Tor Martin Frøberg Wang

Digitalizing Manual Supervisions of Sheep on Pasture

Master's thesis in Computer Science
Supervisor: Svein-Olaf Hvasshovd
June 2022

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Abstract

In Norway, sheep farmers release approximately 2 million sheep on graze every year. Allowing the sheep to go on pasture is good for the animals' welfare, but it also exposes them to dangers that can lead to both injuries and deaths. In fact, around 100 000 of these sheep sadly die every year during the grazing period. Most of these sheep die due to sickness, accidents, or predator attacks.

The Norwegian animal welfare law states that the sheep have to be well treated, and that they must be protected against unnecessary suffering, sickness, harm, or other dangers. The responsibility for securing the sheep's welfare resides with their owners, as they are required by law to weekly supervise their sheep during the grazing period. The supervisions play a very important role in achieving the desired level of animal welfare, and making this process more effective could make it possible to supervise even more sheep in a shorter amount of time.

The farmers are also economically incentivized to perform these supervisions, as they can be financially compensated for any sheep that are killed by predators. To be eligible for this compensation, the farmers must provide documentation that they correctly conducted the necessary supervisions. Currently, pen and paper is being used to document these supervisions, which introduces several disadvantages that may negatively impact the documentation's quality. That is why this Master's thesis presents the design, development, testing and evaluation of a digital system that aims to mitigate some of the current disadvantages, and make the supervision process more efficient and effective.

I have called this new digital system the "Herd" system, and it consists of a mobile application and an accompanying website. Both the mobile application and the website have been thoroughly user tested throughout this project, and the results from these user tests have been very promising. The results have shown that the system is easy to use in an effective and efficient way, and that it has achieved a high level of user satisfaction.

The system in its current form fulfills all the functional and non-functional requirements that were included in the project scope, and it would be possible for farmers to start using it on their supervisions. With that said, there is still work that can be performed and features that can be added to make the Herd system even better and more useful.

Sammendrag

I Norge slipper saubøndene omtrent 2 millioner sau ut på beite hvert år. Det å la sau gå på beite er godt for dyrevelferden, men det eksponerer de også for farer som kan føre til både skader og dødsfall. Rundt 100 000 av disse sauene dør faktisk hvert år mens de er ute på beite. De fleste av disse sauene dør på grunn av sykdom, ulykker, eller rovdyrangrep.

Den norske dyrevelferdsloven sier at alle sau må behandles godt, og at de må beskyttes mot unødvendig pinelse, sykdom, skade, eller andre farer. Ansvaret for å sikre sauenes velferd ligger hos eieren av sauene, da de er lovpålagt til å utføre ukentlige tilsynsturer under beiteperioden. Disse tilsynsturene spiller en viktig rolle i å oppnå det ønskede nivået av dyrevelferd, og det å gjøre de mer effektive kan gjøre det mulig å utføre tilsynsturer av enda flere sau på enda kortere tid.

Sauebondene har også et økonomisk insentiv til å utføre disse tilsynsturene, da de kan få kompensasjon for enhver sau som blir drept av rovdyr. For å være kvalifisert til å motta denne kompensasjonen, må bonden gi dokumentasjon på at de nødvendige tilsynsturene ble utført. Denne dokumentasjon blir nå skrevet med bruk av pen og papir under tilsynsturene. Bruken av pen og papir skaper flere ulemper som kan negativt påvirke kvaliteten på dokumentasjonen. Det er derfor denne masteroppgaven presenterer designet, utviklingen, testingen og evalueringen av et digitalt system som har som mål å fjerne noen av de eksisterende ulempene, og dermed gjøre tilsynsturene raskere og mer effektive.

Jeg har gitt dette nye digitale systemet navnet "Herd", og det består av en mobilapplikasjon og en tilhørende nettside. Både mobilapplikasjonen og nettsiden har gjennom dette prosjektet blitt brukertestet grundig, og resultatene fra disse brukertestene er veldig lovende. Resultatene viser at systemet er enkelt å bruke på en rask og effektiv måte, og at designet har oppnådd et høyt nivå av brukertilfredsstillelse.

Systemet i dens nåværende tilstand oppfyller alle de funksjonelle og ikke-funksjonelle kravene som var inkludert i prosjektomfanget, og det ville vært mulig for bønder å begynne å bruke systemet på tilsynsturene deres. Med det sagt, så er det fremdeles mer arbeid som kan utføres og flere funksjoner som kan implementeres for å gjøre Herd systemet enda bedre og mer brukbart.

Preface

Throughout this project, both a mobile application and a website have been developed. I recommend installing the application and visiting the website, as testing them will give a more detailed understanding of the work that has been performed.

The mobile application has been released on the Google Play Store for Android mobile phones, and can be installed using this URL.

https://play.google.com/store/apps/details?id=herd2.app.tmfwang

The website has been deployed and is available on the following URL. Please keep in mind that the website has been deployed on a free service called Heroku, which makes the website go to sleep after not being used in a while. The consequence of this is that you may have to wait a few seconds for the website to "wake up" when you are visiting it.

https://master-herd-web.herokuapp.com/

To save the reader's time when testing out the system, I have already created a user profile where I have performed and uploaded a few supervisions. Logging in with this profile account will allow the reader to inspect supervisions without having to perform them themselves. The following credentials can be used to log in with this user.

Email - TestUser@Herd.com
Farm number - HERD-2022
Password - HerdMasterProject2022

The source code for the website, mobile application and the backend API have been stored on GitHub. The GitHub repositories have been made public, and can be visited on the following URLs.

Mobile application - https://github.com/Tmfwang/master-herd-app
Website - https://github.com/Tmfwang/master-herd-web
API - https://github.com/Tmfwang/master-herd-api

Acknowledgements

I would like to thank my supervisor Svein-Olaf Hvasshovd for providing valuable feedback throughout this project, and for trusting me to come up with my own solutions to the task of digitalizing the sheep supervision process.

I would like to thank my family for always being there for me, and for participating in my user tests. This project would not be possible without your support.

I would like to thank my cousin Jenny Wang for borrowing me her Android mobile phone that was used extensively when developing and testing the mobile application. Thank you for making the development process a lot easier.

I would like to thank Maria Andersen, Martin Gløsmyr, Jan Petter Nordvåg, Anastasia Tsivileva, and the rest of my room mates for always supporting me during this project, and for creating a great social environment at home. This motivated me extremely, and it made my last year as a student unforgettable. Thank you also for participating in my numerous user tests. Your feedback elevated the design of the mobile application and the website to greater heights.

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1 Introduction

1.1 Motivation

Every year, Norwegian sheep farmers release their sheep for grazing. The grazing period usually lasts from the middle of May to the middle of September. During this period, the Norwegian government requires that the sheep are supervised by either the sheep farmer, or any other supervisor [1]. These supervisions have to be performed at least once every week, or more often if the threat level against the sheep is suspected to be higher (e.g. when bad weather is forecast, or when predators have been spotted nearby) [1]. Tasks that are performed during supervisions include, but are not limited to, counting the grazing sheep, locate and help lost or injured sheep, and find any deceased sheep and ascertain their cause of death. Following the end of the grazing period, a report, which documents what was observed during the supervisions, is created and sent by the sheep farmer to the government.

Today, the sheep supervisions are usually documented by the supervisor using pen and paper. The use of pen and paper introduces several disadvantages that may impact the quality of the documentation. These disadvantages include the difficulty of writing paper notes while using binoculars, the notes' fragility with regards to bad weather and rain, and the lack of standardization or a common structure for the notes. Digitalizing this sheep supervision process could positively contribute to the quality and efficiency of the supervisions and their documentation. This digitalization could be beneficial both for the person performing and documenting the supervision, and for the different governmental entities that receive the annual reports. A mobile application would improve the accuracy, value and quality of the report, which could make the related administrative tasks easier and less costly, as well as contribute to improving the sheep's animal welfare by better assisting farmers and government entities in understanding how and why sheep die or get injured.

1.2 Project Description

This master's project is a continuation of the specialization project that was carried out during the autumn semester of 2021. The project in its entirety involved designing, developing and user-testing a system with the goal of making sheep supervisions more structured, efficient, and effective. During the project, both a mobile application and an accompanying website were developed. The mobile application is meant to be used to document what is being observed during supervisions, while the accompanying website is used to inspect previously-conducted supervisions and to generate and download a report of these. The name of this new system, consisting of both the website and the mobile application, is chosen to be "Herd".

The mobile application had to support the interaction with a map to register the positions of the different observations that are made during a supervision. In addition to this, the application also had to track and store the location of the user during supervisions. Tracking and saving the user's path serves not only as documentation of where the supervisions were performed, but it could also be used in decisions of where to conduct future supervisions.

There are multiple types of observations that the mobile application had to support. It had to support the registration of the number of observed sheep, including the sheep's wool color. It had to support the distinction between ewes and lambs, and it had to allow the supervisor to register the color of the sheep's ties and owner marks. In addition, the application needed to have the ability to register observations of predators, and of dead or injured sheep.

An important tool that is used during sheep supervisions are the binoculars. Binoculars are necessary as the observed sheep are often far away from where the supervisor is located. This is something that had to be taken into consideration during the design and development of the mobile application, as it had to support registering the observations while at the same time using binoculars during certain parts of the supervision.

The Herd website had to support the inspection of supervisions, and it had to support the generation of a PDF report that summarizes the user's supervisions. This PDF needs to include all the information that is of interest to the different governmental entities.

1.3 Stakeholders

When a new system or product is developed, it is essential to recognize who the stakeholders are and how they will be affected by the new system. Understanding the stakeholders and their needs is important, as this could move the design and development of the system in new and exciting directions that weren't previously thought of. This subsection will look at some of the possible stakeholders of the Herd system.

1.3.1 The Norwegian Food Safety Authority

The task of ensuring that all Norwegian food is produced in a safe and responsible way resides with the Norwegian Food Safety Authority (Mattilsynet). Ensuring that the Norwegian sheep experience a good animal welfare is included in this task. Access to correct, structured and precise data on the grazing sheep, including their causes of death, sickness or injury, could prove considerably helpful for this authority in their endeavour of limiting the deaths of grazing sheep and upholding a good animal welfare.

1.3.2 Farmers

The Herd system's end-users are the farmers who are performing supervisions of their sheep. Due to both moral and economical reasons, the farmers are interested in ensuring good welfare for their sheep. The Herd system could make the documentation process of the supervisions more effective, thereby making it easier to perform supervisions. In addition, the system could provide structure and quality to the data that is being collected during the supervisions, which can make it easier for the farmer to better understand what dangers their sheep are exposed to while on pasture.

1.3.3 Other Supervisors

It is not required that the farmers themselves are the ones that perform the supervisions of their sheep. The supervisions of a farmer's sheep could be conducted by, for example, neighboring sheep farmers, or by any other individual who is interested in performing these supervisions. For these "external" supervisors, the Herd system could be beneficial in making the supervision process easier, faster and more effective, so that they can supervise more sheep in a shorter amount of time.

1.3.4 The County Governor

In Norway, sheep farmers have a right of reimbursement in cases where their sheep are killed by wild predators. In order to get their reimbursement applications approved, it is necessary to provide proof that the supervisions were performed correctly and that the dead sheep was indeed killed by a predator. The county governor is responsible for handling these reimbursement applications, and the Herd system could assist in the processing of these applications by providing more accurate and structured supervision data.

1.3.5 The Norwegian Environment Agency

The Norwegian Environment Agency is called when a grazing sheep is suspected to have been killed by a predator [2]. Their task in this regard is to help the farmer determine the sheep's cause of death. This task could be made easier by the more accurate observations provided by the Herd system, especially in regards to the location of the deceased sheep.

1.4 Structure of the Report

This report will detail the work performed on the Herd system, which consists of both a mobile application and a website. The mobile application was mostly designed and developed in the specialization project during the autumn semester of 2021. The accompanying website, and the server and database that connects the mobile application and the website, were created during the Master's project in the spring semester of 2022. The accompanying website will in this report often be referred to as the "Herd website", while the mobile application will often be referred to as the "Herd mobile application". This report is structured as follows.

- In Section 2, the research questions and the research strategy will be presented.
- In Section 3, the background is presented, and any existing solutions are examined.
- In Section 4, both the functional and non-functional requirements for the mobile application and the accompanying website will be communicated.
- In Section 5, an explanation of the design method is given. The section further presents the different user personas and user scenarios that were created during the design pre-study.
- In Section 6, the design of the paper prototype for the mobile application is explained. The section further discusses some important design choices behind the prototype, as well as taking a look at the design rationale. In addition to this, the user tests of the prototype, and the results from these, are presented.
- Section 7 is similar to the previous section of the paper prototype, but here we instead look at the design of the *implemented* mobile application.
- Section 8 presents the design of the paper prototype for the website. The section further discusses some important design choices behind the prototype, and also looks at the design rationale. In addition to this, the user tests of the prototype and the results from these are presented.
- Section 9 is similar to the previous section of the paper prototype, but here we instead look at the design of the *implemented* website.

- Section 10 looks at the technology choices that were made with regards to the development of the mobile application, the website, and the API.
- Section 11 presents the architecture of the Herd system using the physical view, development view, process view and logical view from the 4+1 model.
- Section 12 gives a test plan, and looks at the results from testing the functional and non-functional requirements for both the mobile application and the website.
- Section 13 discusses the final solution, and reviews the research questions.
- Section 14 presents the conclusions.
- Section 15 looks at the possible improvements, additions and enhancements that could be implemented in the Herd system in the future.

2 Research Methodology

2.1 Research Questions

The following three research questions were established based on the goal of digitalizing the current method of documenting the sheep supervisions. These research questions were derived at the beginning of the specialization project [3, page 3].

- What changes could the digitalized system introduce to the sheep supervision process?
- How can the mobile application support the use of binoculars during the observation registration process?
- How usable is the digitalized system for documenting sheep supervisions?

The first research question is about looking at what advantages and disadvantages the new digitalized system may introduce when compared to the current solution of using pen and paper to document the supervisions. This is an important research questions as the aim is to improve, not worsen, the supervision process.

The second research question is about how binoculars are essential to parts of the supervision process, and how the Herd application can be designed and developed to support this. This also includes user testing how successful the application is in enabling the use of binoculars.

The third research question looks at how usable the Herd system is for documenting sheep supervisions. The definition of *usability* is "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [4].

2.2 Research Strategy

The "Design and Creation" strategy is the methodology's main research strategy. The emphasis of this strategy is the development of new IT products [5, page 109]. In this research strategy, the IT product could serve three different roles. The first of these roles is when the IT product is the main focus of the strategy [5, page 109]. The second role is when the IT product is the end-result of a process-focused project, and the third role is when the IT product serves as a vehicle for something else [5, page 109]. For this project, the Herd system introduces IT in a new domain that has not yet been digitalized. The Herd system therefore has the role of being the main focus of the strategy, and is thus itself seen as a contribution to knowledge [5, page 109].

The "Design and Creation" research strategy is commonly seen as a problem-solving approach that embodies an iterative process involving five different steps [5, page 111]. These five steps can be seen throughout different parts of this project:

- *Awareness* is the recognition and articulation of the problem that needs to be solved [5, page 111]. This step was performed in collaboration with my Master's supervisor Svein-Olaf Hvasshovd. He has conducted several sheep supervisions himself in the past, and he has been supervising previous Master's students that have worked on projects related to this process. The conversations with him were essential in understanding and recognizing the difficulties of the sheep supervisions and the current analog (paper-based) solution of documenting them.

- *Suggestion* is the "creative leap from curiosity about the problem to offering a very tentative idea of how the problem might be addressed" [5, page 112]. The tentative ideas of how the problem might be addressed is here seen through various parts of the project, as communicated through the design prototypes for both the Herd application and the Herd website.
- *Development* is where the design suggestion is implemented [5, page 112]. This step involves the development and implementation of the Herd website and the Herd mobile application.
- *Evaluation* "examines the developed artefact and looks for an assessment of its worth and deviations from expectations" [5, page 112]. This includes not only evaluating if the developed solution fulfills the requirements, but also evaluating its effectiveness, efficiency and level of satisfaction.
- *Conclusion* is "where the results from the design process is consolidated and written up, and the knowledge gained is identified" [5, page 112]. This step can be seen in the later parts of this report, as Section 13 discusses the project and Section 14 gives a conclusion.

3 Background

3.1 Sheep In Norway

In Norway, sheep farmers have to release their sheep on pasture for at least 16 weeks every year [6]. Allowing the sheep to graze for these weeks improves both the welfare of the animals, and it is a good utilization of Norway's available land resources. Due to the rough terrain in large parts of Norway, a significant part of the land does not have sufficiently fertile soil. In fact, difficult terrain and a harsh climate result in approximately two thirds of the land only being suitable for grass production [6]. The best way to properly utilize these difficult land areas is therefore through sheep that can consume the grass that is growing there [6].

3.1.1 Sheep Dying During Graze

Allowing the Norwegian sheep to freely graze every year positively impacts the sheep's welfare, but it also exposes them to dangers that can cause both injuries and deaths. Farmers in Norway release in total approximately 2 million sheep for grazing every year [7], and around 100 000 of these sheep unfortunately die during this grazing period [8]. Maybe surprisingly enough, numbers from 2019 reveal that only 17 566 of the deceased grazing sheep were killed by predators [9]. This means that other causes, like accidents and sickness, were the cause of death for the more than 80 000 remaining sheep that died.

The government provides the farmers the right to be compensated whenever their grazing sheep are killed by predators like eagles, bears, wolverines, wolves, or lynxes [9]. The statistics from 2019 showed that over 45 million NOK was provided by the government as compensation for over 17 500 deceased lambs and sheep, given out to a total of around 1100 different sheep farmers [9]. If a farmer wants to apply for compensation, it is important that they have the documentation that they correctly conducted the necessary supervisions, and that they have proof that a predator actually was the cause of the sheep's death.

3.1.2 Sheep Supervisions

The animal welfare law in Norway declares that the sheep have to be well treated, and that they must be protected against unnecessary suffering, sickness, harm, or other dangers [9]. The responsibility for securing the sheep's welfare resides with the owner of the sheep, as they are required by law to weekly supervise them during their grazing period [9]. The supervisions play a very important role in achieving the desired level of animal welfare, and making this process more effective could make it possible to supervise even more sheep in a shorter amount of time.

During a supervision, farmers can perform different types of observations. The Herd mobile application will support the registration of the most relevant ones, which are presented in this list:

- The number of lambs
- The number of ewes
- The number of sheep in general
- The color of the sheep
- The color of the ewes' ties

- The color of the owner mark(s)
- Injured sheep, the type of injury, and the injured sheep's tie and owner mark color
- Dead sheep, the assumed cause of death, and the dead sheep's tie and owner mark color
- Predators, including the type of predator (lynx, eagle, bear, wolverine, wolf, or other)
- The location and time of the observation

The distance between the supervisor and what is being observed impacts what information that is usually registered. When this distance is over 30 meters, it becomes more difficult to spot the color of the tie or owner mark on the sheep. As the distance increases, so does also the difficulty of observing the difference between lambs and adult sheep. Dead or injured sheep are usually observed at close ranges, so distance doesn't play a large role here. Areas where distance does make an impact, and where binoculars is a relevant tool, are when making observations of the amount, type (ewe, lambs, or sheep in general) and color of the sheep, and observations of the color of the sheep's ties.

3.1.3 Sheep's Tie and Owner Mark

When an ewe is released on pasture, they are equipped with a colored piece of plastic commonly called a "tie". By looking at the color of this tie, the supervisor can know how many lambs the ewe has. The supervisor can detect if any lambs are missing by comparing the *observed* amount of lambs with the *expected* amount of lambs as indicated by the ewe's tie color. Official guidelines for the color of these ties have been created by the Norwegian Sheep and Goat Organization. These guidelines include that the color red means that the ewe has no lambs, the color blue means one lamb, the color yellow or a clear color means two lambs, and a green tie color indicates an ewe with three lambs [10]. A sheep with a colored tie can be seen in Figure 1.

