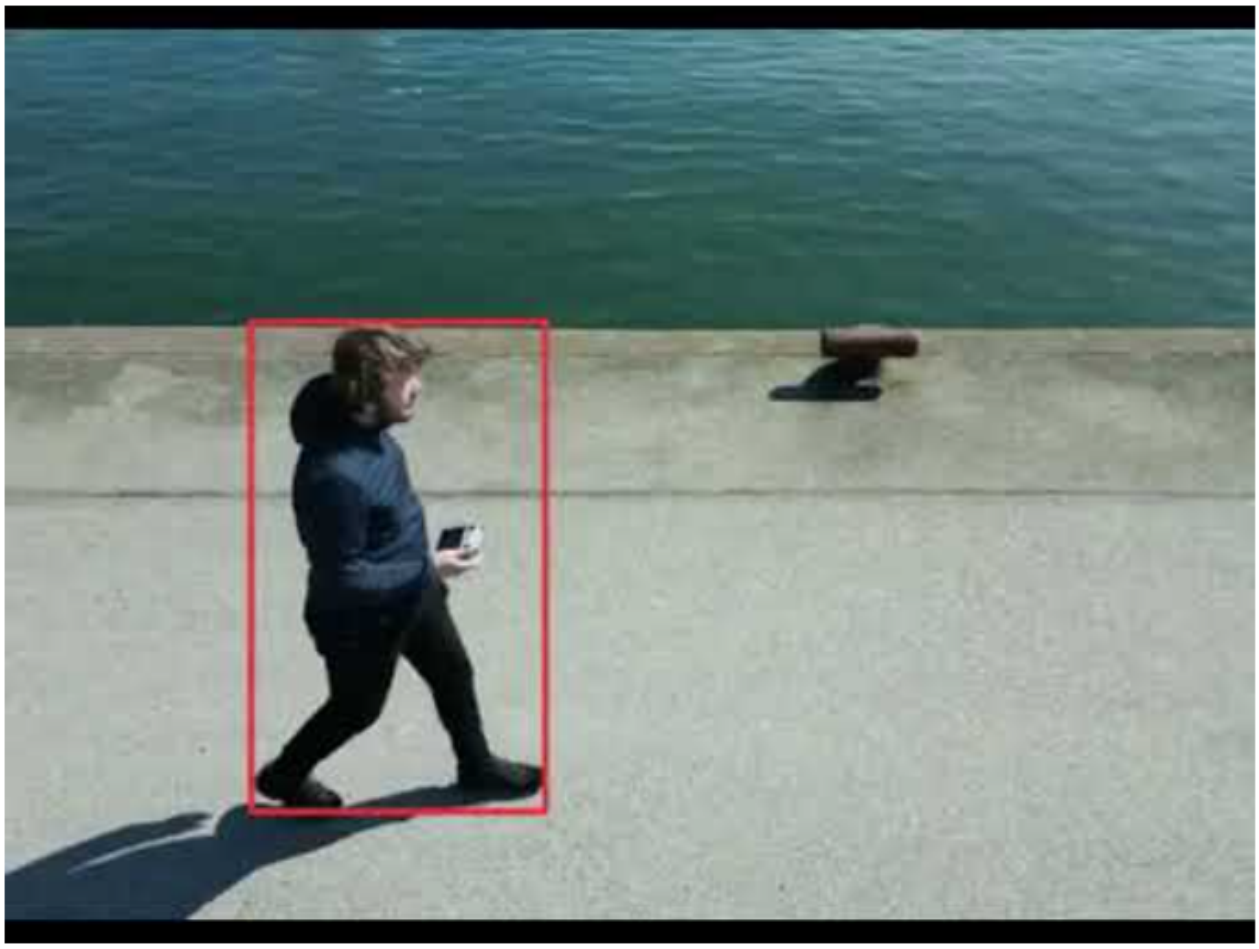


44. Hvis der er noget som du brænder for at sige, lige er kommet i tanke om, eller føler vi har glemt så kan du nævne dem nu. *

