Multiview Platform

A co-designed user interface for multi-drone systems in biomass monitoring

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Abstract

Drones are finding usage in an increasing number of fields, including search and rescue, entertainment, monitoring, and more. Additionally, there has been a move away from single drone systems to multi drone systems, in which a swarm of drones is utilized. These multi drone systems face new design challenges, such as balancing automation and human control, as well as trying to answer how to present the data gathered by the drones. The goal of this paper is to utilize the design process of co-design to create an artifact that can help inform such design decisions. The context used in this paper is the monitoring of a biomass power plant, in which the drones are tasked with providing imaging of the biomass and the plant. Stakeholders were utilized to help understand the problem from a practical point, as well as provide a knowledge base to work from. This paper has resulted in an artifact and the detailed process of its creation.

Contents

I. Introduction

Unmanned aerial vehicles also known as drones are increasingly being employed in a greater quantity. Not only as entertainment but also across different industries, and are in general prevalent enough to have dedicated drone laws, and pilot certifications. Companies, like Amazon, have begun using drones to deliver small packages, and others are using drones to get geographical data[1].

The range of applications of drones is grand and covers anything from monitoring, and searching to transportation, communication, and videography. Using drones can help solve a large field of problems but comes with their own challenges. One set of challenges and a big field of research is the human-drone interaction(HDI) but the current research lacks validity and should be explored through industrial application. [2]

In addition to this, there has been a move from the traditional one-to-one relationship between operator and drone, to using drone swarms. This increase in the amount of drones has created a new set of design challenges. The greater number of drones results in more information being sent back to the operator, causing potential critical information to be missed[3]. In addition, there are not any established guidelines for designing user interfaces for this context, as the field is still fairly new[4].

Robotto is a company developing a multi drone system to solve a variety of task including search and rescue, firefighting and wildlife preservation. They are an AI company using their technology to provide drone autonomy to tasks, thereby reducing the human interaction needed to operate the system. As it is autonomous, it is not the actual flight data which is important but the enhanced result. This drone data will be enhanced with AI output and non-standard sensor data which requires the development of new multi-modal tools. In order to limit the scope of the project, we chose Robotto as a single set of stakeholders for their domain knowledge in the industrial application of drones and their work with different users.[5]

II. Related Works

Our related work focuses on the applications relevant for understanding interfaces for drones and the theories that could be applied to design such interfaces.

Problems with multiple screens

Research regarding CCTV operators found the very nature of CCTV control centers can leave operators vulnerable to cognitive failures during proactive security surveillance. Typically, a single operator is responsible for a large number of screens displayed on a media wall. Cognitive and perceptual overload is likely when the number of CCTV cameras to be monitored exceeds the available screen space, meaning that operators need to switch between camera feeds at regular intervals rather than having all viewpoints available at any one time. This susceptibility is compounded by the dynamic nature of the task, the use of long shifts or unsociable hours, and visual or auditory distractions and interruptions.[6]

Applications designed for drones

Numerous companies have implemented a variety of technologies across a wide range of industries. This includes energy, defense, telecommunications and mining, where they have utilized the last decade of research in machine learning to create technology able to identify and track objects, 3D map and do volumetric scanning. This has brought with them a wave of interfaces for interacting with a drone, either to plan or review a mission. A consistent design choice in mission planner interfaces is the ability to map routes via way-points, area of interest and object of interest. Interfaces for review tools mostly consists of a map displaying the route of the drone and contains enhanced metrics, like converting power usage to a graph.[7]–[9]

Human-Centered Artificial Intelligence

The Human-Centered Artificial Intelligence (HCAI) framework, proposed by Ben Shneiderman, urges a change in how we think of autonomy. Contrary to the misconception that increased automation reduces user control, the decoupling of these concepts introduces a two-dimensional HCAI framework. This framework present the possibility of achieving both high levels of human control and high levels of computer automation. Human control, especially in settings like cars, aircraft, or power station control centers, may cognitive effort over extended periods, but human attention can fluctuate, necessitating alerts to focus on emerging issues. Excessive human control carries the risk of fatal errors. Complex control panels can confuse users, leading to uncertainty. Therefore, finding a balance between automation and human control is crucial for designing systems that optimize safety, reliability, and trustworthiness.[10]

Information Overload

The definition of Information Overload, has not been set in stone. In this paper the definition used will be the one found by Belabbes et. al. which defines information overload as:

> "A negative psychological state in which individuals feel that they are receiving too much information, which hinders their ability to carry out their tasks."