Figure 1: A sheep with a colored tie around its neck [10]

In addition to the colored tie, the sheep also has a colored owner's mark attached to its ear. The owner's mark has a color that indicates which of the neighboring farms the sheep belongs to, as well having an identifying number that is unique for the specific sheep [11]. Any color except salmon-red and white can be used for these marks [12], which also means that neighboring farms have to agree on which colors they want to use.

3.2 Existing Solutions

In this subsection, we will examine what digital solutions already exist for performing and documenting sheep supervisions. Looking at the existing solutions is an important step in better understanding the landscape of the current market and what new value my own solution is going to bring to the table. I'll start by looking at different mobile applications that might be useful for documenting information and locations when performing sheep supervisions. I'll then move on to examining some existing solutions that could possibly complement, and be used in tandem with, a mobile application that is dedicated for documenting sheep supervisions. The complementary solutions would for example be able to provide positional tracking of the sheep on pasture, which could be a great assistance when trying to locate grazing sheep during supervisions.

3.2.1 Mobile Applications

Skandobs
Skandobs is a service created as a collaborative effort between "Naturvårdsverket Sverige" (Swedish Environmental Agency) and "Rovdata Norge" (Predator Data Norway). Skandobs provides a service open for anyone who wants to register a predator that they have observed. The possible predators that can be registered include wolves, wolverines, lynxes, and bears. The service can be accessed on Android and iOS through their respective mobile applications, and through a computer via their website. [13]

With Skandobs, users can document the most relevant information from a predator observation. This includes the observation's location and time, the predator type, what had been observed (e.g. predator's tracks, injured or dead preys, or the actual predator), and photos or videos of the observation. When a predator observation has been registered, it can be uploaded to Skanobs' public database that can be searched and filtered by any user.

Predator observations is an important part of performing sheep supervisions, and the Skandobs service is a good tool for that purpose. It has several useful features, like the support for registering observations without internet connectivity, but it also lacks some features that are essential for sheep supervisions. Skandobs does not track the user's path during a supervision, it does not generate a downloadable report of a user's supervisions, and users can't download maps for offline use. The service is good for registering observations of predators, as this is the purpose it was developed for, but it is not functional for a supervision's other important observation types.

The Skandobs application's front page can be seen in Figure 2. Figure 3 illustrates the search and filter functionality of the public predator observations, while Figure 4 shows how the public predator observations are displayed on a map.

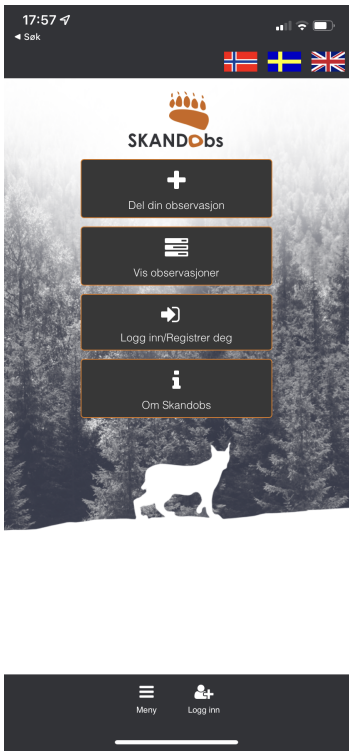

Figure 2: The Skandobs application's front page

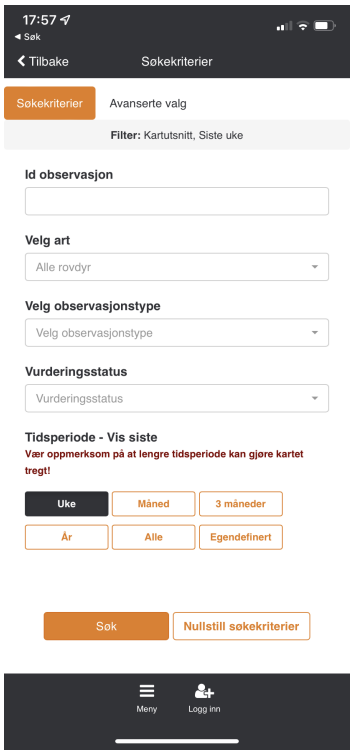

Figure 3: Search and filter functionality of public observations in Skandobs

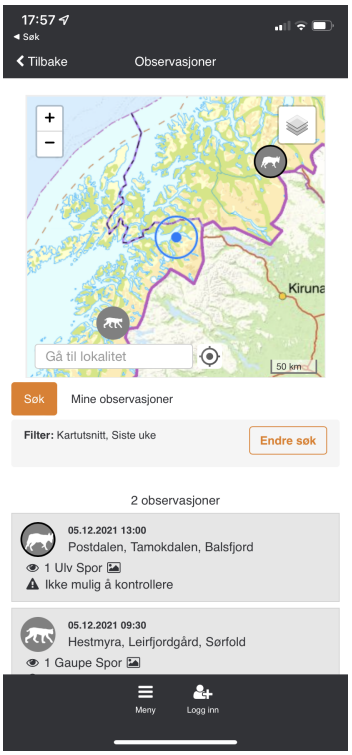

Figure 4: Public predator observations in Skandobs

Norgeskart Friluftsliv

Norgeskart Friluftsliv was created by Håvard Sataøen as a collaborative project with Avinet, and this service is available for Android, iOS, and web [14].

Norgeskart Friluftsliv supports tracking a user's path, using a map to register points of interests, and downloading maps so that they can be used without internet connectivity. The application was developed to be used by hikers, but it could be used during the supervision process as well. The "points of interests" contain a field for "description", which supervisors could utilize to store information about an observation. Even though this would allow supervisors to document anything they need, manually having to write text in a single field is both ineffective and unsystematic when compared with a possible solution that is purpose-made for sheep supervisions.

Norgeskart Friluftsliv's default page on mobile can be seen in Figure 5. Figure 6 shows that the application can track and store the path that a user walks, while Figure 7 shows that a point of interest can be registered with both a name and a description.

Figure 5: Norgeskart Friluftsliv's default page on mobile

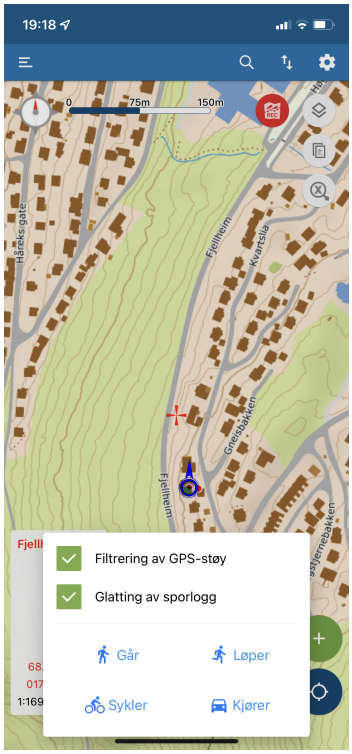

Figure 6: Norgeskart Friluftsliv can track and store the path a user walks

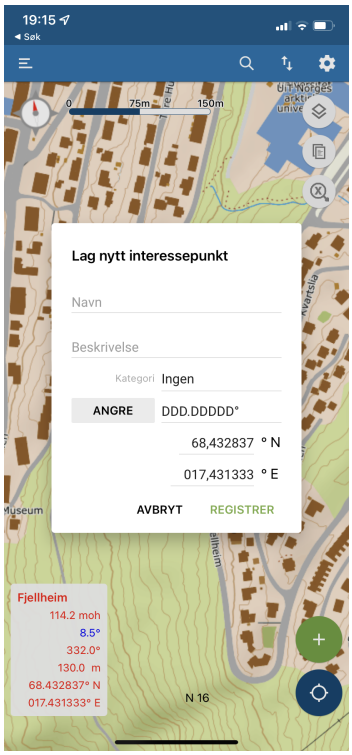

Figure 7: Norgeskart Friluftsliv's page for creating a new point of interest

Beitesnap

Beitesnap was a mobile application that was developed with the purpose of documenting observations of sheep and grazing animals. Beitesnap was developed for both Android and iOS mobile phones, and it was functional both with and without internet connection [15]. From the features described on Beitesnap's website, it supported most of the aspects that are necessary for documenting sheep supervisions [15]. I was unable to download and explore Beitesnap myself, as the application is sadly no longer functional after having been discontinued. I could not find any reason for this discontinuation either on their website nor anywhere else.

3.2.2 Complementary Solutions for Sheep-Tracking

FindMy

FindMy produces electronic devices that provide location tracking of grazing sheep. The device makes use of low-orbit satellite technology to detect and transmit the location of the sheep to the farmer. By utilizing GPS satellites, and not a mobile network, FindMy's devices become functional in all land areas regardless of the available cellular service. The device can be seen attached to a couple of sheep in Figure 8. [16]

Farmers can interact, analyze and observe the data that is generated from their electronic sheep devices through FindMy's various digital solutions. This includes a mobile application for Android and iOS, and a desktop client for Mac and PC. FindMy's digital solutions can notify the farmer when a sheep has stopped moving (indicating injury, death or sickness), when sheep are moving in a strange or unfamiliar pattern (which can indicate nearby predators disturbing the sheep's movement), or when a sheep has moved outside an area that is pre-defined by the farmer. [16]

Figure 8: FindMy's electronic tracking device attached to a couple of sheep [16]

Telespor

Telespor has developed an electronic device similar to FindMy's device, called "Radiobjella", which can be seen in Figure 9. Like FindMy's device, the "Radiobjella" is also attached to a farmer's sheep to track their locations. By utilizing Narrowband IoT and LTE-M technology, Telespor provides two-way communication between the sheep's "Radiobjella" device and the farmer. In contrast to FindMy's device that is operational anywhere because of their use of low-orbit satellites, Telespor's device relies on the existence of cellular service in the areas where the sheep are located. [17]

When comparing Telespor's product with FindMy's, the device from Telespor is seemingly more limited in their set of features. Telespor's product provides mainly the sheep's locations, and the feature of being notified when a sheep stops moving [17]. FindMy's device on the other hand, provides location heatmaps, geofence notifications, detection of strange movement patterns, and more [16].

Figure 9: Telespor's location device: "Radiobjella" [17]

Smartbjella

Another provider of a sheep-locating electronic device is "Smartbjella", which is similar to FindMy's and Telespor's devices. To communicate with the "Smarbjella" device, farmers can use an iOS/Android mobile application, or a desktop client. Similar to Telespor's device, Smartbjella utilizes the same narrowband IoT technology, also making it reliant on cellular service being available. [18]

The features offered by Smartbjella are similar to what is provided by Telespor and FindMy. These features include tracking of the sheep, and notifying the farmer when a sheep moves outside a pre-defined area or when it stops moving. [18]

Figure 10: Smarbjella's electronic location device [19]

3.2.3 Evaluation of the Existing Solutions

After looking at the mobile applications that exist on the market, we can see that none of the existing solutions supports all the features that are necessary to perform and satisfactorily document sheep supervisions. As an example, a supervisor could use the mobile application from "Norgeskart Friluftsliv" to document observations, but this will likely be both ineffective and unsystematic due to the application's lack of structure and customizability.

We've also looked at multiple products in the market that can provide location tracking of the grazing sheep. Supervisions of sheep are still necessary and government-mandated when using these products, as the products do not replace the usefulness of conducting supervisions [1]. Nonetheless, these types of products do provide valuable assistance to anyone performing supervisions, as it reduces the time spent on discovering where the grazing sheep are located. In addition to this, these products all supported the feature of notifying the farmer when a sheep has stopped moving, which makes it quicker and easier to find any sick, dead or injured sheep.

4 Requirements

4.1 Elicitation

All the requirements for both the Herd website and the Herd mobile application were elicitated together with my Master's supervisor, Svein-Olaf Hvasshovd. He has a significant experience and understanding of the process of, and challenges with, supervising grazing sheep. This knowledge has been accumulated by professor Hvasshovd not only by conducting sheep supervisions himself, but also through him being a supervisor to multiple Master's students that worked on related projects. The most essential requirements for the Herd mobile application were elicited during our initial meeting at the start of the specialization project in the autumn semester of 2021, while the requirements for the Herd website were elicitated at the start of the spring semester of 2022. These initial meetings laid the groundwork for my understanding of the problem area, and of the feature set that is to be supported by the new digitalized system.

Weekly meetings were arranged with professor Hvasshovd. These meetings were a good area for sharing ideas, solutions, design prototypes, development progress, and implementations. This initiated discussions and refinements concerning existing requirements, possible additional requirements, and how the requirements are prioritized.

User testing was another significant contribution to the requirements elicitation. This type of testing was a great way of refining current requirements so they better aligned with the needs of the user, and for discovering additional requirements that were overlooked during the initial elicitation meetings.

4.2 Mobile App - Functional Requirements

In this section, the functional requirements for the Herd mobile application will be presented. These requirements are identical to those that were elicited during the specialization project [3]. The requirements for registering a new user profile can be seen in Table 1, while the requirements for logging in are seen in Table 2. Table 3 presents the requirements for every map in the application. Requirements that are directly related to the supervision of sheep are shown in Table 4, while the requirements that are related to registering observations are given in Table 5.

The "Priority" column in the tables below indicates each functional requirement's priority. If a requirement has a priority of "low", it means that it would be good if it was fulfilled, but that it could be omitted in favor of more important requirements. A "medium" priority requirement *should* be implemented in the system, while a requirement with a "high" priority is essential and *must* be fulfilled.

Table 1: Functional requirements for registering a new profile account

ID	**Priority**	**Description**
FR1.0	High	The app should allow a user to register a profile account
FR1.1	High	The app should require the user to provide their e-mail address when registering for an account
FR1.2	High	The app should require the user to provide a password when registering for an account

FR1.3	Low	The app should require the user to provide their full name when registering for an account
FR1.4	Low	The app should require the user to provide their farm number (gårdsnummer) when registering for an account
FR1.5	Low	The app should allow the user to provide their cadastral number (bruksnummer) when registering for an account
FR1.6	Low	The app should require the user to provide the municipality of which the farm is located, when registering for an account

Table 2: Functional requirements for logging in with an existing profile account

ID	**Priority**	**Description**
FR2.0	High	The app should allow a user to log in using their e-mail, farm number and password
FR3.0	Medium	The app should allow a user to log out
FR4.0	Low	The app should persist a user's login

Table 3: Functional requirements for maps

ID	**Priority**	**Description**
FR5.0	High	The app should allow a user to use a map during supervisions
FR5.1	High	The app should support using maps at any location within Norway
FR5.2	Medium	The app should allow a user to zoom in or out on any map using pinching
FR5.3	Medium	The app should allow a user to pan any map using scrolling/dragging
FR6.0	High	The app should allow a user to download map tiles (areas of a map) for offline-use
FR6.1	Medium	The app should allow a user to download as many map tiles as they are able to store on their phone's storage
FR6.2	Medium	The app should allow a user to delete all downloaded map tiles from their phone
FR6.3	Low	The app should always check for and use a downloaded map tile *before* trying to retrieve it from the internet

Table 4: Functional requirements for supervisions

ID	**Priority**	**Description**
FR7.0	High	The app should allow a user to start a supervision
FR7.1	High	The app should allow a user to finish an ongoing supervision
FR7.2	Medium	The app should allow a user to cancel an ongoing supervision
FR7.3	Medium	The app should automatically register the start- and end-time of a supervision
FR8.0	High	The app should allow a user to perform supervisions without internet access
FR8.1	Low	The app should allow a user to perform supervisions without having to log in to their profile account

FR9.0	High	The app should track and store the path a user walked when performing a supervision
FR9.1	Medium	The app should show a user's position on a map during supervisions
FR9.2	Medium	The app should continue to track and store the path a user walked when performing a supervision even when the app is backgrounded or the phone gets locked
FR9.3	Medium	The app should *display* to the user the path they walk while performing a supervision
FR10.0	High	The app should allow a user to register observations while on a supervision
FR10.1	Medium	The app should allow a user to view the observations that are registered during a current ongoing supervision
FR10.2	Low	The app should allow a user to delete observations from a current ongoing supervision
FR11.0	High	The app should allow a user to upload a locally-stored supervision to the cloud

Table 5: Functional requirements for registering an observation

ID	**Priority**	**Description**
FR12.0	High	The app should require a user to define the approximate location of what is being observed
FR12.1	Medium	The app should automatically register the user's location when an observation is registered
FR12.2	Low	The app should automatically register the current time when an observation is registered
FR13.0	High	The app should allow a user to choose the type of observation
FR13.1	High	The app should support 6 types of observations: ewes, lambs, sheep in general, predators, injured sheep, and dead sheep.
FR14.0	High	The app should allow a user to register the number of observed sheep, ewes and lambs
FR14.1	High	The app should allow a user to register the wool color of the sheep, ewes and lambs
FR14.2	Medium	The app should give a user the ability register the tie color of the sheep and ewes (this is usually registered when a user is close enough to see it, which is typically around 30-50 meters away)
FR14.3	Medium	The app should give a user the ability register the owner mark color of the sheep, ewes and lambs (this is usually registered when a user is close enough to see it, which is typically around 30-50 meters away)
FR15.0	Medium	The app should allow a user to register the type of injury, tie color, and owner mark color of an injured sheep
FR16.0	Medium	The app should allow a user to register the cause of death, tie color, and owner mark color of a dead sheep
FR17.0	Medium	The app should allow a user to register the type of predator that is being observed

4.3 Mobile App - Non-Functional Requirements

The ISO/IEC 25010 standard defines "Quality attributes" for computer software [20]. In this standard, attributes that contribute to software quality are grouped into eight different categories. "Usability" is one of these, and this was chosen as the main quality attribute for the design and development of the Herd mobile application. The reason why usability is the main focus, is because one of the main goals of this project was to develop a system for performing and documenting supervisions of sheep in an efficient, satisfactory, and effective way.

In addition to the main quality attribute, we have secondary quality attributes that are also important during software development. *Performance* was chosen as the secondary quality attribute to focus on for this project. Performance is an important aspect of the Herd application, as users may become annoyed or dissatisfied if the system is performing poorly. Poor performance could also cause a supervisor to lose their focus on what they were trying to observe.

The quality attributes' non-functional requirements are defined and communicated using *scenarios*. These scenarios were created during the specialization project [3]. Scenarios are made up of six parts (as seen in [21]):

- **Source of stimulus**. This is some entity (a human, a computer system, or any other actuator) that generated the stimulus. [21]
- **Stimulus**. The stimulus is a condition that needs to be considered when it arrives at a system. [21]
- **Environment**. The stimulus occurs within certain conditions. The system may be in an overload condition or may be running when the stimulus occurs, or some other condition may be true. [21]
- **Artifact**. Some artifact is stimulated. This may be the whole system or pieces of it. [21]
- **Response**. The response is the activity undertaken after the arrival of the stimulus. [21]
- **Response measure**. When the response occurs, it should be measurable in some fashion so that the requirement can be tested. [21]

Table 6 through Table 12 present the scenarios for the main quality attribute of *usability*, and Table 13 and Table 14 give the scenarios for the secondary quality attribute of *performance*.