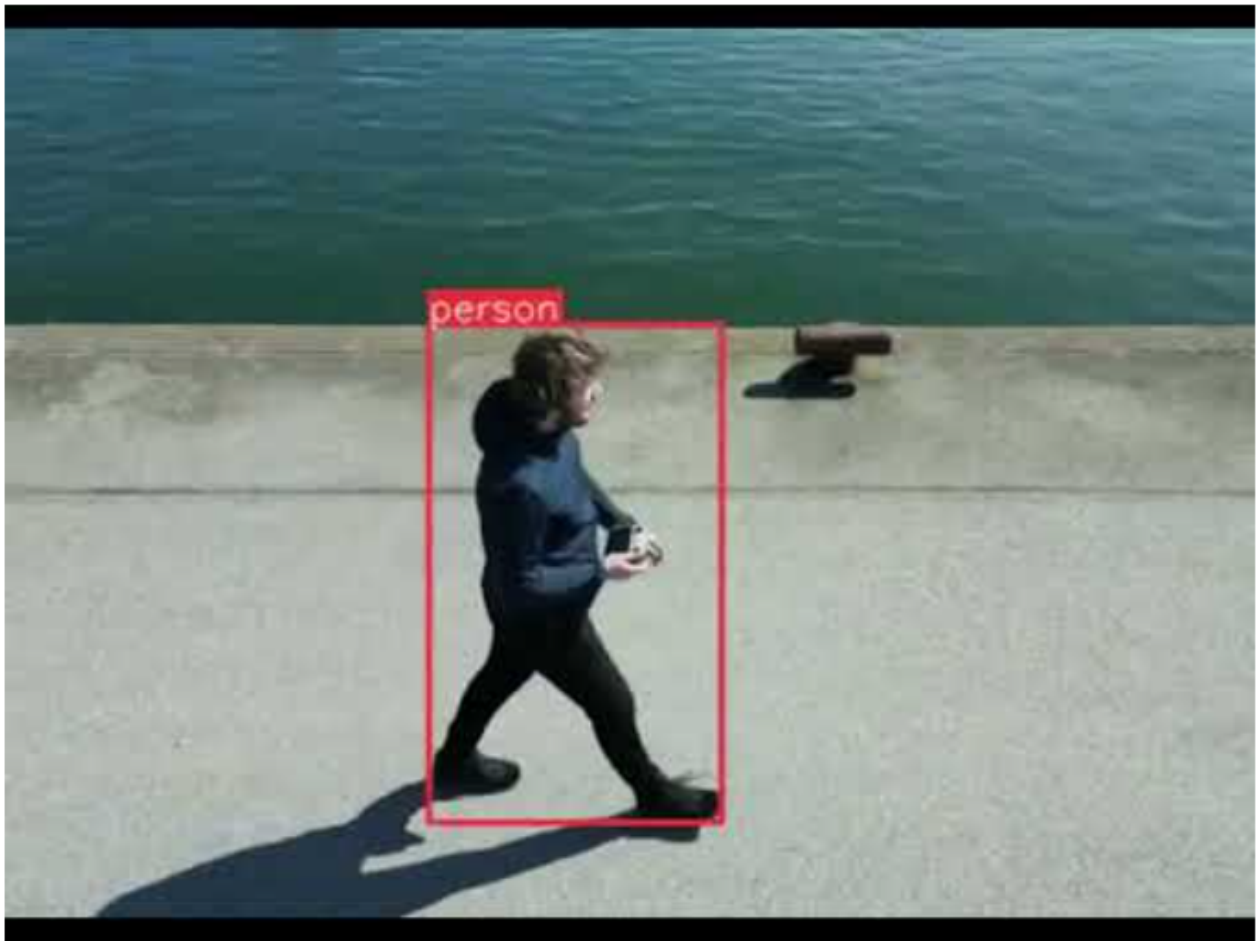
Markér alle, du er enig i.