There are several factors that work together to cause information overload. These are the working environment, and brain ability and cognition. Additionally, there are three factors influencing interface design, which are poorly defined information needs, intrinsic and extrinsic information characteristics, and the information environment. Poorly defined information needs is when users are not certain what information they are looking for, making it difficult to filter information. Intrinsic information characteristics are characteristics that are inherent to information, the quality of the information can both increase or decrease the risk of information overloading. Extrinsic information characteristics are external factors, these can be the quantity of information, and the speed at which it is represented. Especially the quantity of information presented can cause information overload[11]. The information environment refers to how and where information is viewed. The information environment is the design and tools of the interface to display and filter information. [12]

Co-design approaches to drone solutions

One of the approaches used to solve some of the interaction challenges in this context is the use of research trough design. The research paper "Chasing Lions: Co-Designing Human-Drone Interaction in Sub-Saharan Africa" uses co-design in order to establish the context of their problem area and validate the need for a participatory approach when designing for drone solutions.[13] The paper "The Next Generation of Human-Drone Partnerships: Co-Designing an Emergency Response System" uses co-design in order to create a design for an interaction with drones within a specific context and concludes that the participatory design provided a solid foundation for the design of the system and established a shared vision between developers and stakeholders for moving the project forward.[14]

III. Research Problem

To develop a user interface facilitating the use of a multi-drone system, we will engage in a collaborative design process with Robotto. The objective is to conduct research through design, creating the interface in close cooperation with Robotto. The goal of this project is to answer the following research question:

> "How to apply co-design to create a design for a user-interface aiding biomass plant managers in using a multi-drone system?"

Our primary focus will be addressing challenges associated with striking a balance between human control and automation, ensuring the solution will be beneficial instead of hindering human capability. Additionally, measures will be implemented to prevent information overload for the user when presenting data.

IV. Methods

For this paper the chosen research approach is research through design, referred to as RtD. This approach attempts to bridge the gap between research and design with the goal of generating new knowledge by employing the design processes. This new knowledge can take many different forms including: new perspectives on a problematic situation, insights into how theory can be better applied, new design methods that allow designers to tackle new challenges, and artifacts that embody theory. To summarize, is generative, when compared to other research approaches[15]. A challenge with doing is that, even with a well

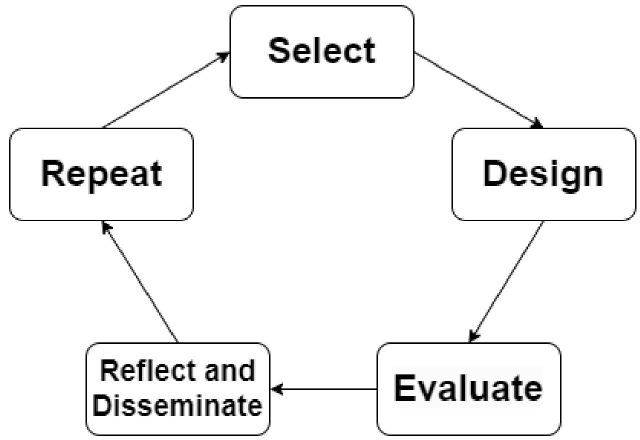


Figure 1: The five steps of RtD

documented process, it is not expected that the findings are able to be reproduced.[16] Simplified there are five steps to perform a project, Select, Design, Evaluate, Reflect and Disseminate, and Repeat. The first step, select, is the selection of a field or problem worth investigating. Design is the step that explores and attempts to understand the problem, this can be done through literature reviews and workshops. Evaluate is the step that is used to evolve and challenge the initial framing, the step helps in reframing the problem and giving new perspectives. Reflect and Disseminate, is the step where the team reflects upon what they have learned and disseminating the results of the previous steps. The last step, Repeat, is simply to repeat the process, by continually researching the same problem, more perspectives can be discovered, and more knowledge can be gained. To evaluate whether the contributions of a process are good, four lenses are used. These four lenses are process, invention, relevance, and extensibility. Process is the evaluation of the rigor applied to the process. Due to the results not being able to be reproduced, the process must be documented to such an extent, that it can be reproduced. In addition, the rationale for choices made in the process must be documented with equal rigor.

Invention refers to whether the contribution is significant. It must be demonstrated that the contribution is an integration of various subject matters, and that it can be used to give guidance. Relevance is the benchmark for interaction design. To prove that a contribution is relevant, it must be articulated why the contribution is a preferred state. Lastly extensibility is the ability to build upon the contribution, either to conduct further research or apply it in the real world.[17]

co-design

Co-design was chosen as the design approach for creating the multiview platform design artifact. Co-design provides an understanding of the user's context and experience and allows for the incorporation of that context and experience into the final product. Co-design is defined by SISCODE as: "a non-linear process that involves multiple actors and stakeholders in the ideation, implementation and assessment of products, services, policies and systems with the aim of improving their efficiency and effectiveness, and the satisfaction of those who take part in the process" [18]

The co-design process was made as a series of co-design sessions, discussing and brainstorming a series of designs. After each session, the feedback and ideas produced were made into a new set of designs. The process could then be repeated using the new design as a base for the next session. Each design was implemented solely by the researchers based on the information and ideation done through the initial research and at each co-design session.

Each co-design session consisted of a selection of features through a guided walkthrough of the provided design, followed by an open ideation discussion. This selection was primarily based on the stakeholders' disagreement with a feature's current interaction design. The ideation consisted of an open discussion between the stakeholders and the researchers on the context and possible designs for each feature. For each selected feature, a number of first low-fidelity sketches to later high-fidelity sketches were made. Each sketch showcased a design for each identified way to interact with a feature. The sketches were then combined into a set of prototypes and used as the base for the next session.