UR1 - The user should, in less than 2 minutes, be able to learn how to start and finish a supervision

Table 6: Usability scenario 1 - Learn how to start and finish a supervision

Source of stimulus	End user
Stimulus	User wants to learn how to start and finish a supervision
Artifact	User-interface
Environment	Runtime
Response	User is able to start and finish a supervision without errors
Response measure	User correctly understands, in less than 2 minutes, how to both start and finish a supervision

UR2 - The user should, in less than 10 minutes, be able to learn how to register all types of observations

Table 7: Usability scenario 2 - Learn how to register all types of observations

Source of stimulus	End user
Stimulus	User wants to learn how to register all types of observations
Artifact	User-interface
Environment	Runtime
Response	User is able to, without errors, register observations of a group of sheep, ewes, lambs, predators, injured/sick sheep, and dead sheep.
Response measure	User correctly understands, in less than 10 minutes, how to register all the different types of observations

UR3 - The user should, in less than 10 seconds, be able to cancel the registration of an observation

Table 8: Usability scenario 3 - Learn how to cancel the registration of an observation

Source of stimulus	End user
Stimulus	User wants to minimize the impact of mistakenly starting the observation registration process
Artifact	User-interface
Environment	Runtime
Response	User is able to, without errors, cancel the registration of an observation.
Response measure	User correctly understands, in less than 10 seconds, how to cancel the registration of an observation

UR4 - The user should, in less than 1 minute, be able to learn how to inspect previously-conducted supervisions

Table 9: Usability scenario 4 - Learn how to inspect previously-conducted supervisions

Source of stimulus	End user
Stimulus	User wants to learn how to inspect previously-conducted supervisions
Artifact	User-interface
Environment	Runtime
Response	User is able to, without errors, inspect information about previously-conducted supervisions
Response measure	User correctly understands, in less than 1 minute, how to inspect previously-conducted supervisions

UR5 - The user should, in less than 1 minute, be able to learn how to download a map

Table 10: Usability scenario 5 - Learn how to download a map

Source of stimulus	End user
Stimulus	User wants to learn how to download a map for offline-use
Artifact	User-interface
Environment	Runtime
Response	User is able to use the map download functionality without errors
Response measure	User correctly understands, in less than 1 minute, how to download a map

UR6 - The user should, in less than 30 seconds, be able to learn how to delete downloaded maps

Table 11: Usability scenario 6 - Learn how to delete downloaded maps

Source of stimulus	End user
Stimulus	User wants to learn how to delete the downloaded maps from their device
Artifact	User-interface
Environment	Runtime
Response	User is able to delete the maps without errors
Response measure	User correctly understands, in less than 30 seconds, how to delete the downloaded maps

UR7 - The user should, without errors and while using binoculars, be able to register lambs, ewes and sheep in general, and their wool and tie color

Table 12: Usability scenario 7 - Make registrations while using binoculars

Source of stimulus	End user
Stimulus	User wants to register observations while using binoculars
Artifact	User-interface
Environment	Runtime
Response	User is able to make the correct registrations without errors
Response measure	User is able to, without errors and while using binoculars, register lambs, ewes and sheep in general, and their wool and tie color

PR1 - The user's location should be established and displayed to the user in less than 10 seconds

Table 13: Performance scenario 1 - Establish and display the user's location

Source of stimulus	End user
Stimulus	User enters a page that has a map
Artifact	Application
Environment	Runtime
Response	User is correctly located, and the location is displayed on the map
Response measure	The user is located, and the location is displayed, in less than 10 seconds

PR2 - The application should upload a locally-stored supervision in less than 5 seconds

Table 14: Performance scenario 2 - Upload a locally stored supervision

Source of stimulus	End user
Stimulus	User tries to upload a locally-stored supervision
Artifact	System
Environment	Runtime
Response	The locally-stored supervision is uploaded to the server
Response measure	The supervision is uploaded in less than 5 seconds

4.4 Website - Functional Requirements

As with the mobile application, the Herd website allows the user to register and login with a user account. The website's requirements that are related to registering and logging in are identical to those of the mobile application. These requirements are therefore not necessary to present again in this section, and they can instead be seen in Table 1 and Table 2.

The website's functional requirements for presenting, deleting, filtering and sorting supervisions can be seen in Table 15. The functional requirements for inspecting supervisions are presented in Table 16, while the functional requirements for the supervision report are given in Table 17.

Table 15: Functional requirements for presenting, deleting, filtering and sorting supervisions

ID	Priority	Description
FR1.0	High	The website should present the user with their, and only their, supervisions
FR2.0	High	The website should allow a user to filter away supervisions that were performed *before* a set date
FR2.1	High	The website should allow a user to filter away supervisions that were performed *after* a set date
FR3.0	Medium	The website should allow a user to sort the presented supervisions by date, number of observations, and duration
FR3.1	Medium	The website should allow a user to sort their supervisions in either ascending or descending order
FR4.0	Medium	The website should allow a user to delete one or more supervisions

Table 16: Functional requirements for inspecting supervisions

ID	Priority	Description
FR5.0	High	The website should allow the user to inspect their supervisions together on a single map
FR5.1	Medium	The website should allow the user to inspect their supervisions next to each other on different maps; one map per supervision
FR6.0	High	When inspecting a supervision, the website should allow the user to click on an observation, which should reveal all information about that observation
FR6.1	High	When inspecting a supervision, the website should show the path that the user walked when they performed that supervision

Table 17: Functional requirements for the supervision report

ID	Priority	Description
FR7.0	High	The website should allow the user to generate a PDF report of the selected supervisions
FR7.1	High	An image of the map of each selected supervision (showing the user's path and observation locations) should be included in the report
FR7.2	High	The generated report should include what date each selected supervision was performed
FR7.3	High	The generated report should include each selected supervision's total number of observed lambs
FR7.4	High	The generated report should include each selected supervision's total number of observed healthy adult sheep
FR7.5	High	The generated report should include each selected supervision's total number of observed injured sheep
FR7.6	High	The generated report should include each selected supervision's total number of observed dead sheep
FR7.7	Medium	The generated report should include each selected supervision's start time
FR7.8	Medium	The generated report should include each selected supervision's end time
FR7.9	Medium	The generated report should include each selected supervision's total number of observed wolverines
FR7.10	Medium	The generated report should include each selected supervision's total number of observed predators excluding wolverines

4.5 Website - Non-Functional Requirements

The quality attributes that are prioritized for the Herd website are the same as for the Herd mobile application, which were presented in Section 4.3. This means that the primary quality attribute for the website is usability, and the secondary quality attribute is performance. As with the mobile application, the quality attributes' non-functional requirements for the website are defined and communicated using scenarios. The website's scenarios can be seen starting from Table 18 going to Table 24.

UR1 - The user should, in less than 1 minute, be able to learn how register for a user profile

Table 18: Usability scenario 1 - Learn how to register for a user profile

Source of stimulus	End user
Stimulus	User wants to learn how to register for a user profile
Artifact	User-interface
Environment	Runtime
Response	User is able to register for a user profile without errors
Response measure	User correctly understands, in less than 1 minute, how to register for a user profile

UR2 - The user should, in less than 30 seconds, be able to learn how to filter their supervisions by start- and end-date

Table 19: Usability scenario 2 - Learn how to filter supervisions by date

Source of stimulus	End user
Stimulus	User wants to learn how to filter their previously-conducted supervisions by start- and end-date
Artifact	User-interface
Environment	Runtime
Response	User is able to filter the supervisions without errors
Response measure	User correctly understands, in less than 30 seconds, how to filter their supervisions

UR3 - The user should, in less than 30 seconds, be able to learn how to sort their supervisions

Table 20: Usability scenario 3 - Learn how to sort supervisions

Source of stimulus	End user
Stimulus	User wants to learn how to sort their supervisions
Artifact	User-interface
Environment	Runtime
Response	User is able to sort their supervisions without errors
Response measure	User correctly understands, in less than 30 seconds, how to sort their supervisions

UR4 - The user should, in less than 1 minute, be able to learn how to delete a supervision

Table 21: Usability scenario 4 - Learn how to delete a supervision

Source of stimulus	End user
Stimulus	User wants to learn how to delete a supervision
Artifact	User-interface
Environment	Runtime
Response	User is able to delete their supervision without errors
Response measure	User correctly understands, in less than 1 minute, how to delete their supervision

UR5 - The user should, in less than 1 minute, be able to learn how to inspect their supervisions on a map

Table 22: Usability scenario 5 - Learn how to inspect their supervisions on a map

Source of stimulus	End user
Stimulus	User wants to learn how to inspect their supervisions on a map
Artifact	User-interface
Environment	Runtime
Response	User is able to inspect their supervisions on a map without errors
Response measure	User correctly understands, in less than 1 minute, how to inspect their supervision on a map

UR6 - The user should, in less than 1 minute, be able to learn how to generate a supervision report

Table 23: Usability scenario 6 - Learn how to generate a supervision report

Source of stimulus	End user
Stimulus	User wants to learn how to generate a report of their supervisions
Artifact	User-interface
Environment	Runtime
Response	User is able to generate a supervision report without errors
Response measure	User correctly understands, in less than 1 minute, how to generate a report of their supervisions

PR1 - A report of 10 supervisions should be generated in less than 20 seconds

Table 24: Performance scenario 1 - Generate supervision report

Source of stimulus	End user
Stimulus	User selects 10 supervisions and tries to generate a PDF report of these
Artifact	Application
Environment	Runtime
Response	The PDF report is generated and starts downloading
Response measure	The report is generated and starts downloading in less than 20 seconds

5 Design Method and Pre-Study

This section will examine the chosen design method that was employed when creating the design of the Herd website and mobile application. The pre-study for the design will also be presented in this section, which included the creation of user scenarios and user personas.

5.1 The Design Method

ISO 9241-210 defines a standard for how to conduct an iterative user-centered design process [22], and this standard has been followed throughout the development and design of both the Herd website and the Herd mobile application. The core aspect of this process is to achieve a usable and high-quality design by actively having users participate in multiple iterations of the design. Figure 11 gives an illustration of this iterative process.

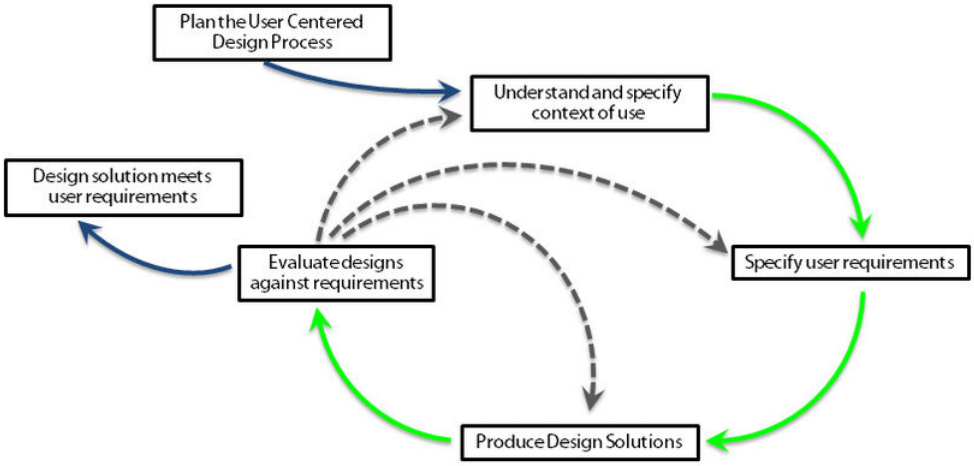

Figure 11: Illustration of the standard for iterative user-centered design as it is defined in ISO 9241-210 [22]

The first step of the design process was to create a plan for the rest of the process. In this phase, I decided that I wanted to initiate the design process by creating relevant user scenarios and user personas. These are good tools for not only understanding the context of use, but also for specifying and communicating it. The next phase in the plan then included creating and user testing both a paper prototype, and a functional implementation, of the Herd mobile application during the autumn semester of 2021, and of the Herd website during the spring semester of 2022. A consideration was made about having a design iteration where I would develop a digital prototype between the development of the paper prototype and the actual implementation, but this idea was quickly laid to rest because of the foreseen constraints on the available time resources. If a larger time budget was available, this second iteration would have been beneficial to possibly discover more usability issues with the design before committing to a final design solution to develop and implement.

After the plan for the design process had been finalized, it was time to start creating the planned user scenarios and personas. The finished personas are presented in Section 5.2, while the scenarios are presented in 5.3. It is important to mention that while the design process of the Herd mobile application and the Herd website are similar and make use of these same user personas

and scenarios, the mobile application was designed, developed and user tested during the autumn semester of 2021, while this took place in the spring semester of 2022 for the Herd website. After the user personas and scenarios were finalized, the next phase of the mobile application's and website's design process was to specify the complete requirements, as seen in Section 4. Following this, the design solution's first iteration, a paper prototype, was created for the mobile application and the website, as seen in Section 6 and Section 8 respectively. The next step for these two design processes was then to user test the paper prototype to uncover any possible usability problems and to see if the design could satisfy the requirements. The findings and results from the user tests were then taken into consideration during the next phase of the design processes, which involved iterating on the design of, and developing, the mobile application and website. After this, the functional website and mobile application were then user tested for the same reasons as their paper prototypes.

5.2 User Personas

Three different user personas were created using statistics from SSB (Statistics Norway) [23][24][25] as the user group's characteristics. *Personas* is a good tool in software design, as it allows and encourages designers to think of users in more specific terms, rather than generic [26]. The different personas can be thought of as arche-typical users that represent the characteristics and goals of larger user groups [26]. This is visible in the form of the percentage seen in the title of each persona below, which serves as an estimated guess of how much of the total target group that could be represented by that persona. It is also worth mentioning that the pictures seen in each persona are not actually of real people, but are generated by an AI on ThisPersonDoesNotExist.com [27]. The three different personas are shown in Figure 12, 13 and 14. The first persona, Dan Remi, is considered as representative of the target group's largest user segment.

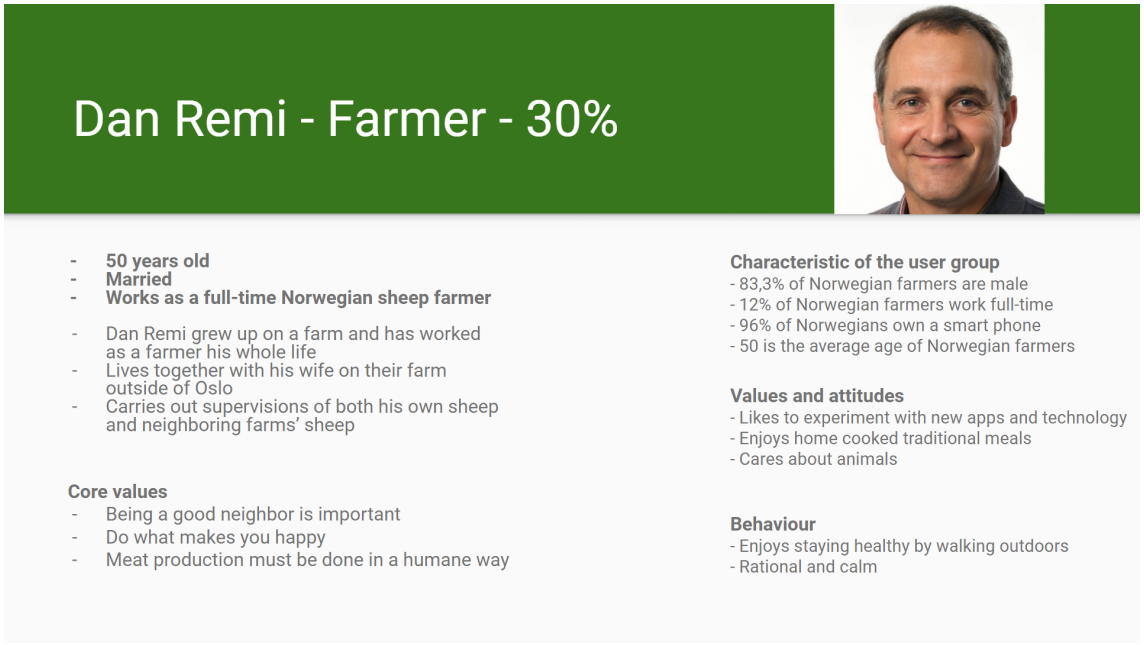

Figure 12: Persona 1 - Dan Remi

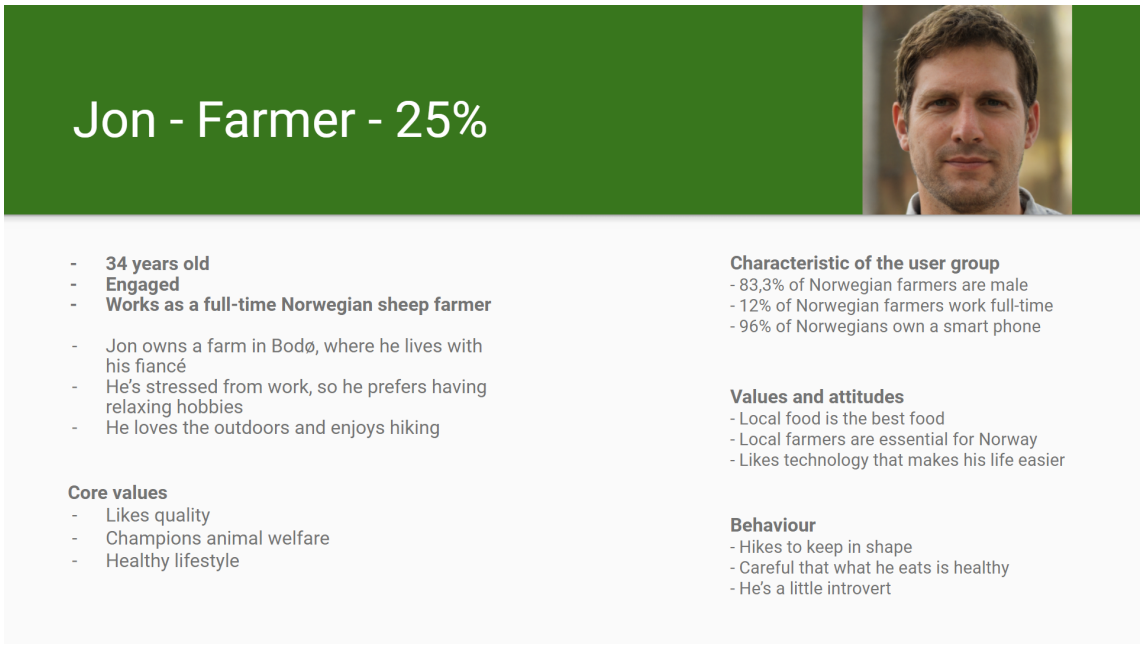

Figure 13: Persona 2 - Jon

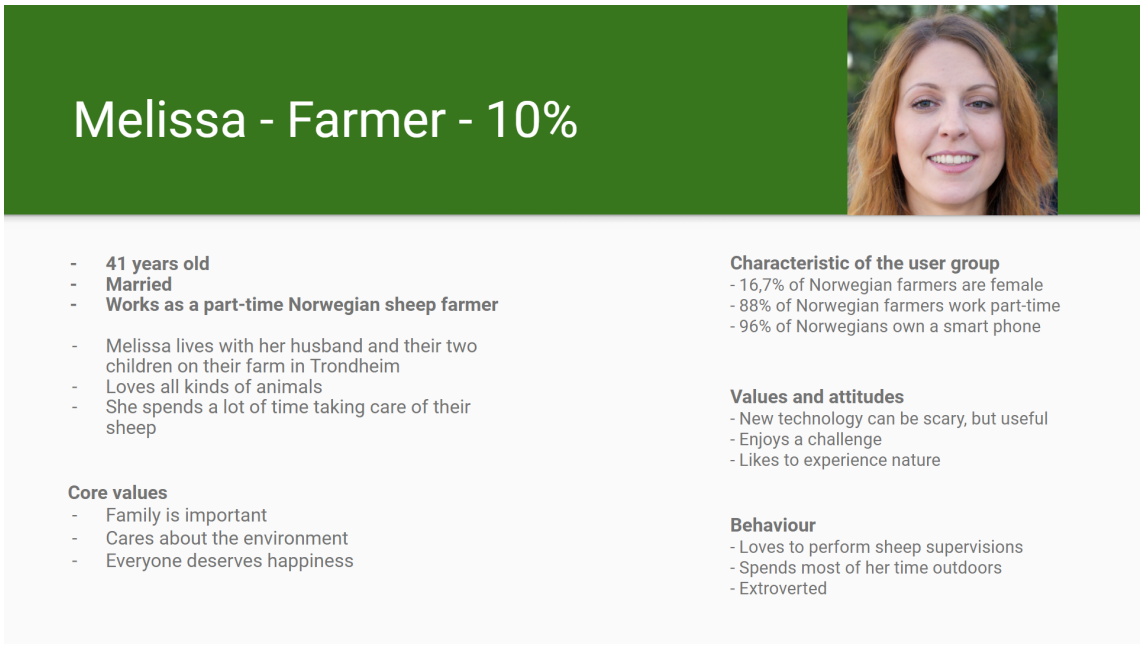

Figure 14: Persona 3 - Melissa

5.3 User Scenarios

"User scenarios" were used to better understand and communicate the Herd system's multiple user situations. These scenarios are helpful when integrating the needs and desires of the users into the design process, and when decisions about functionality and features are made [28]. When creating the scenarios, the user personas and the expected context-of-use served as the foundation. At the start of the project, multiple textual user scenarios were written. Out of these textual scenarios, the four that I felt best communicated common user situations were further processed and 3D-visualized using a digital tool called "Dreams" [29].