- [ ] Jeg har sagt alt hvad jeg har brug for.

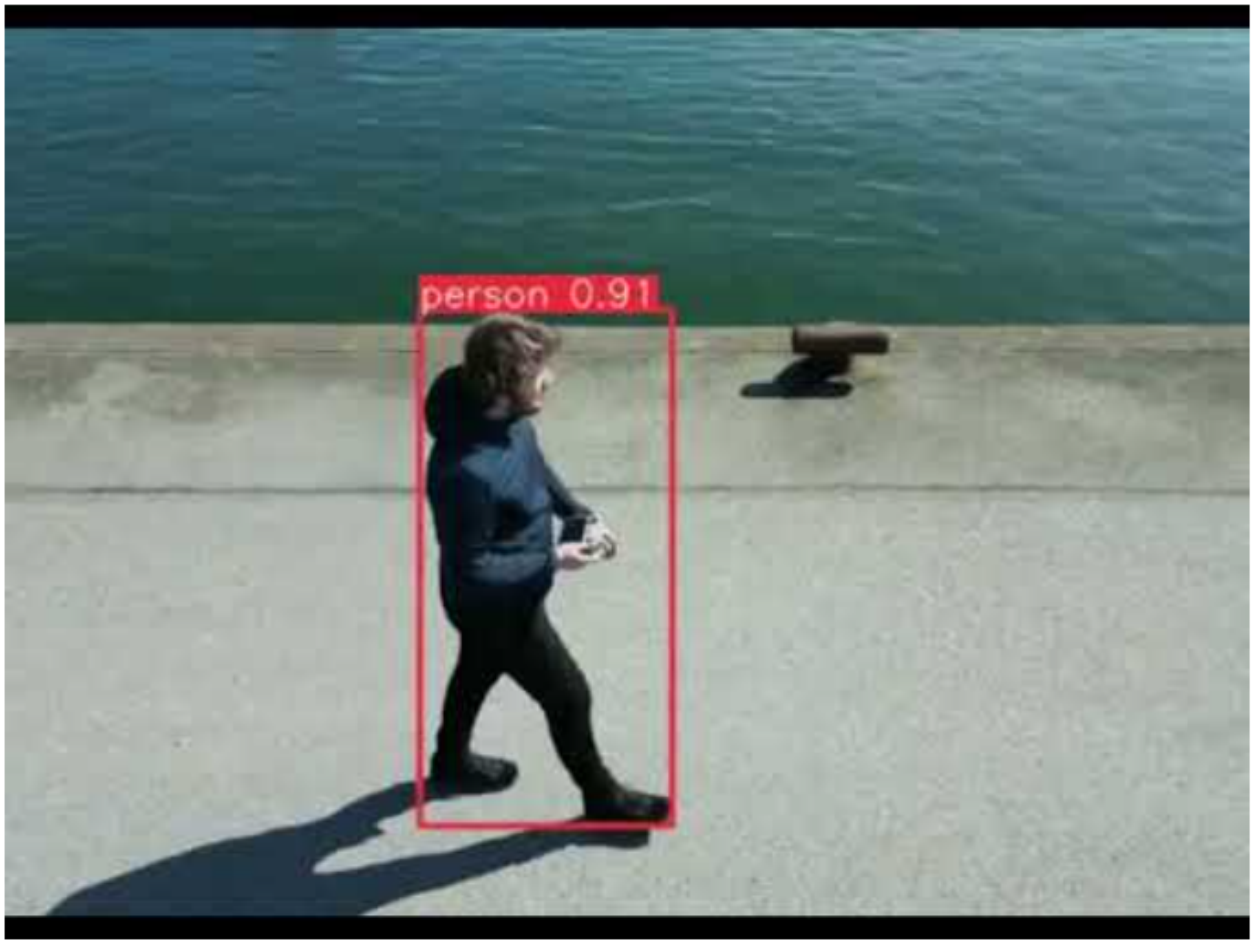
Appendix C
Mockups
Bounding Box
1) Only bounding box