Design foundation

Based on the section I and section II cognitive overload is a very important aspect of HDI. In order to mitigate the cognitive overload inherent in the problem, we have chosen to employ the visual information seeking mantra (VISM) and the Type by Task Taxonomy(TTT) as design tools. Following these tools, our goal is not only to improve usability but also to reduce the mental strain associated with managing multiple drones.

VISM provides assistance for perceptual tasks by taking into account the limitations of human perception to mitigate interruptions. It advocates the principle of "Overview first, zoom and filter, then details-on-demand". TTT expands upon the principles of VISM and advocates for systems that are user-friendly and adapts to the users' needs while also minimizing cognitive load by selecting technologies that align with the task at hand. Made for creating designs where users are viewing collections of data with multiple attributes, it fits well into this project. Together, VISM and TTT serve as the foundation for our design theory in developing the multi-drone user interface.[19]

V. Implementation of design

Before the initial session with Robotto we had limited information about the needs of the user. It was therefore chosen to interview Robotto through an open-ended interview based on the information gathered from the initial research. Robotto was provided with a description of our ideas for problems to solve, and our assumptions about the field, before the interview. The minimal understandings from the initial research and interview can be summarized in two parts:

1) **The context of the problem:**
   a) **Biomass plant:** The chosen biomass plant is Amagerværket that handles several tons of biomass every day. The biomass is stored in large piles in indoor halls and at a loading dock. They have chosen to use drones in the monitoring and measurement processes on the plant. They need daily updates on the amount of fuel available, and they need to ensure that the plant is always running, costing millions in danish kroner if production is stopped.
   b) **Drone missions:** Each drone will fly on scheduled missions at least once a day, providing a feed of Optic, Lidar and/or Thermal video that will be processed by a number of analysis tools providing a number of events.
   c) **Events:** Each event will either be a detected anomaly, temperature, or object, or it will be a measurement of the fuel in an area.
   d) **Users:** The users are trained personal that uses the events to plan their production and to react to if for example a fire was detected in the fuel. Additionally, the users want to use the data to train personal.
2) **The problem to solve:**
   a) **Mission overview:** The user needs an overview and history of the drone missions.
   b) **Drone mission:** The user needs to see what occurred on the individual missions.
   c) The information presented to the user should be clear, relevant, and simple.

To visualize the initial understanding for the stakeholders and to have a base for the first session, an initial design was made. This design served only as a starting point for the discussion.

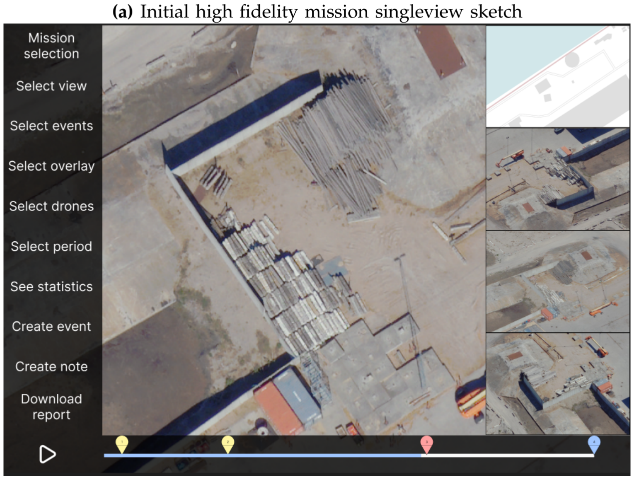
Participants

The participants of the sessions consisted of head figures from Robotto, with experience from several projects concerning search and rescue, industrial drone application and wild life tracking using drones and automatic information analysis. The participant from Robotto worked as representatives to end users and as domain experts in the field of drones in the industry, together with the researchers in the role as developers and experts in HCI. In order to provide an additional perspective in the discussion and selection process, a domain expert in the general area of HDI was also a part of the sessions. This researcher has worked in multiple projects focused on drone swarms and HCI in general.

Initial session: requirement discovery

In order to increase the stakeholders' confidence in providing feedback and clear up misunderstandings, the stakeholders were made aware that the design was assumed to contain flaws and intended to be used only as a base on which a discussion for a better design could be formed. In selecting features for the design, the guided walkthrough of the design was used to clear up misunderstandings about the stakeholder's goals and the context area. Based on the assumed context and problem, the drone mission interface should consist of a video feed, and map in some way overlaid with a series of events as timestamps and locations together with the drones' path or paths being displayed. The initial created design, based on the assumed problem and some inspiration from the existing application in section II, can be seen in Figure 2. We found that each event, in addition to the initial requirements, consists of a single or selection of pictures hereafter