The four user scenarios were created in the specialization project in 2021 [3]. The first user scenario can be seen in Figure 15. This scenario shows how users can document observations of grazing sheep, as well as showing the necessity of a mobile application that supports the use of binoculars during the registration process. Figure 16 gives the second scenario, which shows how a user can register a deceased sheep using the application, and that a supervision can be uploaded to a server. The third scenario is seen in Figure 17, and this shows how a user can register a dangerous predator using the Herd mobile application. The fourth and final scenario is given in Figure 18, where we can see how a user can register an injured sheep in the mobile application, in addition to showing how the website can be used to generate and download a report that summarizes supervisions.

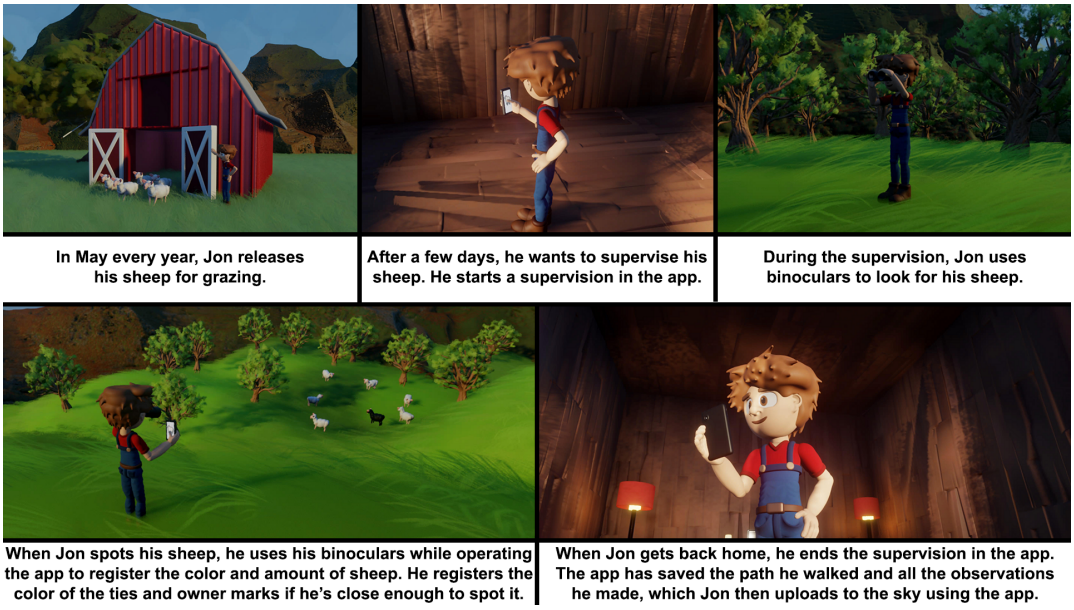

Figure 15: Scenario 1 shows how a user can use the app to register observations of grazing sheep, as well as showing the necessity of a mobile application that supports the use of binoculars during the registration process.

Figure 16: Scenario 2 shows how a user can register a deceased sheep using the application, and that a supervision can be uploaded to a server.

Figure 17: Scenario 3 shows how a user can register a dangerous predator using the application.

Figure 18: Scenario 4 shows how a user can register an injured sheep in the mobile application, in addition to showing how the website can be used to generate and download a report that summarizes supervisions.

6 Mobile App - The Paper Prototype

In this section, the first design iteration of the mobile application, a paper prototype, will be presented. The section starts by looking at how the paper prototype was created, and then the design quality guidelines and the flowchart are presented. Following this, a thorough walkthrough of the paper prototype is given, along with the design rationale. The section ends by looking at the user tests and the results from these.

6.1 How the Paper Prototype Was Created

As this is the first iteration of the design, the design will likely experience large changes and variations. The consequences of making changes to the design should at this point therefore be as small as possible, and that is why the first design iteration was chosen to be a *paper* prototype. A paper prototype does not require as much effort to develop as a real functional application, and it can rapidly be modified when superior design solutions are discovered. The paper prototype was created using a foundation consisting of the design pre-study, the design quality guidelines (seen in Section 6.2), and the functional and non-functional requirements (presented in Section 4.2 and Section 4.3 respectively).

When making the design, I actively incorporated different design principles. Experiences from NTNU courses like IT3402 "Design of Graphical User Interfaces" and "TDT4180 Human-Machine Interaction" made me follow Don Norman's design principles and Jacob Nielsen's design heuristics. By actively following and using these two sets of design guidelines, I hope to more easily achieve a design that delivers a high level of usability and a good user experience.

One risk during this project is that the Covid-19 pandemic forces the physical supervisor meetings to become digital. To mitigate the impact this would have, the paper prototype was drawn using digital software (Photoshop). Having the prototype available digitally would make it a lot easier to present and discuss the prototype with my supervisor in the case where we would be forced to have our meetings digitally. Using digital software to draw the paper prototype also allowed me to effectively reuse control elements and pages that occurred frequently in the prototype.

Even though the paper prototype was drawn using digital software, it is still made in accordance with the ideas of a "low fidelity prototype" [30][p. 389-391]. This means that this is a simplified and non-functional prototype that does not necessarily need to share similarities with the final design solution. This design iteration has not gone through user testing yet, so its low production cost will be beneficial once design improvements are revealed during testing.

6.2 Design Quality Guidelines

Using the design pre-study (presented in Section 5) as a foundation, a set of design quality guidelines were constructed. These serve as universal guidelines that will steer the development of the design, and it will therefore be imperative to keep these in mind when creating both the paper prototype and the future design iterations. The design quality guidelines are presented below.

- **Usability:** The design should be intuitive and self-explainable
- **Content correctness:** The content presented in the design should be trust-worthy and correct

- **Esthetics:** The design should be visually pleasing, without overwhelming the users with unnecessary information and options
- **User-centered design:** The design should be developed with the inclusion of users
- **User experience:** The application should provide the user with a good user experience

6.3 Flowchart

The flowchart for the Herd mobile application's paper prototype can be seen in Figure 19. This flowchart was created to better communicate and apprehend the flow of the application and the interconnectedness of its parts. Dotted-border rectangles in the flowchart depict events or actions, instead of specific pages of the application. A more thorough walkthrough of the mobile application's paper prototype is given in Section 6.4.

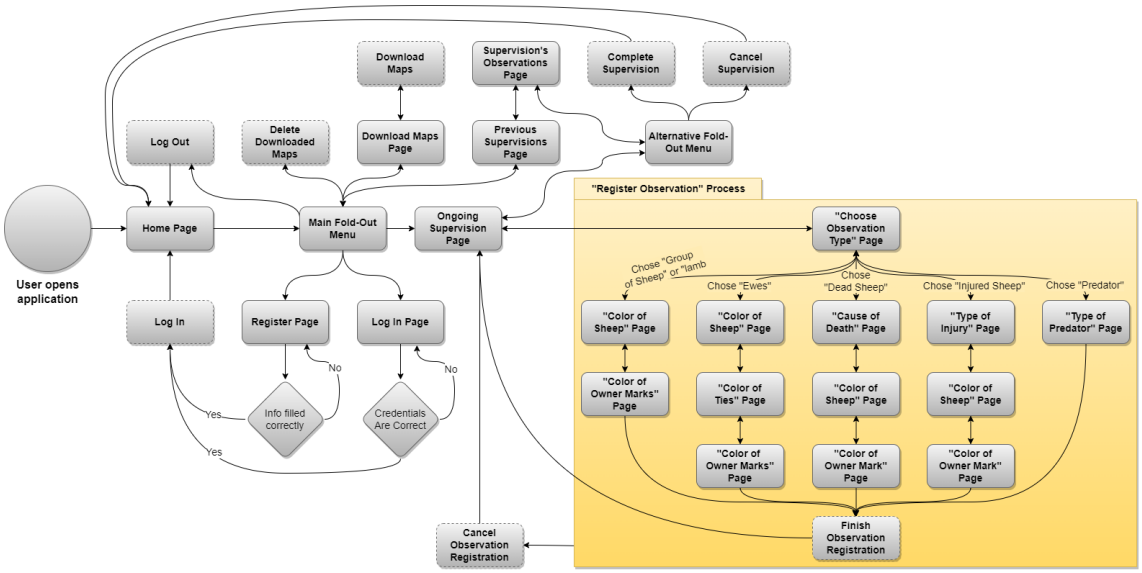

Figure 19: Flowchart showing the flow and interconnectedness of the mobile app's paper prototype

6.4 Walkthrough of the Paper Prototype

A detailed walkthrough of the Herd mobile application's paper prototype will be given in this section. This walkthrough will be helpful for understanding the prototype's usage processes and flows. The language in the paper prototype is Norwegian, as the target users are Norwegian farmers and supervisors. Throughout the walkthrough, multiple references to the prototype will be made, which is presented starting from Figure 20 going to Figure 37.

The Home Page

The home page, seen in Figure 20, is the first page that greets a user when they open the mobile application. On this home page, the user's current location is presented on a map. The map can also be interacted with by using dragging or pinch-zooming gestures. The "hamburger" button in the top left corner reveals a fold-out menu when clicked, as shown in Figure 21. Clicking anywhere outside this menu will close it.

Figure 20: Home page

Figure 21: "Hamburger" fold-out menu

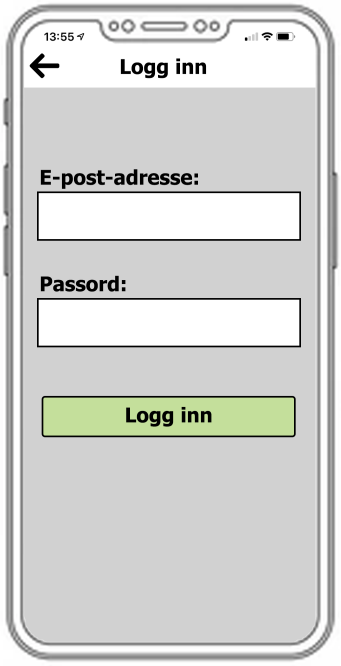

Figure 22: Login page

Figure 23: Register page

Logging in and Registering

There are multiple options in the fold-out menu for the user to choose from. If a user is already logged in, "Logg ut" (Log out) replaces the options of "Logg inn" (Log in) and "Registrer" (Register). The user is brought to the login page, shown in Figure 22, if they click on "Logg inn". On this page a user can enter their password and e-mail to log in. The user is directed back to the home page if the login is successful or if they press the arrow button located in the top left corner.

If the user wants to register for a new user instead of logging in, they can click the "Register" option from the fold-out menu, which opens the register page seen in Figure 23. On the register page, the user can register for a new account by filling in the fields and clicking "Register". After a user has successfully registered, they are automatically logged in and brought back to the home page.

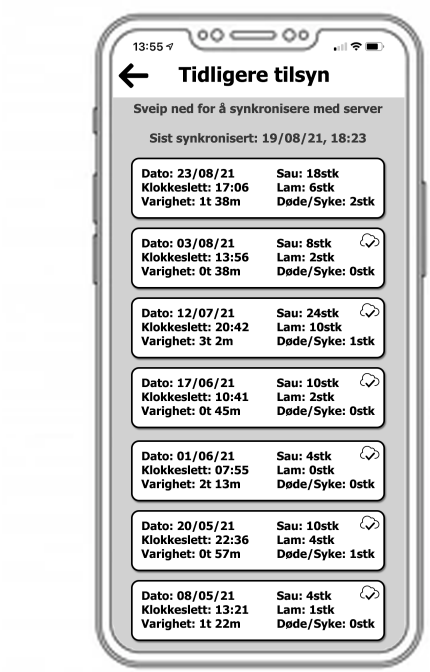

Figure 24: Page showing previous supervisions

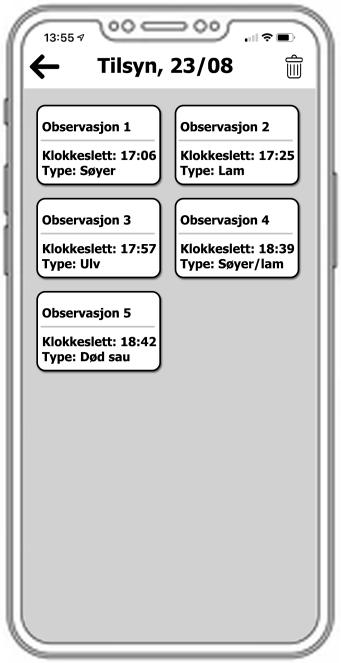

Figure 25: Page showing the observations registered during a specific supervision

Previous Supervisions

The fold-out menu also contains the option of "Tidligere tilsynsturer", which when clicked presents the user with a page showing their previously-performed supervisions, as seen in Figure 24. These locally-stored supervisions can be uploaded to the server by swiping the list downwards. More information can be seen about a supervision by clicking on it from this list, which opens the observations page presented in Figure 25. Here the user can inspect all the observations made during that specific supervision. If the user wants to delete any observation, they can do so by clicking the trash can button in the top right corner, and then click on the "X" button in the top right corner of the observation. By clicking this "X" button, the observation is deleted and the list is updated. Pressing the arrow in the top left corner once directs the user to the list of previous supervisions, and pressing it again directs them back to the home page.

Downloading and Deleting Maps

When the fold-out menu's "Last ned kart" option is clicked, it brings the user to the page for downloading maps, as seen in Figure 26. On this page, there is a button labelled "Last ned dette kartutsnittet" located at the bottom center of the screen. If the user clicks this button, the application will start downloading all the tiles that are currently making up the map on the phone screen, including map tiles for four different zoom levels. The user can return to the home page by pressing the arrow button in the top left corner.

The user could also instead press the "Slett nedlastede kart" option from the fold-out menu. A window will then ask the user for confirmation that they want to delete all their downloaded map tiles, as seen in Figure 27. By clicking "Slett" in this window, all locally-stored map tiles will be deleted from the user's phone.

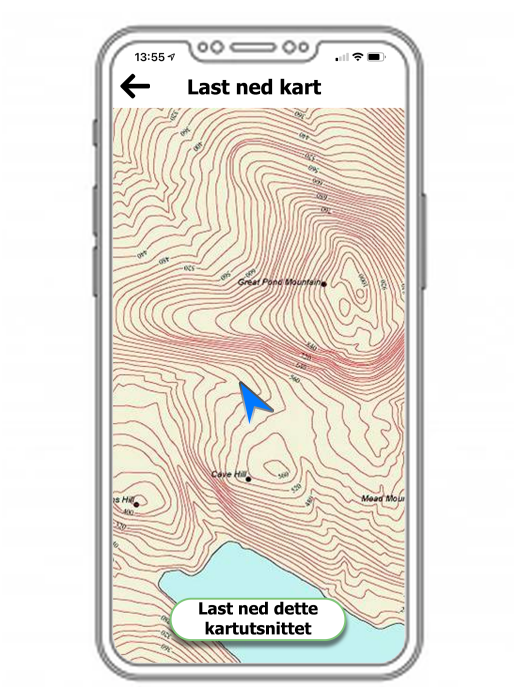

Figure 26: Page for downloading maps for offline use

Figure 27: Modal asking the user to confirm that they want to delete their downloaded map tiles

Starting a New Supervision

If the user wants to initiate a new supervision, they can click the "Start ny tilsynstur" from the fold-out menu, which opens the page seen in Figure 28. The button located at the bottom center of this page, labelled "Ny observasjon", will initiate the observation registration process when clicked, which is a process that starts on the page seen in Figure 30. Before starting this process though, the user is able to select the location of what is being observed. This is done by dragging the map (in Figure 28) so that the centered cross on the screen is placed at the observation's position. While performing a supervision, the hamburger-button opens an alternative fold-out menu when clicked, as shown in Figure 29. This menu can be closed by clicking anywhere outside it.

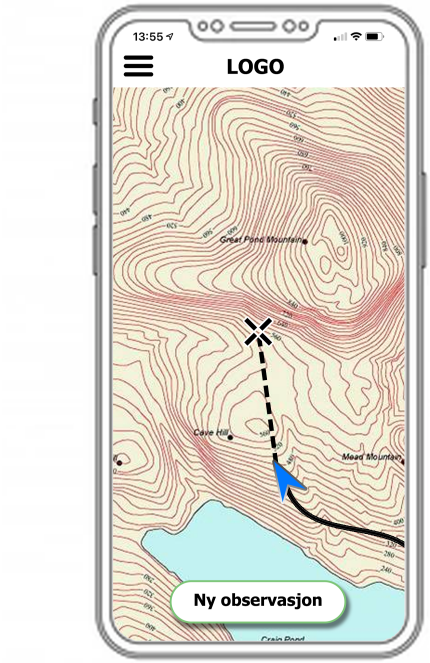

Figure 28: Page when a new supervision is ongoing

Figure 29: The "hamburger" fold-out menu during an ongoing supervision

The Alternative Fold-Out Menu During Supervisions

The alternative fold-out menu contains three different options. The menu's first option, "Fullfør tilsynstur", completes and locally saves the supervision. "Avbryt tilsynstur" is the second option, and choosing this will abort the ongoing supervision and discard any related observations. The final option, "Foreløpige observasjoner", presents the user with the ongoing supervision's observations on a page identical to the one seen in Figure 25. Similar to the page that shows observations from previous supervisions, this page also allows the user to delete related observations.

Choosing the Type of Observation to Register

As mentioned earlier, there is a "Ny observasjon" button on the page for an ongoing supervision (Figure 28). Clicking this button initiates the observation registration process, starting with the user having to choose the observation type, as seen in Figure 30. Here, the user can choose between "injured sheep", "dead sheep", "ewes", "lambs", "group of sheep", and "predators". When a type of observation is clicked on, its color changes to yellow, signaling that this type is now "chosen". If the user then clicks on the "Neste button", the registration process will continue using the "chosen" observation type. Both the "X" button in the top right corner and the "Avbryt" button will, when clicked, abort the registration process and bring the user back to the page for an ongoing supervision.

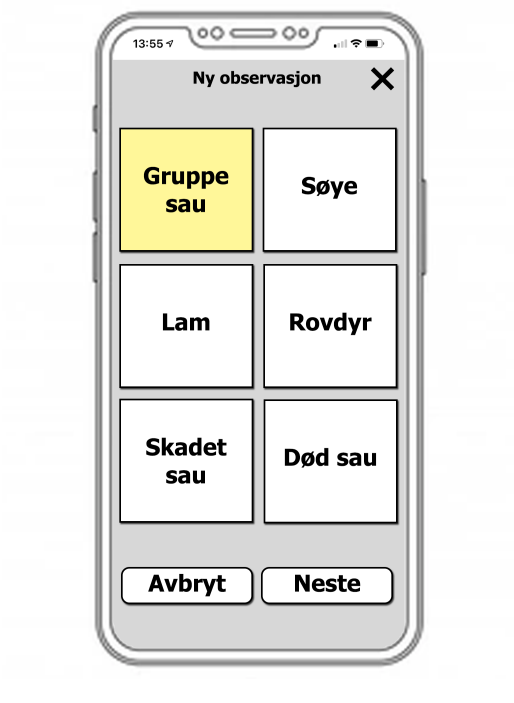

Figure 30: The registration of a new observation starts with having to choose the observation type

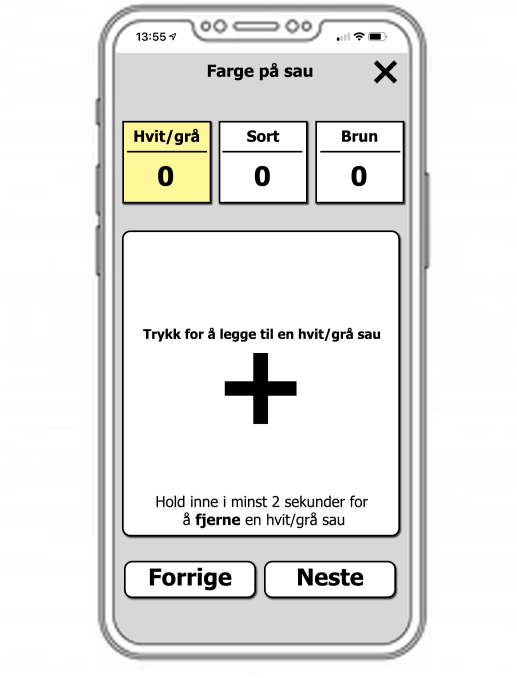

Figure 31: The colors of the observed sheep can be registered

Observing a Group of Sheep or Lambs

If the observation type was chosen to be either lambs or a group of sheep, the next step in the process is to register the color and the amount of observed sheep, as shown in Figure 31. There are three buttons on the top of this page, each corresponding to a different color of sheep. Clicking one of these buttons sets it as the "chosen" color, and then pressing the large "+" button in middle of the screen will increment the number for that chosen color. Similarly, holding the "+"-button down for 2 seconds will decrement the number for the chosen color. The "Forrige" button directs the user back to the previous step when clicked, and the "Neste" button moves the user to the next and final step seen in Figure 32.