2) Bounding box with label

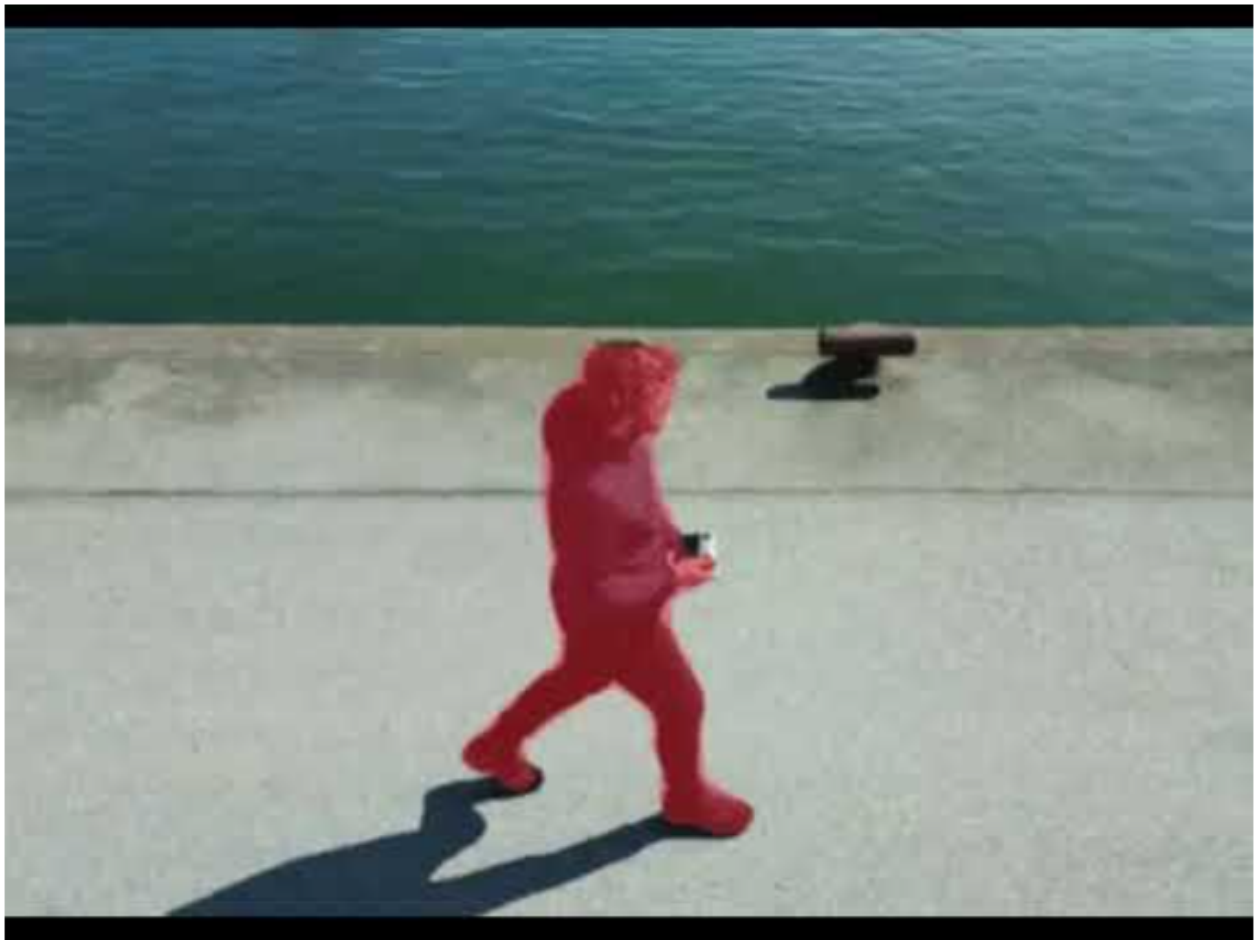


3) Bounding box with labels



4) No bounding box, with labels