(a) Initial high fidelity mission singleview sketch

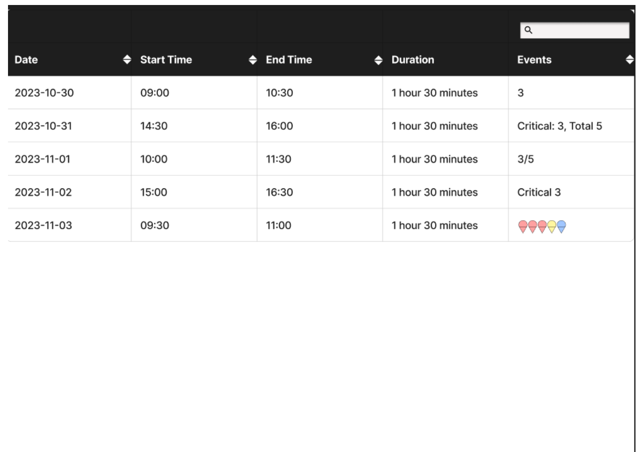


(b) Initial high fidelity mission multiview sketch

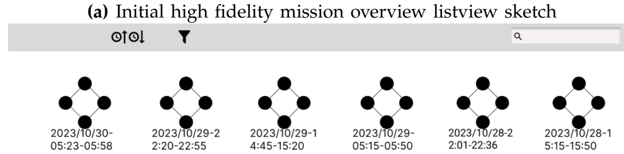
Figure 2: The initial mission view sketches

called snapshots together with some relevant data like timestamp, GPS coordinates and event type. There is and should be no video feed, it is only the events and the information in them that is relevant, the timing between each event is not relevant in the mission view, therefore the temporal aspect is filtered away. That also meant that the drone path itself was not relevant information, as we had assumed.

Based on the initial session, the minute of which can be seen in Appendix A where all minutes from all the sessions are present, it was determined that each mission interface consists of a map with the events accurately placed and shown, and a list of all the in mission events sorted by time of occurrence. Additionally, the operator needs to be able to select and see each event in detail. This is used to create the design for the next session.



(a) Initial high fidelity mission overview listview sketch



(b) variant low-fidelity mission overview image view sketch

Figure 3: The initial mission history sketches

Based on the defined context and problem, two versions of the mission overview were made, which can be seen in Figure 3. The first variation shown in Figure 3a consisted of a list view of the conducted missions with relevant data sorted in columns, and possible different variations of event overview shown. An alternative mission overview design seen in Figure 3b was created to explore other possibilities or additions to the mission overview screen. It was concluded that there was a higher interest in developing the list view in further ways. The mission's overview could from the discussion be further defined to be providing information concerning the amount of events found during each mission, together with an overview of the total measured volume of fuel available. The graph will be enhanced with an estimate of fuel consumption as to provide an intuition about the remaining fuel. This is aligned with the HCAI frameworksection II as only information supporting the task is added. A misalignment would be to make alerts which tell the user when the fuel should be restocked as this would introduce high levels of computer automation and possibly introduce a false sense of security. The resulting design is used as baseline for the next session.

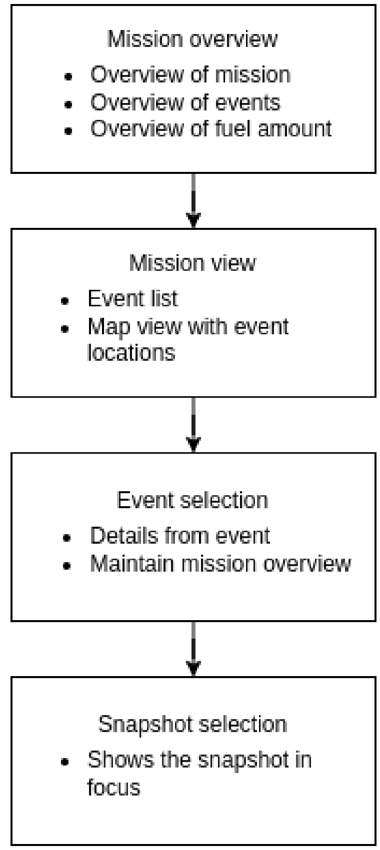


Figure 4: Base structure for design

Second session: design foundation

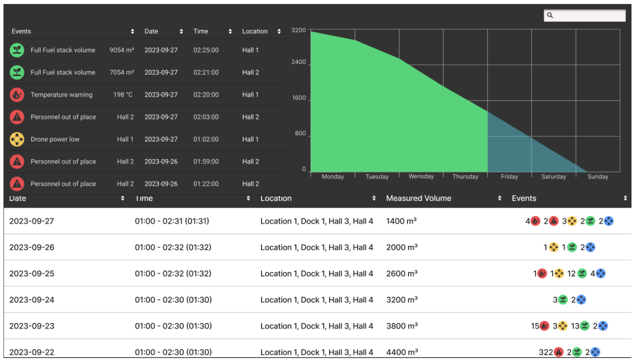
The second session had the focus on establishing the foundation for the design using the design variation created from the first session.

A base structure for the design was made in order to keep the principle of "Overview first, zoom and filter, then details-on-demand" from VISM in regard when making the design. The structure can be seen in Figure 4.