In the final step seen in Figure 32, the owner mark colors can be registered in the same way as how the sheep's colors were registered. The user can finish the registration process by clicking "Fullfør" on this page. This will save the observation, and direct the user back to the page for the ongoing supervision.

Observing Ewes

The process of registering ewes is very similar to that of registering groups of sheep or lambs. What differentiates the two processes is that for ewes there is an extra step for registering the color of the ewes' ties, as seen in Figure 33. This step happens between the step of registering the sheep's wool color and the step of registering the color of the owner marks, and is also performed in the same way as these two steps.

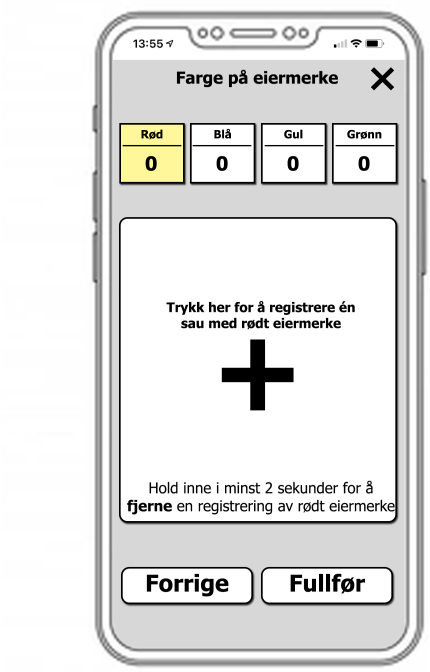

Figure 32: Registering the colors of the sheep's owner marks

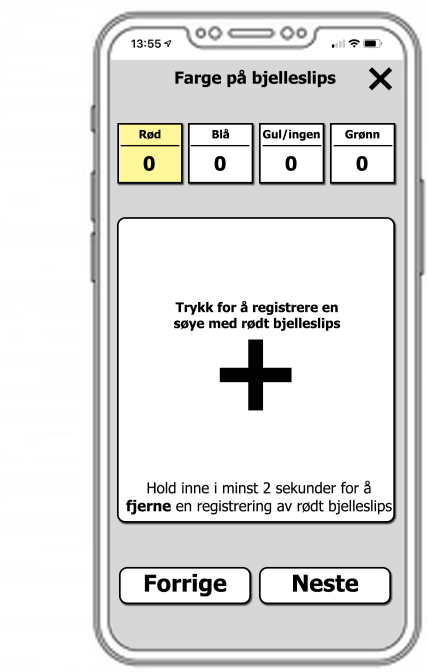

Figure 33: Registering the colors of the sheep's ties

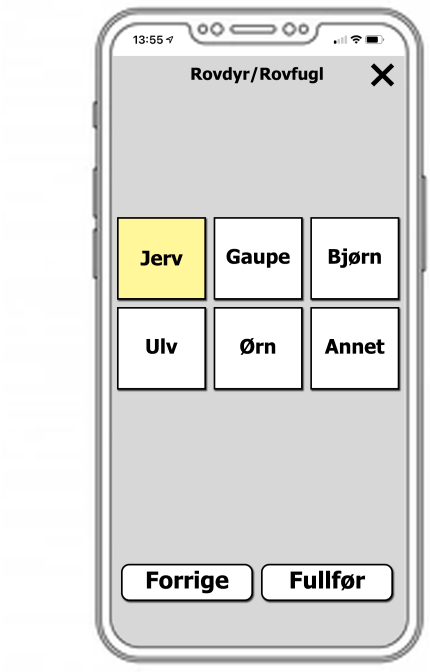

Figure 34: Registering predators

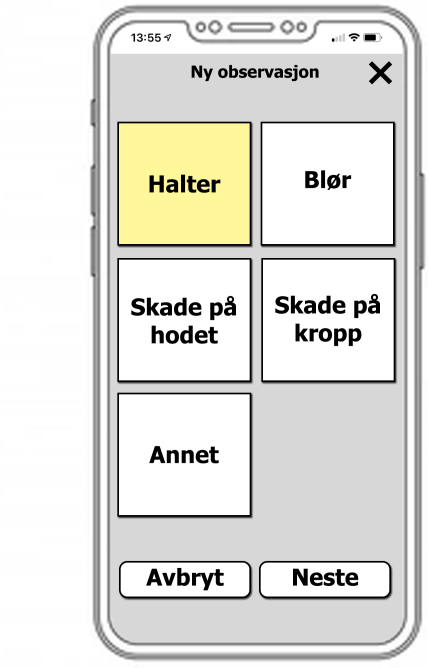

Figure 35: Registering the injury type of an injured sheep

Observing Predators

The registration of a predator observation includes only one step, which is shown in Figure 34. At this step, the user can select which predator was observed, and then click on "Fullfør" to finish and save this registration.

Observing an Injured Sheep

Figure 35 shows the next registration step for observations of injured sheep. On this first step, the user can choose what injury the observed sheep had obtained. The "Neste" button directs the user to the page seen in Figure 36. On this page, the color of the injured sheep can be registered in the same way as with the type of injury. By pressing "Neste", the user is sent to the final step, where they can register the color of the owner mark, as shown in Figure 37. On the final step, the registration process is finished once the user presses the "Fullfør" button, which saves the observation and sends the user back to the ongoing supervision page.

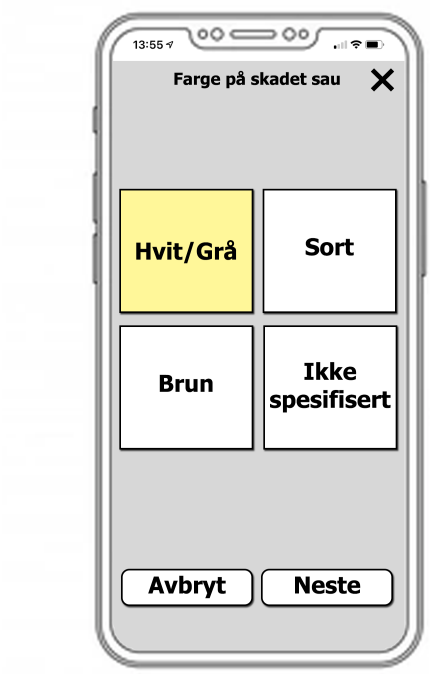

Figure 36: Registering the wool color of an injured sheep

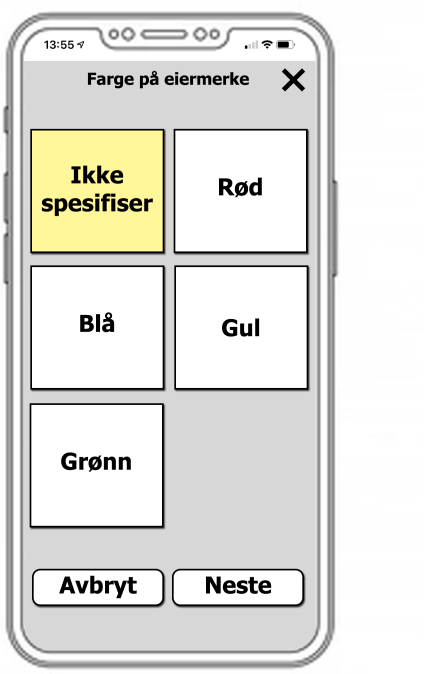

Figure 37: Registering an injured sheep's owner mark color

Observing a Dead Sheep

If the chosen observation type is dead sheep, then the registration process is quite similar to the registration process of an injured sheep. Instead of choosing the type of injury (as in Figure 35), the user choose the suspected cause of death (e.g. sickness, attacks by predators, or drowning accidents). The remaining steps of the registration process involve registering the color of the owner mark and the color of the sheep in the same way as in the registration of an injured sheep.

6.5 Design Decisions and Rationale

In this section, the largest design decisions will be explored and explained. The section will also give a design rationale by describing how Jacob Nielsen's design heuristics and Don Norman's design principles have been brought into the design of the mobile application's prototype. These design principles and heuristics are popular guidelines that have been used to create a design that hopefully feels intuitive and informative to the user.

The first large decision that had to be made was deciding what the user should be greeted with when they open the mobile application. The initial thought was that the user should be shown a home page where they are greeted with a welcoming message, and that the user navigates through the

application's different pages using a tab-bar located at the bottom of the page. After considering this method of navigating, I came to the realization that the amount of pages would be too large for a tab bar. This resulted in the decision of navigating using a "hamburger" fold-out menu instead. The welcoming message was also replaced with a map showing the user's location, as I recognized that the welcoming message did not contribute anything considerable to the user's experience. This map is also a good example of Don Norman's principle and Jacob Nielsen heuristic of "feedback". Jacob Nielsen says that feedback of the status of a system should always be given to the user [31], while Don Norman argued that every user action needs a reaction [32]. The map is able to give the user feedback about two important aspects of the application. The first of these is that the user gets feedback that they successfully gave the application permission to use their location. The second is that the user gets feedback that the map is functional and is able to use and display their location.

Another significant design decision originated from the requirement of having the mobile application support the use of binoculars. This decision involved making a design that can easily be used without the user having to look at their phone screen for certain parts of the supervision process. Per my supervisor, Professor Svein-Olaf Hvasshovd, the parts where a user typically use binoculars are when they are registering the number of sheep, and when they are registering the sheep's wool color or tie color. Multiple solutions to support binoculars were considered, many of which featured or relied on different swiping gestures. However, I quickly realized that having too many swiping gestures could easily become cumbersome and confusing. With this is mind, the solution that I identified as the best at solving this problem, was a solution largely inspired by the type of physical hand-held counting devices as seen in Figure 38. This solution can be seen in the paper prototype as well, in Figure 31. This solution involves having a button, inspired by the physical counting device, that increments the amount of the selected color when clicked. The button was made considerably large so that it will be easier to accurately press it while using binoculars. The amount of the selected color can be decremented by holding down this same button for at least 2 seconds. The idea behind using the same button for increments and decrements is to lower the amount of remembrance and precision required from a user who is using binoculars, so that they more easily can achieve what they want without making mistakes or errors. This specific solution was user tested, as can be seen in Section 6.6.

Figure 38: The type of physical hand-held counting device that inspired the paper prototype design

The design heuristic and principle of "feedback", that was mentioned earlier, is crucial when making a design that will not confuse the user. It is important to keep the user aware of the status of the system and inform them that their actions actually had an effect, and this can be seen examples of throughout the application beyond the already-mentioned home page. The map displayed on the "ongoing supervision" page is a good example of this. As seen in Figure 28, this map contains a line spanning between the location of the user and the location of what is being observed. Through this line, the user receives feedback that the relational location for the new

observation is being updated when the user moves the map. Additional elements for providing feedback, such as messages for when observations and supervisions are cancelled or saved by the user, are planned to be implemented in the actual implementation. These were not implemented in this first design iteration, the paper prototype, as it could exponentially increase the amount of additional pages in the prototype, which would require a considerable amount of time to create.

The design principle of "consistency" from Don Norman is similar to Jacob Nielsen's fourth heuristic of "consistency and standards". Consistency means that the same action should give the same effect [32]. It is an important principle as it allows users to apply and utilize their existing knowledge and experiences about the effect of an action. A consistent design will also avoid confusing the user, by always having similar actions cause the same responses. Consistency has been important when making the design for the mobile application, and one apparent example of this is the "X"-button that is visible during the observation registrations. The effect of clicking this button is consistent in all the different parts of the registration process.

"Affordance" is another important design principle of Don Norman. This principle is all about the relation between the actions an element communicates to the user via its design, and what actions the element actually supports [32]. If an element *looks* clickable, it should also *be* clickable. The principle of affordance has been utilized through all parts of the prototype, by for example using shadows, labels and icons for making buttons seem clickable.

Affordance is complemented by another design principle by Don Norman called "constraint". As mentioned, the design principle of affordance tells us which actions an element supports and communicates to the user. "Constraint", on the other hand, is about telling the user which actions an element does not support [32]. A good example of how constraint can be used is the greying-out of buttons, to signal that the button cannot be clicked. For the design prototype, this way of using constraints is planned with the "Neste" button seen when registering an observation. By greying out this button, the design communicates to the user that the process cannot continue without first performing some action on the current page.

"Mapping" is a design principle by Don Norman that is important for making the user understand the concepts and control elements in the design, effectively increasing the application's intuitiveness. This principle focuses on the relation between controls and their effect [32]. An example of how mapping is used in the prototype can be seen when registering an observation (Figure 33). On this page, there is a "Forrige" (Previous) button placed to the left of the page, and a "Neste" (Next) button placed to the right. The placements of these button resemble a timeline, which effectively maps to the buttons' effect of moving the registration process forward or backward.

The third heuristic by Jacob Nielsen is about user control and freedom. This heuristic focuses on always allowing users the ability to exit or cancel an action, as a user could perform or start actions by mistake [31]. The "X" button, seen in the prototype when registering an observation, is a good example of how this heuristic has been used. This button provides the user with the ability to cancel the registration process at any time.

6.6 User Testing

The mobile application's paper prototype was user tested on three different people. The prototype was user tested in order to discover any possible issues with the design, which could be used to improve future design iterations, and to get an understanding of how usable, efficient and satisfactory the design actually is [33].

6.6.1 The User Testing Method

The "Wizard of Oz" method was used for conducting the user test [30][page 391]. When using this testing method, the prototype was printed out on multiple paper sheets, where each sheet represented a unique page in the application. The method also includes three different roles, in addition to the role of the test subject. These roles are "wizard", "test leader" and "observer". The wizard's responsibility during the test was to augment the actual system. This means, that whenever the user interacted with the paper prototype, the wizard had to change the paper sheet accordingly. The test leader on the other hand, was responsible for introducing the system to the user, explain to them how the test will be performed, perform the test by reading the test tasks, and ask the evaluation questions after the tasks have been completed. The observer was responsible for observing the user during the test, and make notes of any difficulties, problems, comments or remarks made or encountered by the user that could be significant for the future iterations of the design. For this round of user testing, I had the role of both wizard and test leader, while my brother assisted me by taking the role of an observer. The setup for the user test can be seen in Figure 39.

Figure 39: How the user test for the mobile application paper prototype was set up. The "wizard" changes the active paper sheet whenever the test user makes an interaction. The user also always has their current test task visible in front of them.

As mentioned, the user was given a set of tasks that they had to solve during the user test. These tasks are worded so that they will not help or lead the user in how to solve the problem. This way of wording the tasks is important for the validity of the user tests, as getting help through the tasks could make the user not encounter the possible usability problems with the design prototype. This is also why the leader of the test could not assist the user if they got stuck and could not complete one of the tasks. In total, there were 13 tasks that the user had to solve during the user test, and these tasks can be seen in appendix A.

There were seven different questions, seen in appendix B, that the test leader asked the users after the tasks had been completed. These questions were asked to gain further insight into the user's experiences, both good and bad, with using the prototype. The questions also allowed the user to come with their own ideas and suggestions for how the design could be improved or expanded. Any additional questions that arose during the user test were also asked by the test leader or the observer.

The user test itself followed the testing guidelines described by Gry Seland, which consists of the following 10 different test steps [34]:

1. Introduce yourself
2. Describe what the purpose of the user test is
3. Inform the user that they can abort the test any time they want
4. Describe to the user the equipment that is present in the room
5. Teach the user how to think out loud
6. Explain to the user that you cannot offer them any assistance with the tasks during the user test
7. Give the user a description of the project/product and the task
8. Ask the user if they have any questions, and then run the test
9. Complete the test
10. Ask the follow-up questions to the user, and ask any new questions if any appeared during the test

6.6.2 Results from the User Tests

The user tests for the paper prototype of the mobile application were performed on three different people. The first user was a 51 year old male, the second a 50 year old female, and the third a 26 year old male. These test subjects are not sheep farmers themselves, but they have friends and family who are, and they are therefore aware of the supervision process that needs to be performed on Norwegian sheep. All three test subjects are also comfortable using smartphones and technology in general.

The user tests generated valuable feedback about both the positive and the improvable parts of the design. All the users were able to accomplish the 13 different test tasks, seen in appendix A, without any major issues. All in all, the users were satisfied with the design, but they also discovered areas of the design where improvements could be made.

After the tasks had been solved by the users, they were asked what they liked about the design. All three quickly mentioned that one of the best parts of the design was its intuitiveness. One user said that they "quickly understood what to click, and what not to click", while another user said that the design had "large buttons that were easy to click" and that the design "presented the different options and alternatives in a way that was clear and manageable". The third user also spoke positively about the design's intuitiveness, and mentioned that "it was easy to use" and that they "were not overwhelmed with unnecessary information".

In addition to the intuitiveness, there were other parts of the design which stood out as positive for the test users. One of these parts was the map that is visible during supervisions. All three

users liked that the map showed the path that they had walked, and one of them said that "this would help me see where I have been and where I have not been" and that the path on the map also "would help me find my way back to where I started after I have performed the supervision".

All three users also liked that the map supported offline use, and they all quickly understood how to use the prototype to download a map section. They all realized that it was the current map section visible on the mobile screen that would be downloaded, and one of the users mentioned that "if I wanted to download a larger area, I would've zoomed out and then clicked on download". Another user spoke on the offline functionality, in that they have had "trouble trying to use other map apps in places without cellular service, so it's smart that this app supports downloading the maps while at home, before going out on the supervision".

The users did not exclusively have positive experiences with the design, as they also encountered areas in which they saw potential for improvements. One such area appeared during the pages for registering an observation. The paper prototype is designed so that in order to complete an observation registration, the user has to go through every step of the process by clicking the "Neste" (Next) button (as seen in Figure 32). This works well in situations where the user has something to register on every page, but it does not work well if the user is lacking some information. If, for example, the only information a user was able to observe was the sheep's wool color, then the current design still forces them to click through the pages for completing the rest of the registration. The test users expressed that being forced to click through pages, where they did not have anything to fill in, felt "time consuming and frustrating". One of the users argued that "if I know I don't have any more information to fill in, I should be able to just complete the registration at that point without having to go through these other steps".

Another aspect that confused some of the test users was the cross in the middle of the screen, which represents the location of what is being observed, as seen in Figure 28. Two of the users initially expressed confusion over what the point of this cross was, but both understood its meaning eventually. These same users argued that this confusion possibly stems from the fact that a paper prototype was used. The paper prototype lacks the depth and interactiveness of an actual working mobile application, and if this cross is still included in the next iteration of the design, it will be important to test if the improved interactability removed any confusion that the users may experience.