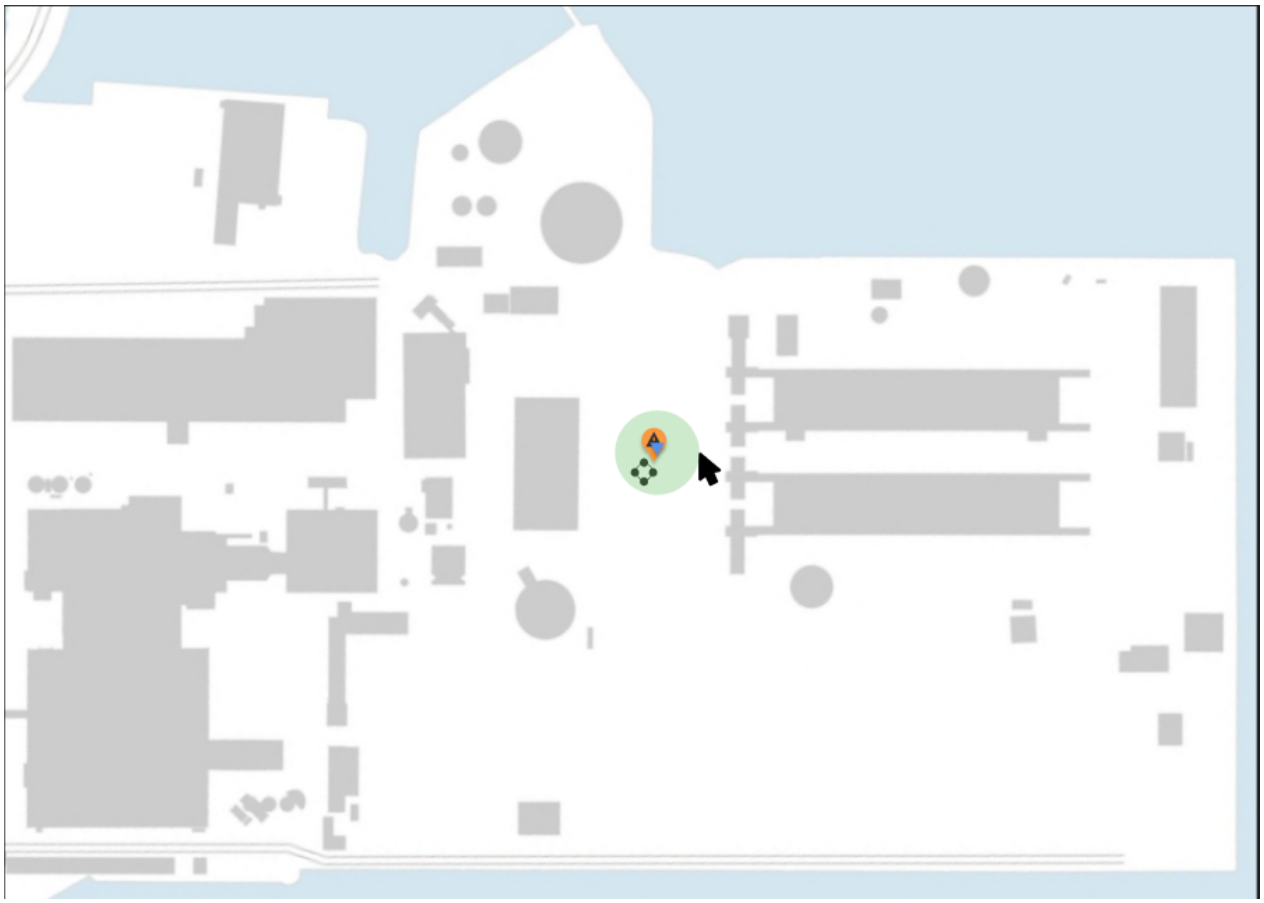
5) Segmented area



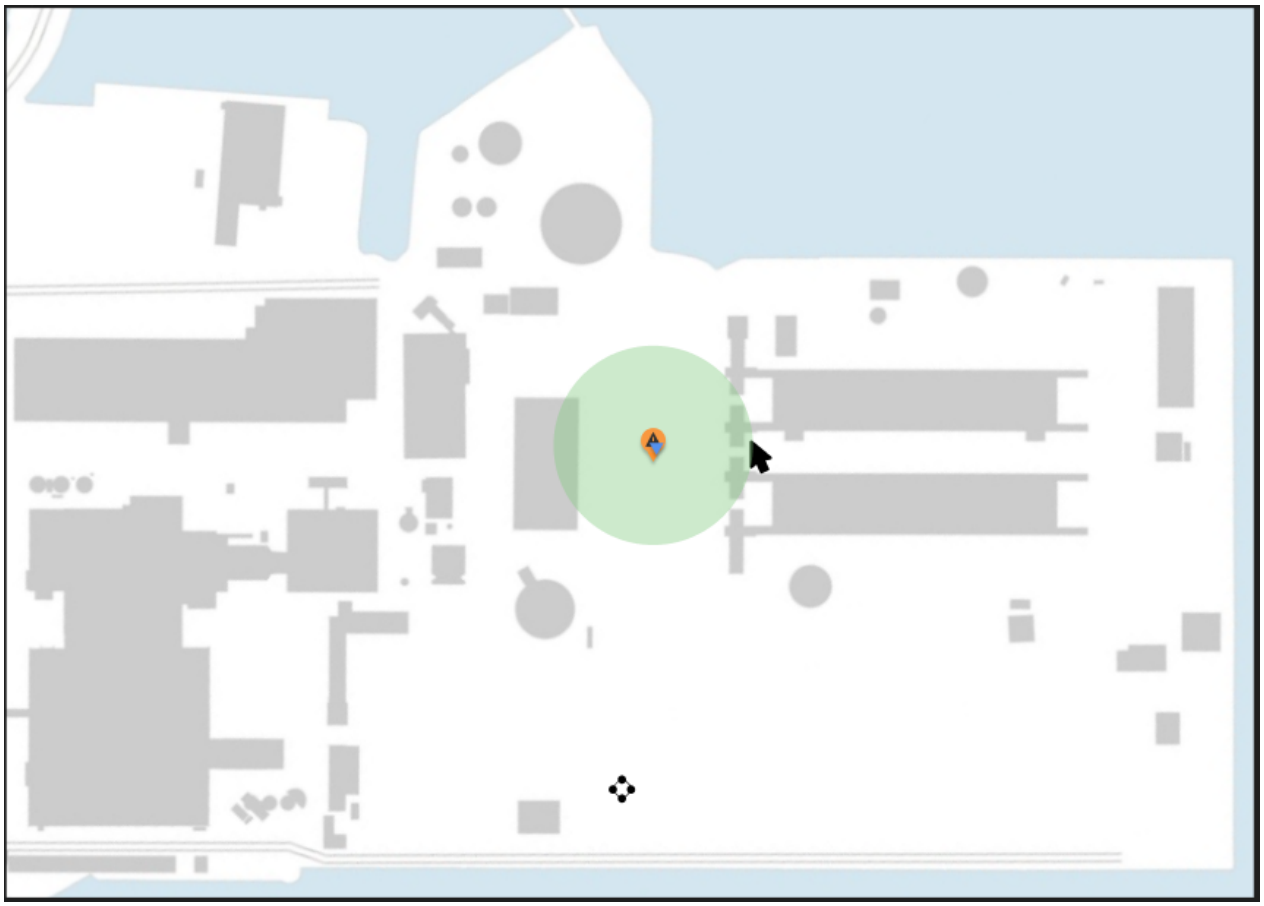
A. Control Methods