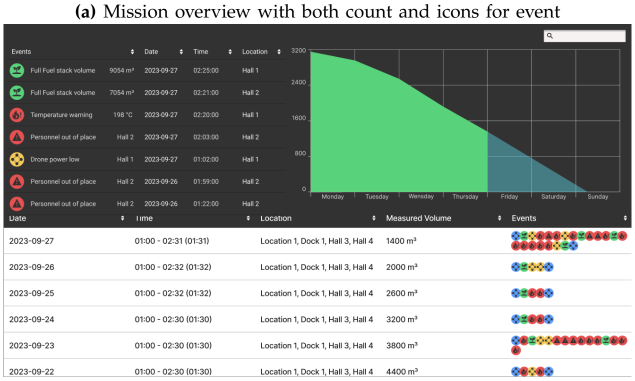
The basic structure of the design shown in Figure 4 consists of four levels. The first level of the design and also the level the user will start their journey from is the overview of the missions. Trough this level, the user will have an overview of all missions in the system, and the current and past events and fuel levels. The user can then filter and find a desired mission. The designed variations of the mission's overview can be seen in Figure 5.

The overview of the mission's design shown in Figure 5 was made through an expansion of the initial list view created in the initial design. A graph of the fuel, showing the past week of fuel measurements, was made in addition to the initial list of missions. The individual total measurements were also added to each mission in the list. A list of the most recent events was also added to the overview, making the event info readily available to the user, and enabling them to react to any new events. Three variations were made of the event tab in the list of missions. In Figure 5a both the event icon and the number of events is shown, this was the chosen variation. In Figure 5b only the event icons are shown but in temporal order. In Figure 5c only the number of events is shown but sorted in critical and non-critical events.

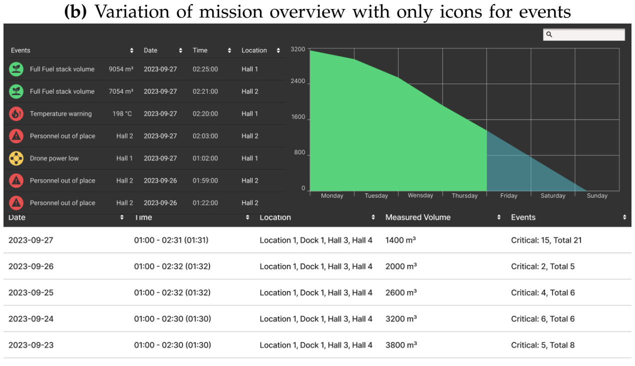
The second level of the design is the mission view, here further detail is provided through a more de-



(a) Mission overview with both count and icons for event



(b) Variation of mission overview with only icons for events



(c) Variation of mission overview with only count for events

Figure 5: Three variations of mission overview

Figure 6: V2 mission view

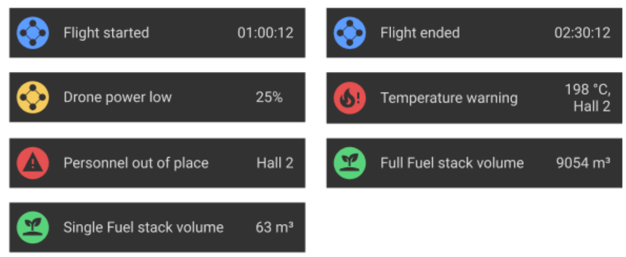


Figure 7: V2 event types

tailed list of events and a map showing the location of each event, the design of which took inspiration from the existing applications found in section II. Additionally, it was proposed to allow the user to extract the information of the mission in accordance with TTT. The design can be seen in Figure 6.

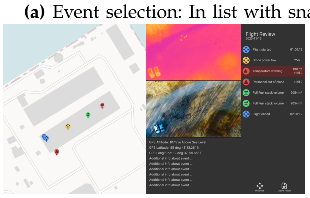
The different designed events for the second session can be seen in Figure 7.

The focus was on displaying the potential structure of the events and the use of different colors and icons that could be used to display different events of different severity and type. The exact event types needed is not know at this point. The structure of the events is split in three. An icon with color to make it easily recognizable, a title for the event to provide clarity, and the most relevant information from the event, like location, time, or amount. The different colors and icons are used to show how changing either the color or icon can help change the expressed meaning or severity of the event.

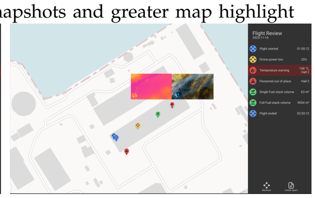
The third part of the base structure is the event selection. The purpose of the event selection is to provide detail-on-demand for the events in accordance with VISM and TTT. The relevant details are the snapshots from each event and potentially the event information. The three different variations of displaying the event selection can be seen in Figure 8.