One of the major aspects that was tested during the user test, was the design's ability to support the use of binoculars during specific parts of the registration process. To test this, the users were asked to register the color of the sheep without looking at the screen. All test users managed to do this, with a varying degree of success. They all understood and liked the button for incrementing and decrementing the amount of different sheep colors. One of the users said that "using the same button for increasing and decreasing the value was very intuitive to me, and it made me not worry about whether or not I was clicking the correct button, as there was basically only one button to click". With that said, the users did encounter some difficulties too. Their short time of using the prototype was not enough to be able to memorize the order of the buttons that are used to change the selected color (seen in Figure 31), which caused some users to be unsure of what color that they had actually selected. One of the users expressed that if they "had more time with the application, I would start remembering where the different colors are placed, and I would more easily be able to register something while using binoculars". Another user argued that "if the prototype would read out loud the new color when I click it, it would be really helpful when using it with binoculars" and that the application "should read the current amount out loud too, because I can quickly lose count when I count it myself". All in all, from the user tests it seems that while the current version of the design is a good start for supporting the use of binoculars, there are still improvements and additions to be made.

6.7 Suggestions for Design Improvements

All the test users were asked the follow-up question of how they would rank the design on a scale from 1 to 10, where 10 means that the design is flawless and needs no improvements. Two of the users gave it an eight, and one gave it a seven. After the users had given their score, they were asked to comment on what improvements would have to be made to increase this score. These comments, along with everything already said in subsection 6.6.2, created the foundation of how to further refine the design of the mobile application. This resulted in the following list of improvement suggestions for the next design iteration.

- The users expressed a desire to be able to immediately finish an observation registration at any step of the process. To avoid users having to click through registration steps unnecessarily, the next design iteration should include an extra button at each step. If the user clicks this button, the registration would be saved with the current information that the user has provided. This extra button could for example be placed at the bottom of the page, together with the "Forrige" ("Previous") and the "Neste" ("Next") buttons.
- One user mentioned that having a supervision's observations being presented in a list felt a bit rigid and unintuitive. Instead of presenting these observations in a list (as seen in Figure 25), they could be presented interactively on a map. Each observation could then be a marker on the map, and these could be shown on the map together with the path that the user walked. Presenting observations this way would allow the user to not only recognize the specific observation based on what was observed, but they could also recognize it by the location of where it was registered. The observation markers on the map could also be clickable to allow the ability to reveal more information about that specific observation.
- The wording in the dialog box that appears (as seen in Figure 27) when trying to delete the locally-stored map sections was perceived as a bit intimidating to one of the users. The test user said that she "felt a little scared to do what I wanted to do because of the wording in the warning message". This message could perhaps be worded more softly, so instead of saying "If you delete the downloaded map, you will no longer be able to use the map without an internet connection", the message could be worded similar to "If you delete the downloaded map, you need to have an internet connection to continue using the map".
- The application should support reading aloud the color and amounts during the registration process. This would be very beneficial to users that are making observations while using binoculars. By having auditory feedback, the user can be aware of the current amount and color without having to look at the mobile screen.
- There should be an alternative way to switch the selected color when making observations. The current design requires the users to memorize where the different colors are located, and then accurately click on that color. This works well when the user is able to look at the screen, but it can be problematic when used together with binoculars. The next design iteration could perhaps add a simple swiping functionality, that can be used to change the selected color. This would remove the requirement that the user needs to memorize where the different colors are located. For example, when on a page where colors can be selected (as in Figure 31), the selected color could be changed by swiping the page downwards. This, together with the mentioned auditive feedback, would allow the user to easily change and increment/decrement the selected color without needing to look at the screen.
- One of the colors on the page for registering the sheep's tie (as seen in Figure 33) is "Gul/Ingen" (Yellow/None). A test user thought this option would be selected if the sheep

had either a yellow tie, or no tie at all. The intention was that this option would be used for either a yellow tie or a blank/colorless tie. To reflect this, the label could be changed to "Gul/Blank" (Yellow/Blank) in the next design iteration.

- In the current version of the design, "ewes", "lambs" and "sheep in general" are three different types of observations. One consequence of this is that if a user for example observes a group of one ewe and one lamb, they have to make two separate observations to register this group. Having to split a group of sheep up into multiple different observations, in order to register them, feels cumbersome, time consuming and ineffective. A solution could be to remove the observation types of "ewes" and "lambs", and move these into an observation type of "sheep". We still want the user to be able to make the distinction of ewes and lambs, and one way this may be done is through the "+"-button that is used for increments and decrements. This button could perhaps be split into three different sections; one for ewes, one for lambs, and one for sheep in general.
- After showing the paper prototype to my supervisor, professor Svein-Olaf Hvasshovd, it became clear that it is not necessary to register the *amount* of the sheep's owner marks. When registering observations, it is therefore only interesting to register the color, and not the amount, of the observed owner's marks. The next design iteration should therefore replace the page seen in Figure 32 with a new page similar to the one seen in Figure 37. A group of sheep can belong to multiple farms, so this new page should allow the user to select multiple colors.

7 Mobile App - The Design of the Implementation

In this section, the second design iteration will be presented. This iteration is the actual implemented and working mobile application, and its design is based on the paper prototype seen in Section 6. This iteration still follows the same design quality guidelines as the first iteration, which were presented in Section 6.2. This section will start by giving a quick look at how the second design iteration was created, followed by presenting an updated flowchart of the application. The section then gives a walkthrough of what changes have been made to the design in this iteration. Finally, the user tests of the application and the results from these are presented.

7.1 How the Design of the Implementation Was Created

For the actual implementation of the mobile application, all the suggestions for design improvements that appeared during the user tests (seen in Section 6.7) were incorporated into the updated design. This second version of the design was created during the actual development of the mobile application. It was important at this stage to thoroughly think through what improvements could be made to the design, as changing the design after it has been implemented can be costly and time consuming. As with the paper prototype, the design principles and heuristics of Don Norman and Jacob Nielsen were again utilized in this latest version of the design.

7.2 Updated Flowchart

The user tests brought some changes to the application's flowchart too. The updated diagram is presented in Figure 40, and it shows the flow of this second design iteration. As can be seen in the flowchart, two of the observation types have been removed. It is now no longer possible to choose "ewes" or "lambs" as their own category, as these have been moved into the observation type of "group of sheep".

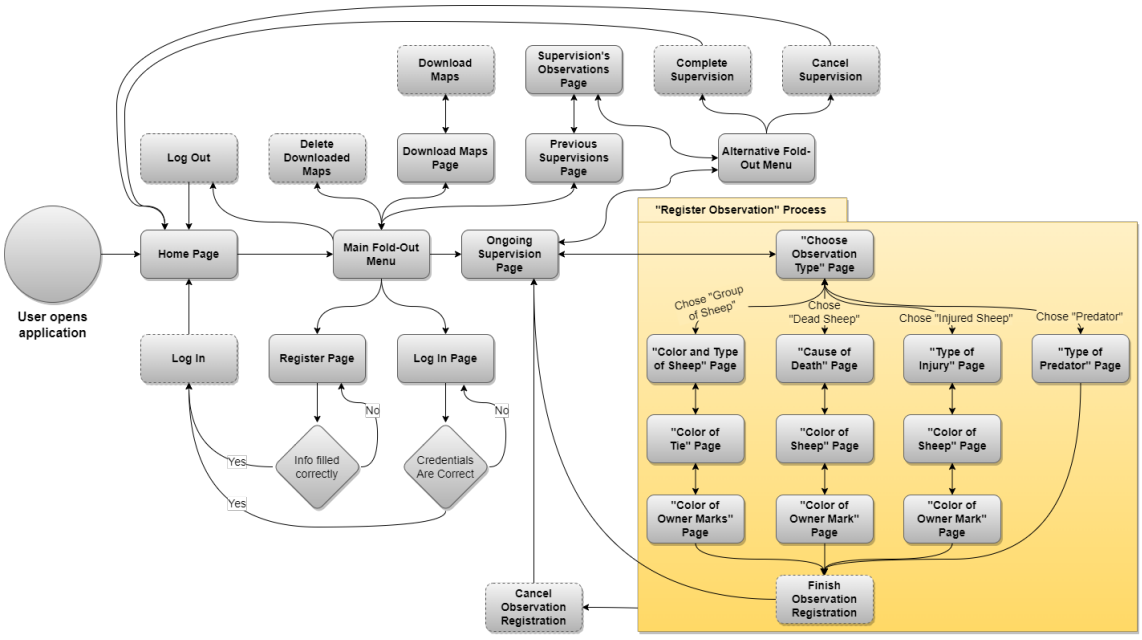

Figure 40: Flowchart showing the updated flow and interconnectedness of the mobile app's implemented design

7.3 Design Changes

Based on the findings during the first user test (seen in Section 6.7), several changes and improvements have been introduced to the design. Nonetheless, large parts of the design in this second design iteration still remain mostly similar to the first iteration (seen in Section 6). Another walkthrough of the entire prototype is therefore not necessary. Instead, the most noteworthy design changes will, in this section, be presented and reasoned. To get the complete picture of the new design, I recommend looking through the full set of screenshots of the Herd application that are presented in appendix C, or download the application using the URL given in the preface, and test it for yourself.

The first noteworthy change can be seen in the hamburger menu in Figure 41. The user-specific options, such as the login and register pages, were moved from the top to the bottom of the hamburger menu. These were given less focus on the screen by moving them further down, as I realized during the user tests that these pages were used considerably less frequent than the other pages in the menu.

Another change in the hamburger menu is the addition of two new options; the "Gå til forsiden" option, and the "Innstillinger" option. Clicking "Gå til forsiden" brings the user to the home page, and this option was added to make the home page more easily accessible for the user. Previously, the user had to close the menu and click the top logo to get back to the home page, so this new option will hopefully make this navigation feel more intuitive.

Clicking the "Innstillinger" option in the hamburger menu directs the user to the new settings page seen in Figure 42. This new settings page was added so that the user can control whether or not they want the new auditory feedback during observation registrations. In these settings, the user can toggle if the application should read aloud the number of sheep, the number of ties, the selected sheep color, and the selected tie color.

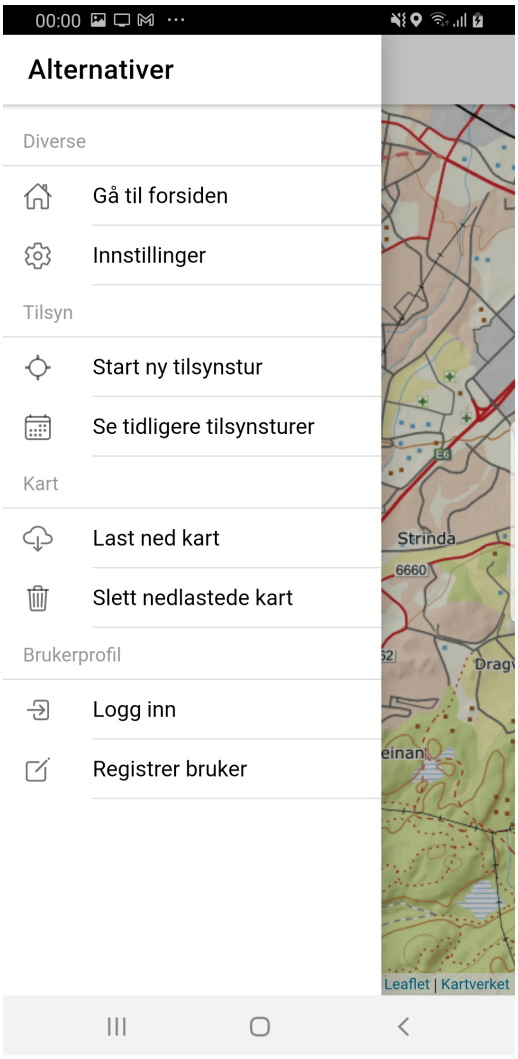

Figure 41: Hamburger menu in the mobile application

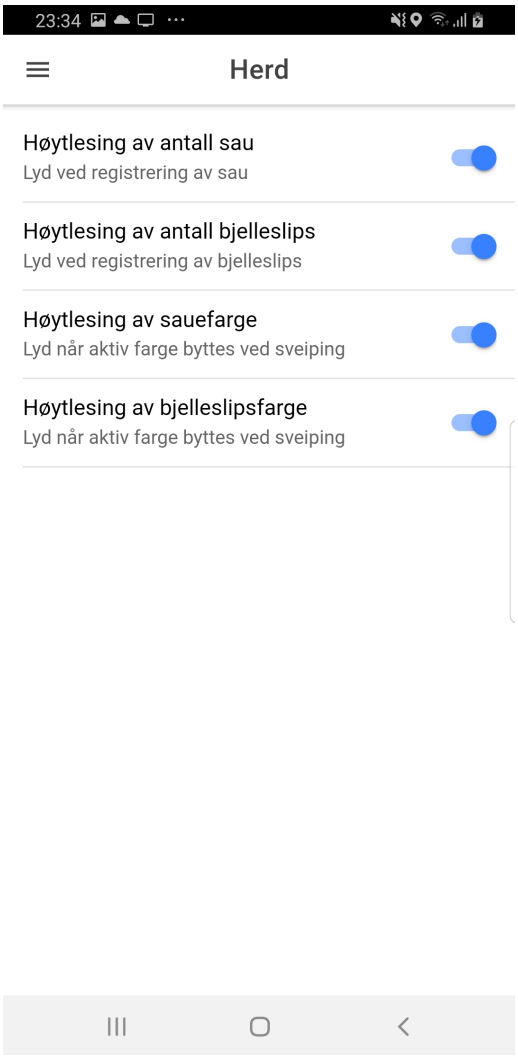

Figure 42: Settings page

The login page, seen in Figure 43, has also changed. The user now needs to provide their farm number to log in, in addition to their email-address and their password. This change was made after conversations with my supervisor Svein-Olaf Hvasshovd, where we discussed how a user would separate their supervisions if they performed them for different sheep farms. The solution became implementing the farm number as an extra login parameter. This way, the user could have separate accounts, and therefore separate supervisions, for each farm they supervise sheep for.

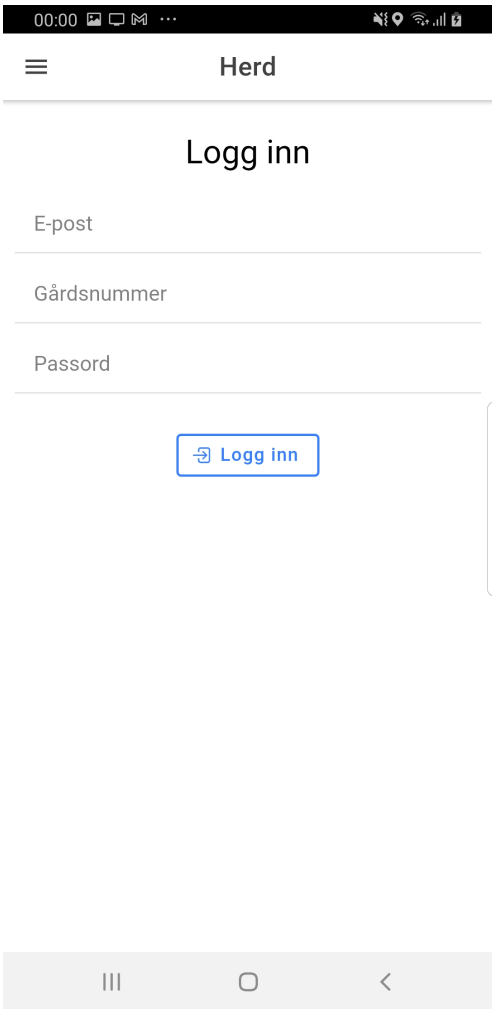

Figure 43: Login page

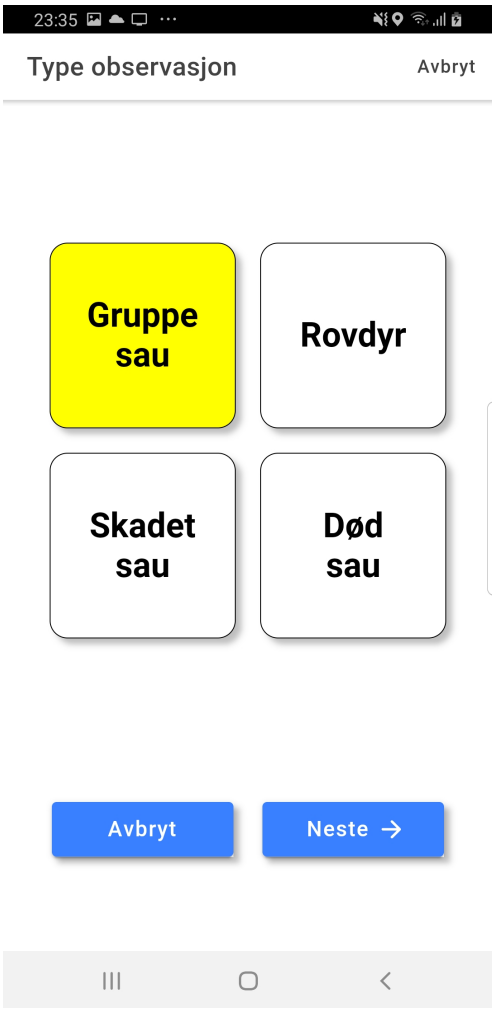

Figure 44: Observation registration page - Choosing the observation type

When a user chooses the type of observation to register, they now have four different options to choose from, instead of six. As seen in Figure 44, the ”Søye” (ewes) and ”Lam” (lambs) options are removed from this page. The distinction between ewes, lambs and sheep in general, is now made on the same page for registering the wool color, shown in Figure 45. There are now three separate ”+” buttons, one for each of the different sheep types. For example, clicking on the ”+” button for ewes while the ”Hvit/Grå” (white/grey) color is selected, the number of white/grey ewes will be incremented by one. Holding down this same button will decrement the same number. This way the user can, on a single page, register observations of different sheep with different wool colors, and therefore avoids having to register separate observations if they observe both ewes, lambs or sheep in general. This change is also beneficial for when a user is using binoculars and observes different sheep types (e.g. both ewes and lambs), as they can register what they observe, without having to perform complicated interactions with the application in order to create multiple separate observation registrations.

An alternative method of changing the selected color has also been added on all pages with the ”+” button, which includes the page in Figure 45. The user can now drag the page downwards and release, and the selected color will be changed and the new active color will be read out loud. This is beneficial for the user when they are using binoculars, as it removes the need to remember the placement of the color buttons and the need to be accurate enough to click them.

Another change to the design can also be seen Figure 45, where a third button has been added to the bottom of the page. Clicking this button will result in the rest of the registration process being skipped, and the observation being saved. This change has been added to all the steps of the registration process, except from the first and the last step. It has not been added to the last step of the process as this step already has this type of button, and it has not been added to the first step of the process as this step is required for all types of registrations.