1) Multiple waypoints

2) Beacon with static area



3) Beacon with user defined are



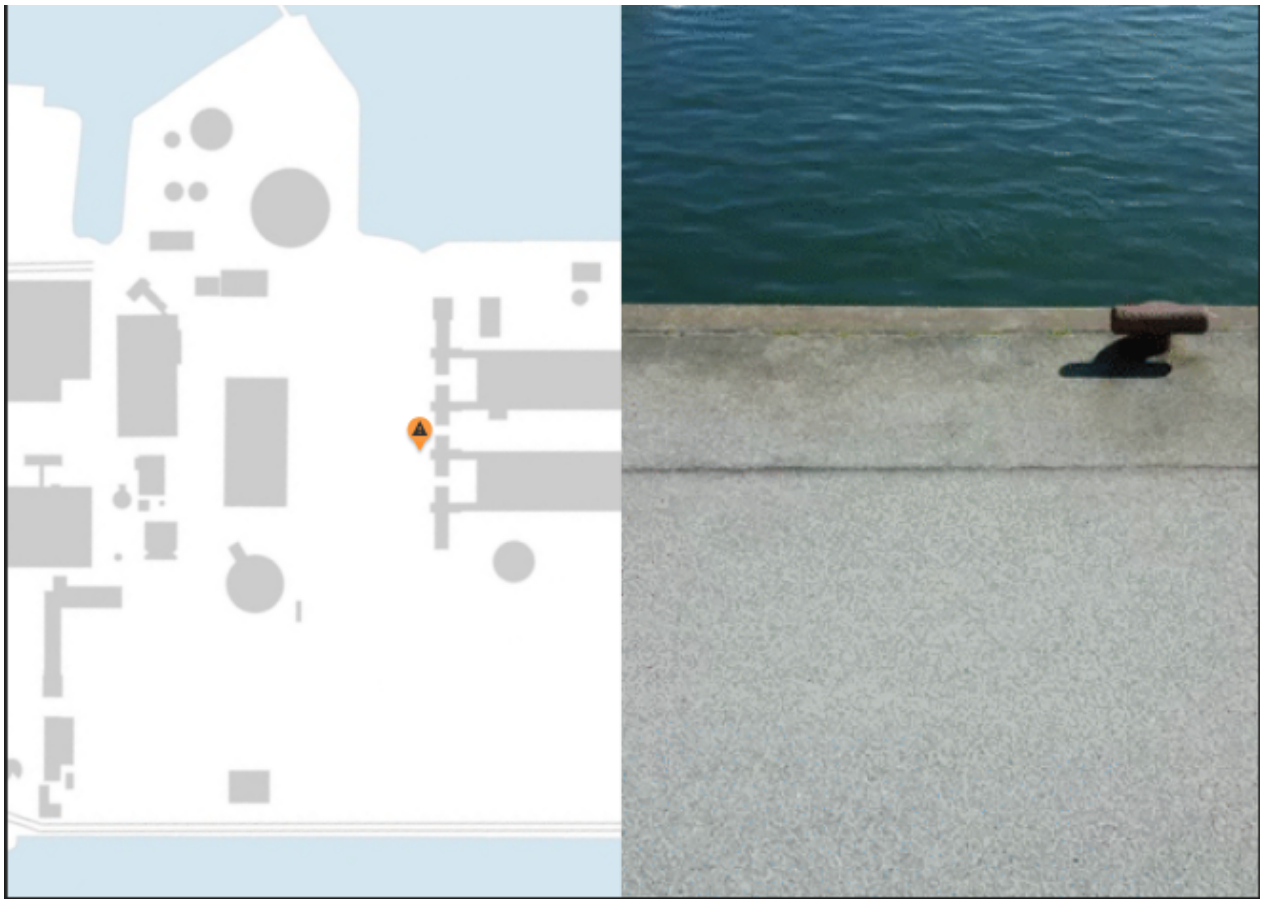
4) Polygon

B. Video popups

1) Videopopup medium

2) Videopopup Full

3) Videopopup Split



4) Videopopup Minimap