All three variations from Figure 8 highlights the

(a) Event selection: In list with snapshots and greater map highlight



(b) Event selection: Pop out with snapshots and info



(c) Event selection: In map with snapshots

Figure 8: Three variations of event selection

selected event and shows in varying form and detail the available information from the events. The event is here assumed to have an optic and thermal snapshot and GPS coordinates, along with some other potential info. In addition to the event highlight in the list, the map marker was also highlighted. There are two variations of the map marker, a minimal highlight and a greater highlight, shown to enable the stakeholders in evaluating the amount of highlight needed and it was found in the session that the greater highlight was better and could be improved by a color selection that differentiated it from the event marker colors. The first variation of the event selection, shown in Figure 8a, presents only the two snapshots inserted below the selected event directly in the event list, this was the chosen variation. The second variation seen in Figure 8b shows the snapshots along with the additional information in a pop out view besides the event list. It was found in the session that the additional information and the extra space consumed by this way of presenting the snapshots was unnecessary. The third variation seen in Figure 8c shows the snapshots directly placed onto the map above the selected event's map marker, this variation was in the session not chosen based on the preference of the stakeholders.

The final level of the base structure is the snapshot selection. The snapshot selection purpose is to provide the highest level of detail provided by a dedicated view of a single snapshot, allowing for closer inspection and further functionality like zoom and panning on the snapshot itself in accordance with TTT. An example of the design for the snapshot view can be seen in Figure 9.

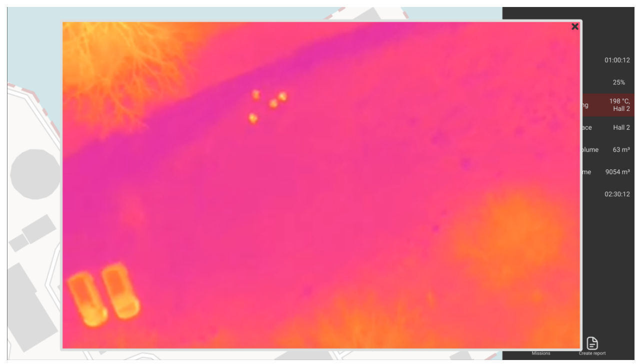


Figure 9: V2 snapshot selection

The snapshot view design consists of a simple pop out view, allowing the user to zoom and pan within the snapshot in accordance with TTT. The sketched design was made to establish if this was a needed feature and as a base for discussion on how it should look and function.

Aside from the primary focus on fuel monitoring, other aspects of the biomass plant were also discussed, such as general monitoring and security. This aspect lead to the ideation of some general new events, an event acknowledgement feature and changed mission overview. In addition, a need for an expansion of the examples of icons and colors available for the events was also presented along with the new events.

The discussed designs and new ideations were compiled and improved into a new set of designs for the third and final co-design session in this project.

Third session: design validation and future

The third and final session was focused on validating the designs created for the fuel monitoring and discussing the future of the project, in regard to the newer security designs expressed in the second session, and approving the work for a collaborative project with Amagerværket directly.
The mission overview had the addition of an acknowledgement feature that allowed showing the specific missions had been seen by a user. This can be seen in Figure 10.

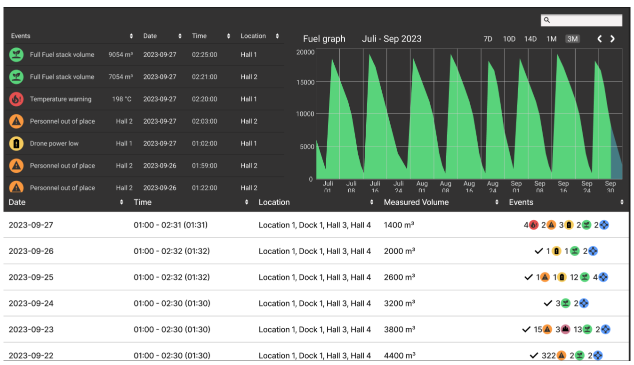


Figure 10: V3 missions overview

The improved mission overview was approved by the stakeholders for use in the biomass monitoring system.
The mission view had the addition of a possibility for a swap between standard view and satellite view and zoom/pan function incorporated. The satellite version can be seen Figure 11.
This mission view and the event selection design was approved by the stakeholders as a final design.
The snapshot view was changed. Instead of making a pop out that hid the mission view, it was made as an inlay and swapped places with the map view, in accordance with TTT as to not hinder user freedom while still providing more detail. The new design can be seen in Figure 12.
By inlaying the snapshot instead of making a pop out, the general structure of the mission view was

Figure 11: V3 mission view with satellite map

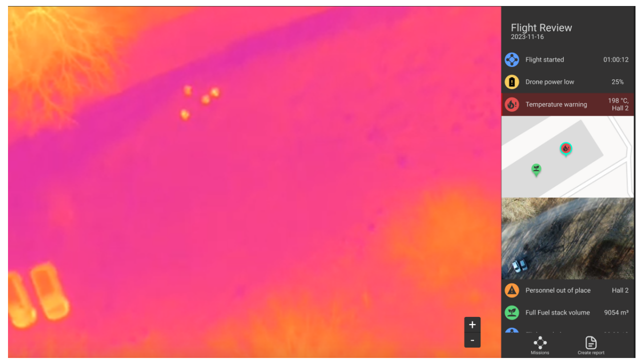


Figure 12: V3 snapshot selection

maintained while still enhancing the detail of the snapshot. Additionally, the relation between the snapshot and map was maintained by inlaying a zoomed version of the map in place of the old position of the selected snapshot. This version of the snapshot view was approved by the stakeholders as the final design.

security

The third session had the addition of exploring how the design could be modified to encompass this different aspect of use in security.The security features of the design are less explored, since Robotto had limited information about its potential use.
The first aspect changed is a change to the events already created. The previous designed event served as placeholders for the eventual final events, and so will these. These events are created to show how the events could look like for a system that also incor-

porated security and safety monitoring. From the second session, it was found that for the security, features the events should have added degrees of severity through new colors and additional icons to encompass new event types. The new event designs can be seen in Figure 13.