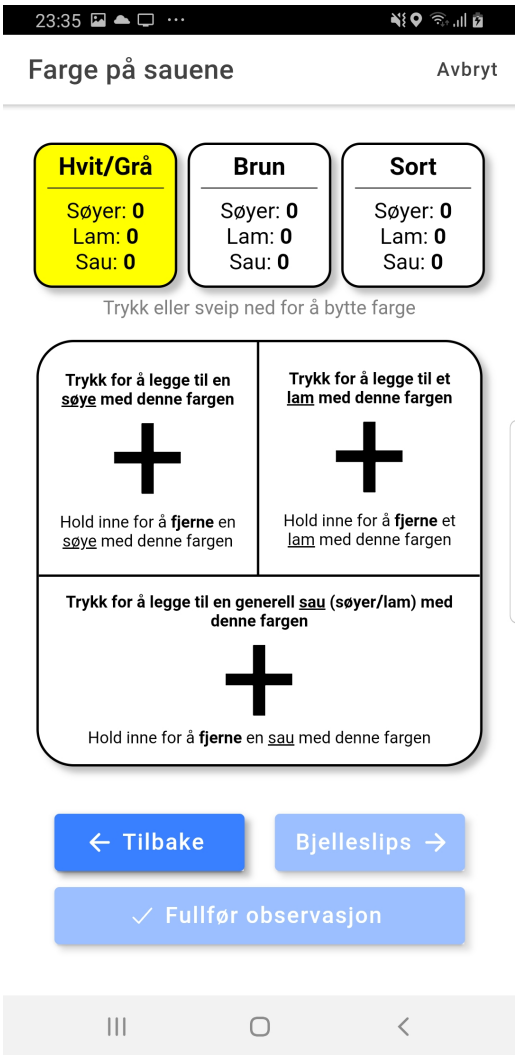

Figure 45: Observation registration page - Counting the ewes, lambs and sheep in general, and their wool color

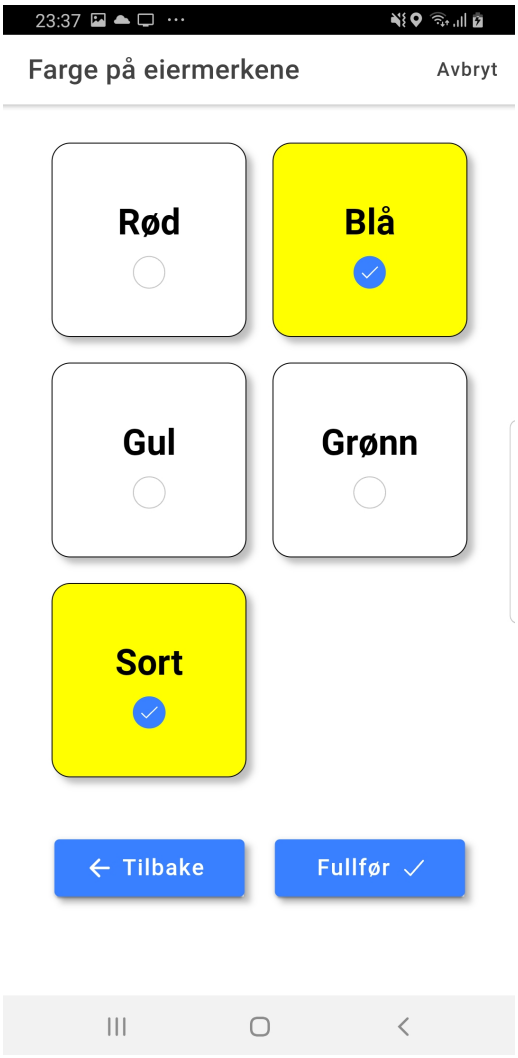

Figure 46: Observation registration page - Color of the owner marks

When registering a group of sheep, the registration of the owner's mark color has also changed. In the first design iteration, both the color and the amount of the owner's mark were registered. In this new version, seen in Figure 46, only the color is registered. The user can now choose none, one or multiple colors to register, depending on what they observed. This change was implemented after conversations with my supervisor Svein-Olaf Hvasshovd, where he explained that it is only interesting to register the color, and not the amount, of the observed owner's marks

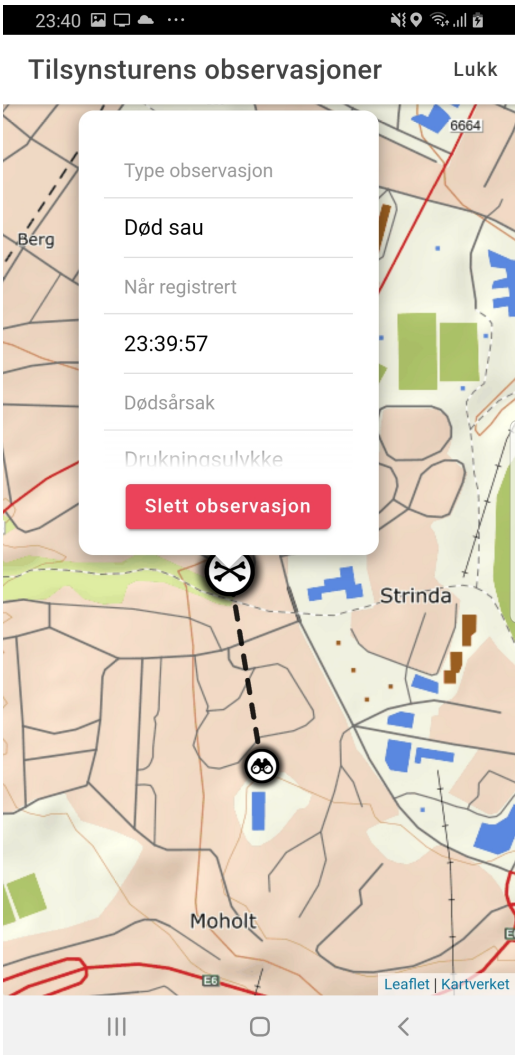

Figure 47: Observation registration page - Counting the ewes, lambs and sheep in general, and their wool color

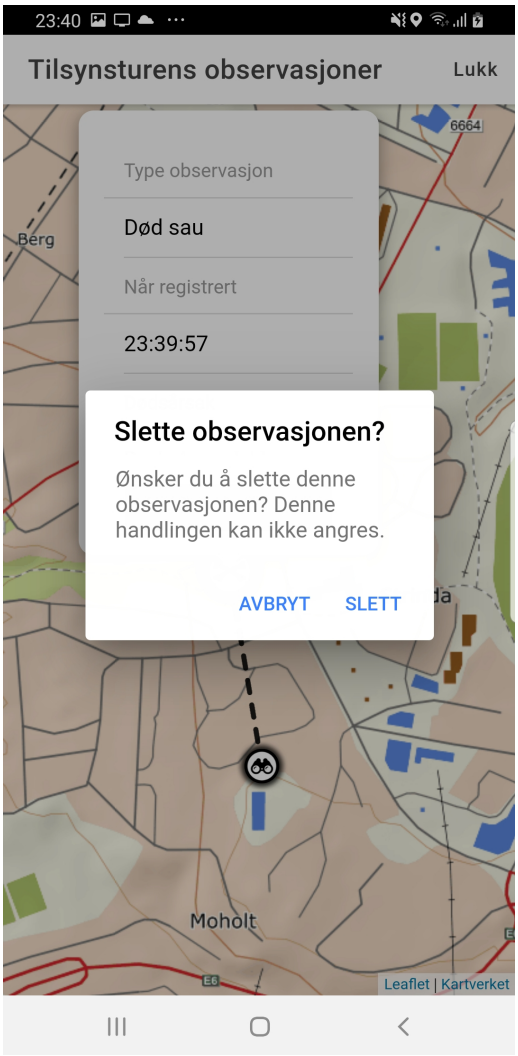

Figure 48: Confirmation message for deleting an observation

There is also a new way of inspecting a supervision's observations. The page in Figure 47 shows how the observations are now presented for a current ongoing supervision. The observations are shown on a map as clickable map pins. When an observation is clicked, a small window is opened, which displays all the observation's information in a scrollable list. This window also includes a button that the user can click to open a confirmation message where they can delete the observation, as seen in Figure 48. Presenting observations on a map, instead of in a list as in the paper prototype (Figure 25), allows us to utilize the location of the observation. By using the observation's location on a map, the user will hopefully be able to recognize the registered observation more easily.

A noteworthy change has also been made to the page of previous supervisions, as seen in Figure 49 and Figure 50. Supervisions are now uploaded individually, by using the menu revealed when sliding the supervision to the left (seen in Figure 49). This gives the user more control over what they upload, as the first design iteration only allowed the user to upload all supervisions together. The user can now also delete individual supervisions by using this same sliding menu, which can be beneficial in cases where the user mistakenly saved a supervision. Clicking on a supervision will open a map similar to the one seen in Figure 47. The only difference in this version of the map, is that observations cannot be deleted. This inability to delete or change observations after

a supervision had been completed was added after a conversation with my supervisor Svein-Olaf Hvasshovd, where we concluded that this was necessary in order to preserve the authenticity of a supervision.

Figure 49: Previous supervisions page - Slide menu for a locally-stored supervision

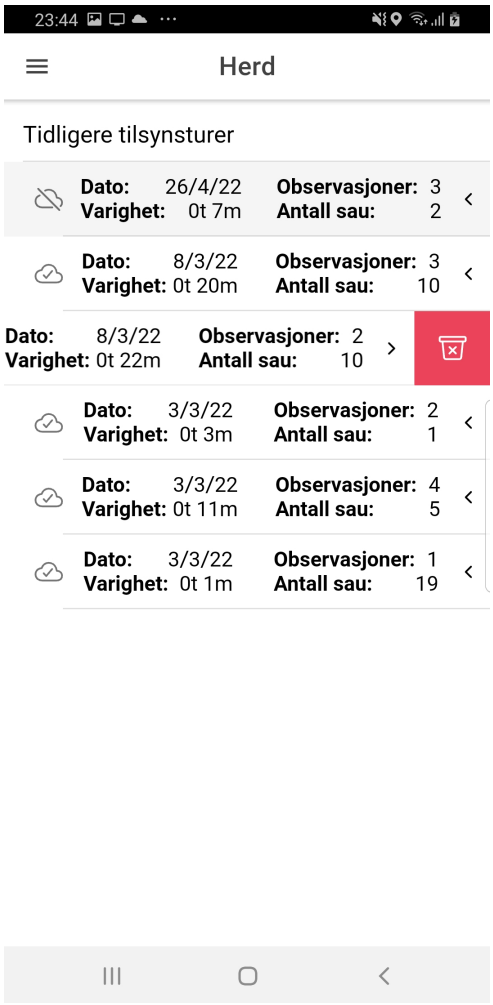

Figure 50: Previous supervisions page - Slide menu for a server-stored supervision

7.4 Design Rationale

The largest design changes have already been justified in Section 7.3, so this section will not repeat the explanation of those changes. Instead, this section will look at how Don Norman's design principles [32] and Jacob Nielsen's design heuristics [31] have been further utilized in this iteration of the design. These principles and heuristics have had a significant importance when trying to create an intuitive design that achieves a high degree of usability.

Don Norman's affordance principle was again central in this iteration. For instance, almost every button now have an icon and color that represent the buttons' actions. An example of this can be seen in Figure 50, where the trash can icon and the red color signals deletion. The same figure shows another good example of how icons can be used, where each supervision in the list have an arrow icon that signals that the element can be swiped to the left to reveal a menu. By using icons and colors correctly, the elements can more accurately communicate their possible actions to the user, thereby increasing their affordances.

The "feedback" principle and heuristic has again been put considerable focus on in this iteration of the mobile application's design. Whenever the user makes an action, like starting, deleting or finishing a supervision, the application will give a relevant feedback message. An example of this can be seen in Figure 51. Another good example of how feedback is used can be seen in Figure 52, where the user is continuously shown the progress of the map download process.

Figure 51: An example of how the user is given feedback when they finish a supervision

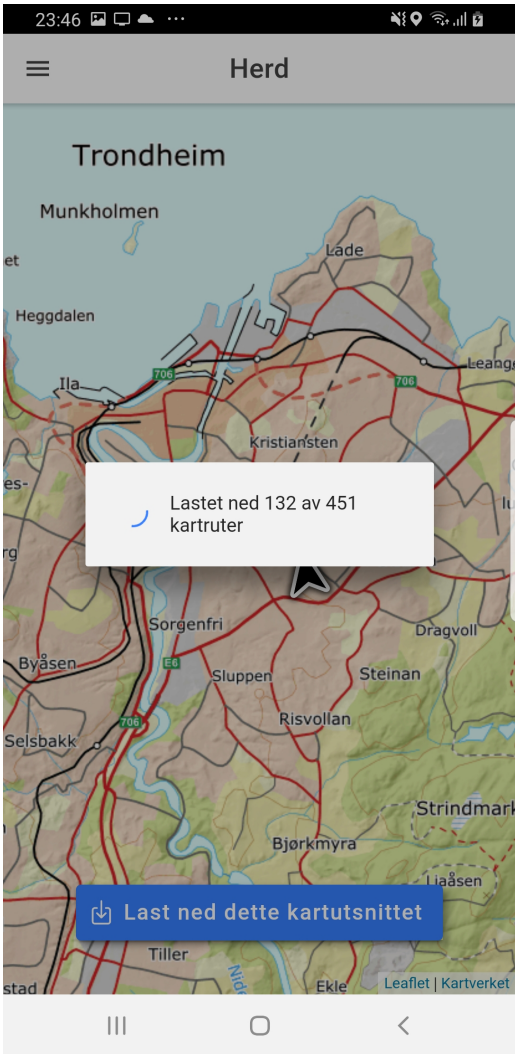

Figure 52: An example of how the user is given feedback of the map download progress

Another type of feedback that was implemented in the mobile application is the use of haptic feedback. An example of this can be seen on the page in Figure 45, where whenever the user increments a value, a small physical vibration is given by the user's mobile phone. Likewise when the user decrements a value, a harder, more intense, vibration is given to the user. The haptic feedback and its different intensities communicate to the user that their action was successful and *what* that action did, which is especially useful when the user is using binoculars and is not able to actively look at the screen.

There is also the new auditory feedback, which is present on for example the page for registering the sheep and their wool color (Figure 45). If the user has enabled auditory feedback, the phone will read out loud the number whenever it is incremented or decremented by the user. The phone

will also read out loud either "søye" (ewe), "lam" (lamb) or "sau" (sheep) when the "+" button that they clicked is not the same "+" button they clicked previously. If the user clicks the same "+" button as they just clicked, then only the number, and not the sheep type, is read aloud. This avoids unnecessary auditory feedback that could become repetitive and annoying for the user. This type of auditory feedback is good for assisting the user when they are using binoculars during the registration process.

"Constraints" is another important design principle. There is a good example in Figure 45 of how constraints have been utilized in this design iteration. On this page, there are two buttons that are greyed out, effectively communicating to the user that these buttons cannot be clicked while the application is in its current state.

Both Don Norman and Jacob Nielsen talk about "consistency", which is something that has been of great importance in this design iteration. Throughout the design, consistency has been permeated in every button, icon, size, placement and color. Examples of this can be seen in Figure 45 and Figure 46. Here, the navigational buttons are always colored blue, and the buttons related to the observation information are always colored white, with a yellow color when they are "selected".

Jacob Nielsen's third heuristic, which is about user control and freedom, has again been placed much focus on. This design iteration builds upon and expands this heuristic. A good example of this can be seen during the observation registration process, as presented in Figure 45. The new button on the bottom of the page gives the user full control of when to complete their registration.

7.5 User Testing

The mobile application was user-tested on five different people. To preserve the authenticity of the test results, none of the test subjects from the first user test attended this user test, as these would already be somewhat familiar with the design. This design version was user tested to not only understand its degree of usability and how well it solves the different tasks (such as the support for binoculars), but also to discover any possible improvements that could be made to the design if the project will be continued in the future.

For the actual user test, the user was given an Android mobile phone that had the Herd app already installed. The test assignments included all the 13 tasks from the first user test, with two new additional tasks added (as seen in appendix A). These two new tasks involved testing that the user understands how to upload and delete supervisions. Each test assignment were read out loud to the user, and placed on the table in front of them so that they can read it themselves.

The user test followed the same ten testing guidelines as in the first user test, which were presented in Section 6.6. After the user had completed all the test assignments, they were asked the same seven follow-up questions as from the first user test, as seen in appendix B. These follow-up questions were asked to better understand the user's experience with the application, and to get insight into which improvements they have for the design.

7.5.1 Results from the User Tests

As mentioned already, the application was tested on five different people, who's ages range from 20 to 26. Due to the Covid-19 pandemic and to minimize risks surrounding this, all the test subjects were my room-mates as part of my student collective. Two of these five people grew up on a sheep farm, and are familiar with the mandatory sheep supervision process.

The user test generated valuable insight into how well the application worked, and how it could be improved. All five test subjects were able to complete the 15 test assignments, seen in appendix A, without much issue. The users were overall very satisfied with the design, and were optimistic about its usefulness for sheep farmers.

When the users were asked what they liked about the design, its intuitiveness was again emphasised. One user commented that "everything was organized in a way that made sense" and that "things that logically belonged together were also placed together on the screen". Another user said that they "liked the icons, because they made it easier to quickly understand what would happen if I click on them". A third user told that they "never felt lost, and I always knew where I was in the application, and where I needed to go".

Another positive aspect brought forward by the users were all the feedback messages that are presented throughout all parts of the application. One user mentioned that "the messages made me always sure that I did the right thing", and another user said that "the messages told me when I tried to do something I wasn't allowed to, and by reading the messages' explanation I understood why I could not do what I was trying to do".

In the user tests of the mobile application's *paper prototype* (talked about Section 6.6), we saw there there was some issues with understanding what the cross in the middle of the screen in Figure 28 meant and how it should be used. The user tests of this second design iteration showed that this is no longer a problem, and the functional implementation's improved affordance and interactability made it easy for the users to understand the use of this cross.

When it comes to the task of making an observation registration while using binoculars, all users were able to complete the task with a somewhat varying degree of success. The use of binoculars takes place while the user is on Figure 45. Three of the five users had, before they started to solve the task, made notice of the text on this page that said that they could swipe downwards to change the selected color. One of these users mentioned that "this was a very good way of changing the color, especially when combined with the fact that the phone read aloud what the new color was". Another used said that "it was nice that the phone told me with sound if it was an ewe or lamb I registered, as I became a bit uncertain of which was which of the three '+'-buttons". Two of the five users had not originally noticed that they could swipe down to change the colors, and as a result of this they had some issues remembering where the correct color button was located. These two users eventually looked at the screen again, which made them notice this swiping functionality. Once they understood that they could use swiping to change the color, the task was easily completed without needing to look at the screen. After the user test, all five users were confident that the current design is sufficient in its support for binoculars.

One user felt that the page for registering the different sheep with different wool colors (seen in Figure 45) felt "a little busy and overwhelming at first". This same user also told that "I was able to get a good overview of the page and what the different buttons and numbers did and meant, but I feel that some of the repeating text in each button could be removed".

Another user encountered a problem when they realized there was a spelling mistake in their name just as they clicked on the register button. They tried to find a way of correcting this mistake by editing their newly-registered profile, but they gave up on fixing their mistake as they realized the application does not support editing existing profiles. The user instead ended up logging out, and making a new account with the correct name.

7.6 Suggestions for Design Improvements

After the users completed the test assignments, they were asked to give the design a score from 1 to 10, where 10 means that the design is flawless and does not need any considerable improvements. Three of the users gave the design a 10, while two of the users gave it a 9, making the average score 9.6/10. They were then asked to give their suggestions for how the design could be improved. These suggestions, along with my own thoughts, serve as the foundation for the following design improvements.

- As one of the users discovered during the user test, it is currently not possible to edit a user profile. Such a feature should be added in the next design iteration.
- The page for registering the sheep and their wool colors (seen in Figure 45) could possibly be improved. One user commented on the fact that each of the three "+"-buttons have a very similar text, which could perhaps be combined and moved outside the actual buttons, effectively reducing the amount of text on the screen. In the next design iteration, one could experiment with this and see how it affects the user's experience with the page.
- Two of the test subjects did not immediately notice that swiping could be used to change the selected color during some parts of the observation registration process. A possible improvement that could help resolve this, would be to give a discrete message the very first time a user enters a page that has this feature. This message would only be shown once, but that, combined with the already-implemented text on these pages that tells about this functionality, should be enough for the user to become aware of the feature.
- Another improvement for the design could be to make it easier for the user to see which parts of the map they have downloaded for offline use. Currently, this is possible to check by turning off the phone's internet connection, and then open the map on the home page. Here, only the map tiles which have been downloaded will be visible. To make it easier and more intuitive for the user, a specific page could be added. This page could show the user a map with only their downloaded sections, which would allow the user to more easily verify that their desired map sections have been downloaded.
- On the page for previous supervisions (seen in Figure 50), all the user's supervisions are presented in the same list. The distinction between server-stored and locally-stored supervisions is only communicated by the icon next to the supervision. As the number of supervisions grows, so does the need for a better way of making this distinction. If the user has a lot of locally-stored supervisions that they want to upload, it would be beneficial if they could separate these away from the supervisions that have already been uploaded. This could possibly be done by allowing filtering of the existing list, or by having two separate lists; one for locally-stored supervisions and one for server-stored supervisions.

8 Website - The Paper Prototype

In this section, the website's first design iteration, a paper prototype, will be shown. The section begins by taking a look of how the paper prototype was created. A flowchart showing the flow of the website is then presented, followed by a walkthrough of the paper prototype. A rationale for the design is then given, before the section takes a look at the user tests and the results from these. The design of the website follows the same quality guidelines as for the mobile application, which were given in Section 6.2.