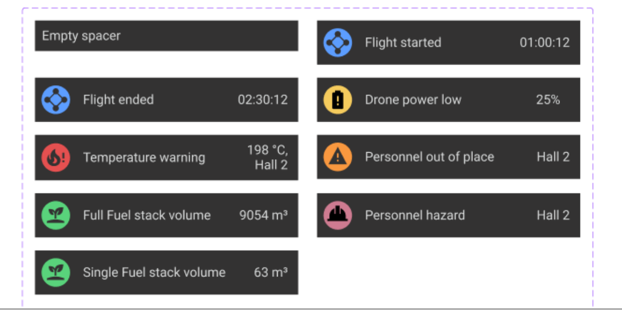


Figure 13: V3 event types

The events require additional research to explore the subject of security and find stakeholders with more experience in the field.

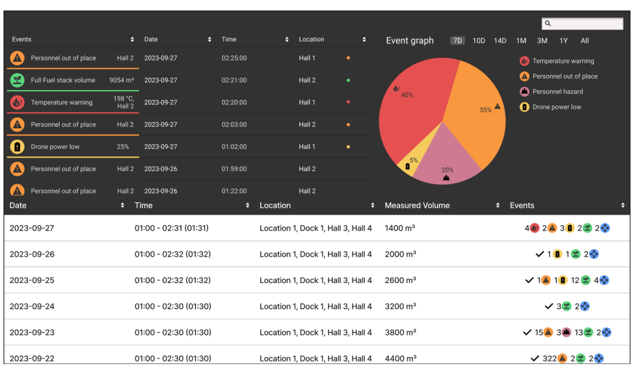


Figure 14: V3 missions overview with new event handling

Additionally, the mission overview has received a change to its design to emphasize the events more. This was done in accordance with the feedback from the second session, concerning the security features of the event notification system and mission overview. The new design can be seen in Figure 14.
The security mission overview, emphasizes the events by changing the graph for the fuel monitoring with a graph of event counts. Furthermore, the notification system is enabled for the event list, adding further emphasis that the most recent events needs to be acknowledged. These features were confirmed by the stakeholders to have value, but again without further research with more relevant stakeholders it cannot be concluded to be a final solution.

VI. Discussion

In this paper the stated research question is:

> "How to apply co-design to create a design for a user-interface aiding biomass plant managers in using a multi-drone system?"

We engaged Robotto in a design process without any clear direction except a description of the drones and the technology's presumed use-case. We chose to use a number of session based interviews and brainstorms together with our stakeholders as our method to apply co-design for making the design. This method worked well in regard to establish the baseline of a design for aiding biomass plant managers in using a multi-drone system. The design was verified through the iterative process described in section IV and section V and provides one answer for our research question.

However, this answer to the research question is only one of many possible answers. Different methods within co-design could have been used to create the final design. Another approach is to apply co-design through workshops as to involve the stakeholder more directly in the design decisions and allow for immediate approval or disapproval of concepts. This would allow for a deeper and more invested discussion but also requires more time from the stakeholders.

Additionally, the design lacks verification. The design is yet to be used to create an implementation in the industry. There is still some uncertainty to the quality of the created solution. The design has been validated repeatedly throughout the co-design sessions using the interviews but lacks user studies crucial for gaining insights into user experience, preferences and potential issues. This is the main point for the future work. Besides these challenges, the stakeholders were enthusiastic and valued the final design highly. We also feel that the methods applied allowed for a solution and process that provided us with good confidence in the stakeholders' satisfaction with the final design.

Limitations

Within this project, there are certain limitations that must be acknowledged. The first being that the number of stakeholders that we have worked with, has been limited. While this was done to limit the project scope to fit the time available, it is still something that should be taken into account. Secondly, is a limited, starting, knowledge base. The project has been the first foray into proper HCI research for the group. It is for this reason that a foundational knowledge base, within the field of HDI, had to be created. Thirdly, is limited time. This is a project done as a semester project. This has limited the time allotted for the project to roughly four months. Due to this, the scope of the project had to be limited, so that a conclusion could be reached at the end of the time period.

VII. Conclusion

We set out to answer the question "How to apply co-design to create a design for a user-interface aiding biomass plant managers in using a multi-drone system", due to multi-drone systems becoming more relevant. It was chosen to limit the scope of the project to biomass plants. To answer the question, we engaged in multiple co-design sessions together with experts in the field. These sessions resulted in three iterations of a prototype interface. In addition the sessions helped in giving Robotto insights into what requirements they have for such an interface. These insights combined with the artefact has helped us consider what the next phase of the project will be.

In conclusion, the research question has been answered in the form of a co-designed user-interface for a multi-drone system but lacks validation. The artifact incorporates VISM, and TTT in order to reduce information overload and the principle of HCAI. Additionally, the paper provides insight into the research and development of such an artifact. The process of creating such an artifact could inspire future research, and the artifact itself can inspire further development.

VIII. Future Work

User study

The created design artifact lacks verification by application in the industry. An investigation into its potential use in the industry and use in reducing information overload could be interesting and will be the focus for our future research. Performing a user study with Amagerværket, could result in a more refined prototype and could possibly expand the relevance and use-cases of the design. One approach could be to create a study based on a number of simulated scenarios created in cooperation with security experts at Amagerværket. Having a number of plant security officers test and evaluate mutations of a prototype based on the baseline design created in this paper. This would be followed by an analysis phase where data collection tools like semi-structured interviews, questionnaires, and observation together with analysis tools like thematic analysis is used to gain a number of insights into what affects cognitive overload, how to reduce it in relation to HDI. These insights could then be used to update and improve the prototype in an iterative process, repeating as necessary. The goal of this would be to create an interface capable of supporting security officers to maintain an understanding of the data from the multi-drone system and to be able to quickly and confidently complete their tasks of finding and responding to security alerts and events related to the biomass plant. This process could also lead to a possible contribution in the form of a number of design guidelines to aid future HDI projects in dealing with multi-drone systems.

Implementation

It could be interesting to investigate the use of the created design. One way of doing this would be to investigate the designs use in creating an implementation for industrial use. This could uncover practical problems that haven't been caught in the paper, while also realizing the preferred state that the artifact shows.

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Appendix A
Co-design sessions

In this appendix, the co-design sessions conducted with Robotto are summarized as minutes

Minute from the first co-design session

Robotto are keen on historical data and statistics, particularly honing in on volume measurements. They imagine drones will fly nightly to keep volume stats updated. We discussed anomaly detection - equipment or people out of place, the system should log pictures with location details. Robotto are only interested in tweaking the flight time as the only form of interaction. The system does not detect issues like rot or damage, lacking the necessary models. Winter poses a challenge as volume becomes unpredictable, and there is currently no mechanism for detecting maintenance needs. Robotto expressed a preference for a simple list of events with small, hover-over images. Camera feeds are of lesser importance. We discussed multiple making security and biomass different artifacts instead of combining. In terms of mission selection, Robotto requested a 'sexy' redesign for the side menu. They made it clear there is no need for a timeline; just provide reports without the hassle of full video checks. Discussing maps, the route is crucial for security, but not so much for biofuel. Temperature information on the map is desired. There's a suggestion from participant about having multiple maps for different purposes, though the exact details are yet to be clarified. Robotto have given the green light for an iteration meeting and granted access to a team chat for quick updates. Next steps involve further clarification on the mapframe. There seems to be some skepticism about the value of a multidrone view.

Minute from the second co-design session

The meeting commenced with a discussion on the satisfactory level of detail in events and icons. It was agreed that the graph data should extend to at least more than a week. Robotto expressed their appreciation for the graph and historical data. The consensus leaned towards preferring numbers when examining icons, with a preference for the first variant. Robotto emphasized the importance of user-defined capabilities for the graph. They specifically requested different colors for warnings, highlighting the need for distinct colors for a person out of place and a temperature warning. It was suggested that a person out of place should be marked with a dark orange color to signify its higher level of danger. Equipment out of place was not considered a current concern due to no models available. Robotto approved Variant 1, which included selecting events with coordinates. There was interest in incorporating a satellite map, leaving it as a user choice for better user understanding. The use of a blue outline for marking was deemed sufficient at the moment, though openness to changing it based on customer feedback was noted. While annotations were considered a potential addition, it was agreed that this feature needed further exploration.

Minute from the third co-design session

When delving into Monitoring event specifics, it was suggested to consult HOFOR regarding the types of events. Robotto mentioned they could only make educated guesses at this point. Shifting the focus to the Mission view, the suggestion was made to consider using a bar chart over time to avoid confusion.

The idea of incorporating cameras or CCTV was brought up, with a consensus to explore this option later. The initial step, however, should involve implementing the ’action review tool.’ Robotto expressed a strong desire to witness the tool’s implementation, including the visualization of data through pictures, JSON events, and CSV measurements. The data already existing on the system was noted. The discussion also touched upon the acknowledgment feature, emphasizing the importance of allowing users to choose the types of events that require acknowledgment. It was suggested that this process should be user-friendly, allowing for easy acknowledgment of multiple events without becoming burdensome. In terms of media, it was agreed that the system would solely rely on pictures, excluding videos entirely. Thermal imaging was specifically mentioned in this context. Concerning the final verification of the system, Robotto complimented its sleek and professional appearance.