8.1 How the Paper Prototype Was Created

This is the first iteration of the website's design, and the design is likely to experience large changes and variations in future iterations. Following the same approach as with the mobile application, the website's first design iteration was also decided to be a paper prototype. A paper prototype works as a low-cost initial version of the design, which allows me to easily change and modify the design without considerable effort or consequence. As with the mobile application, the foundation for the design of the website consisted of the design pre-study, the design quality guidelines (seen in Section 6.2), and the functional and non-functional requirements (seen in Section 4.4 and Section 4.5 respectively).

The design heuristics and principles that played an important role for the design of the mobile application also played a huge role for the design of the website. The design principles from Don Norman [32] and the design heuristics from Jacob Nielsen [31] were again actively used when making the website's paper prototype. These principles and heuristics were used to hopefully achieve a design that delivers a high degree of usability.

Because of the Covid-19 pandemic, all supervisor meetings this semester were held digitally. To make it easier to digitally present and discuss the prototype with my supervisor, the paper prototype was drawn using digital software (PhotoShop). Drawing the prototype digitally also allowed me to efficiently re-use elements that appeared multiple times throughout the design.

8.2 Flowchart

A flowchart has been created for the website's paper prototype. The flowchart is shown in Figure 53, and it shows the flow of the website and how its parts are connected. Rectangles with dotted borders in the diagram indicate an action, instead of a specific page on the website.

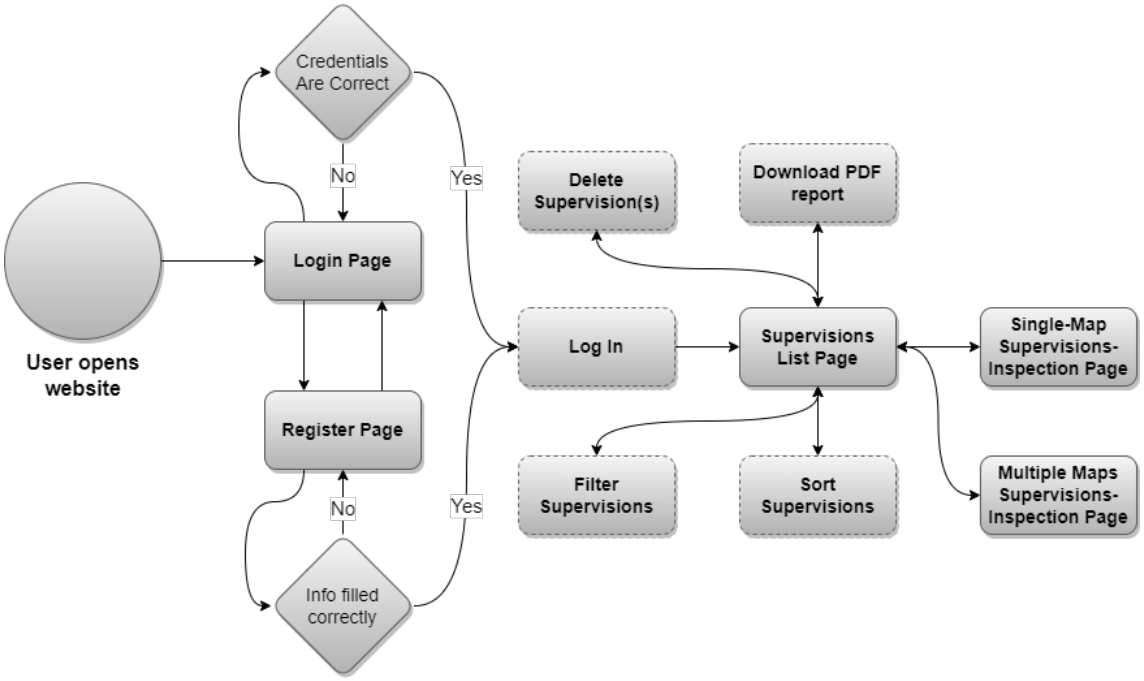

Figure 53: Flowchart showing the flow and interconnectedness of the website's paper prototype

8.3 Walkthrough of the Paper Prototype

A detailed walkthrough of the website's paper prototype will be given in this section. The walkthrough will be helpful for understanding the usage and flow of the prototype. As with the mobile application, the language on the website is Norwegian, as the Herd system is targeting Norwegian supervisors and farmers as their main users. The walkthrough will make references to the paper prototype, which can be seen starting from Figure 54 going to Figure 59.

Logging in

The login page can be seen in Figure 54, and this page is the first thing the user sees when they enter the website. Here, the user can enter their e-mail-address and their password, and then click on the "Logg inn" button. If the credentials are valid, the user is logged in and brought to the supervisions list page seen in Figure 56. If the user does not have an existing account, they can click the "Ingen bruker? Registrer her" text, which brings them to the register page seen in Figure 55.

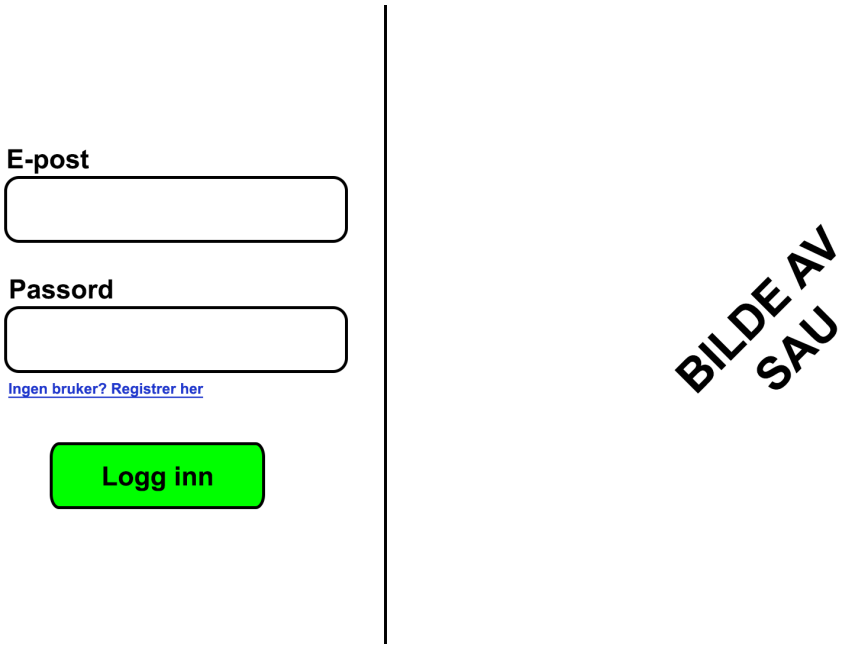

Figure 54: Login page

Registering a User Profile

The register page is presented in Figure 55. On this page the user can enter their information, and then click the "Register bruker" button. If the information is filled in correctly, the user account is created and the user is logged in, and then redirected to the supervisions list page seen in Figure 56. If the user instead realizes that they already have an account, they can click the "Har du bruker? Logg inn her" text, which sends them back to the login page.

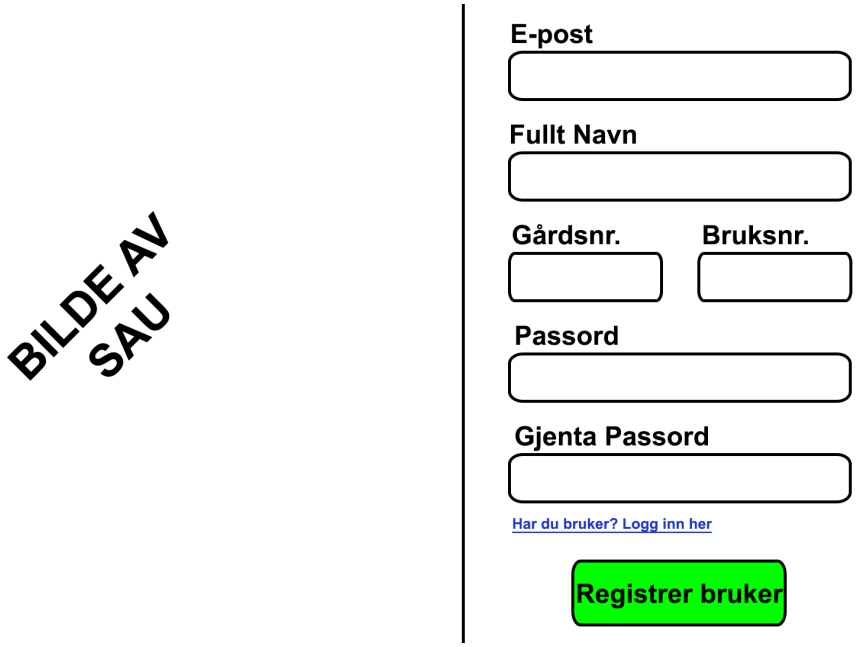

Figure 55: Register page

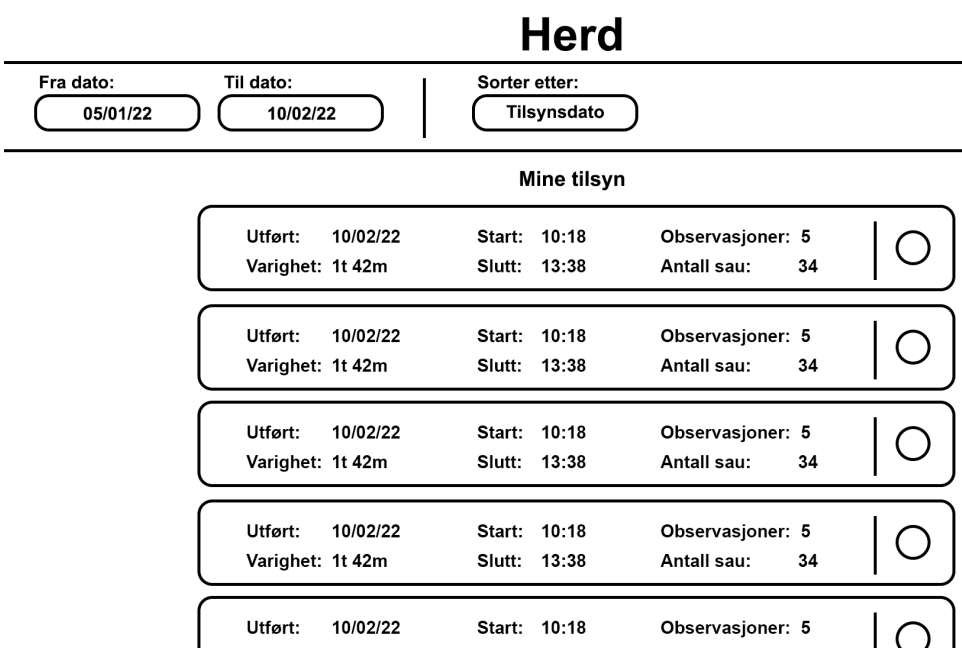

Figure 56: Supervisions list page, with no selected supervisions

The supervisions list

Once a user has successfully logged in, they are sent to the supervisions list page (Figure 56). Here, the user is presented with a list of their supervisions. The user can use the options bar at the top of the screen to filter these supervisions between two dates, and sort them by date, number of observations, or duration. The user can also select supervisions in the list by clicking on them, which can be seen in Figure 57. If the user has selected at least one supervision, then the four buttons shown in Figure 57 become visible. Clicking the "Slett valgte turer" will result in the selected supervisions being deleted, while clicking the "Last ned rapport" will make the website generate a PDF-report that summarizes the selected supervisions. Pressing the "Vis på ett kart" button will open a page, shown in Figure 58, with a single map that displays all the selected supervisions together. Clicking the "Vis på ett kart/tur" will present multiple maps, where each map shows a single selected supervision, as seen in Figure 59.

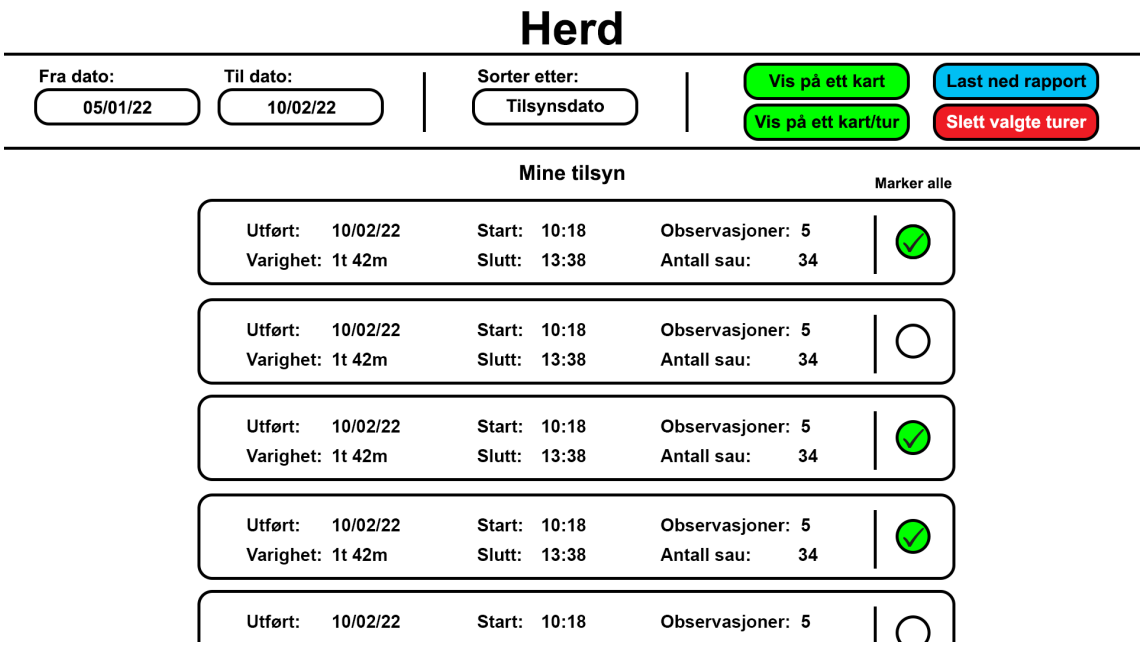

Figure 57: Supervisions list page, with three selected supervisions

Inspecting Supervisions - Single Map

As mentioned already, the user can inspect their supervisions together on a single map, as shown in Figure 58. Here, the path and the observations of each selected supervision are displayed together on the map. To make it easier to distinguish the different supervisions from eachother on the map, their colors are randomized. Clicking on an observation on the map (the circles are observations), will open a window that shows all the information related to that observation. The selected supervisions are also shown in a horizontally-scrollable list at the top of the page. Clicking on a supervision in this list will toggle that supervision's visibility on the map.

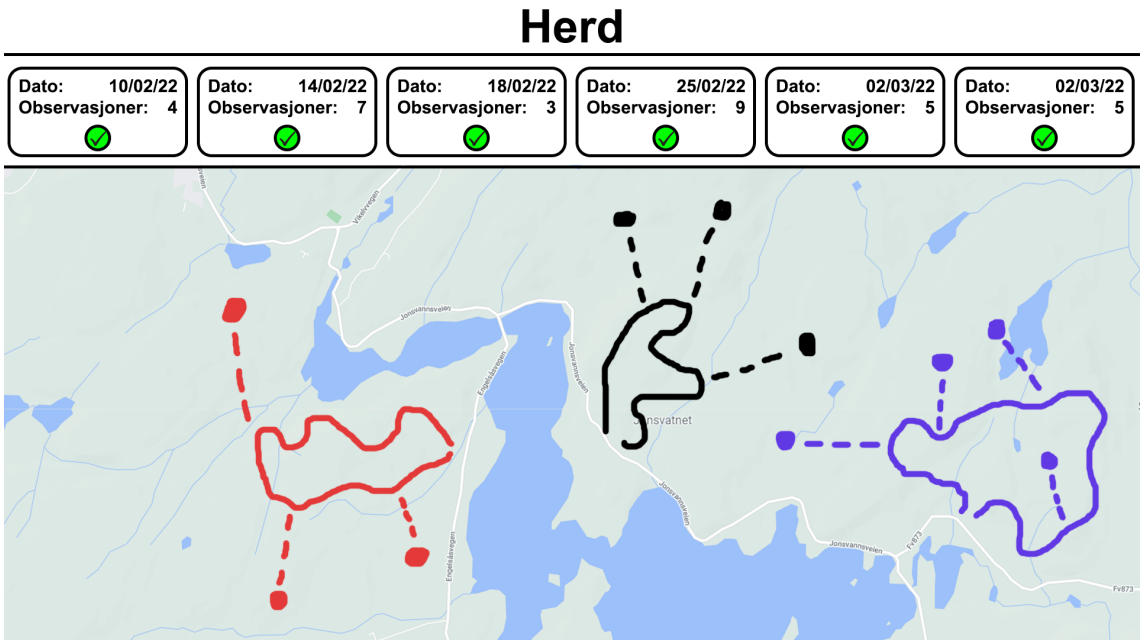

Figure 58: Inspecting multiple supervisions together on a single map

Inspecting Supervisions - Multiple Maps

It is also possible for a user to inspect their supervisions on multiple maps on the same page, as seen in Figure 59. There are as many maps as there are selected supervisions, and the maps on this page can be independently interacted with by the user. The observations on each map can also be clicked on to reveal a window with more information about them.

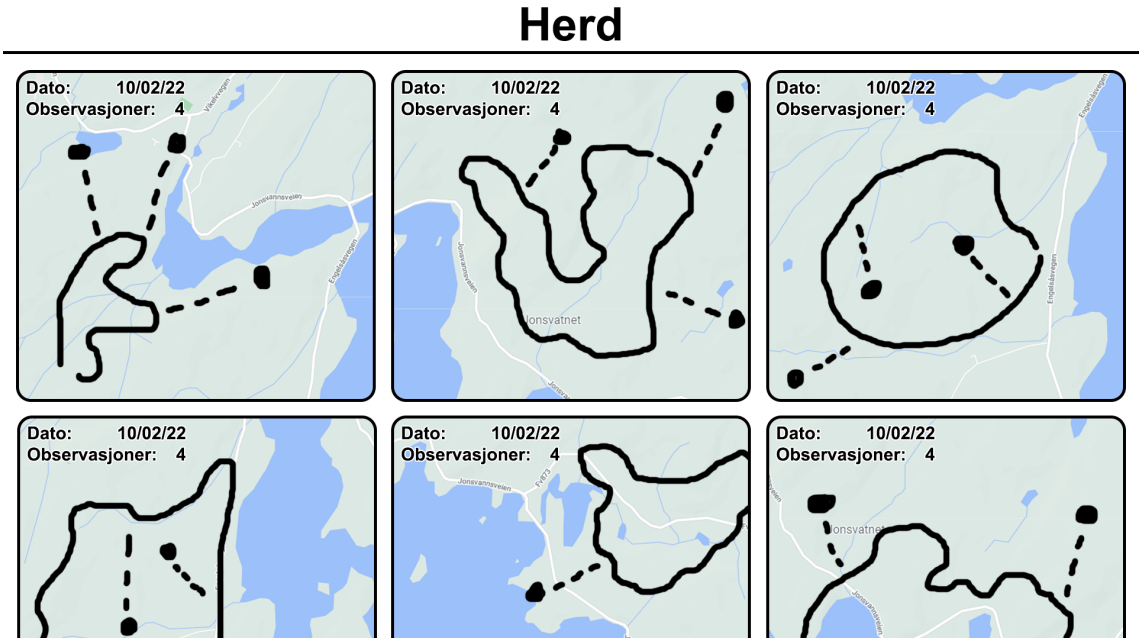

Figure 59: Inspecting multiple supervisions - one map per supervision

8.4 Design Decisions and Rationale

In this section, the largest design decisions for the website will be explored and explained. There will also be given a design rationale by looking at how the principles by Don Norman [32] and the heuristics by Jacob Nielsen [31] have again been incorporated and used in the design of the website's paper prototype. An explanation of these principles and heuristics were given during the design rationale of the mobile application's paper prototype in Section 6.5.

One large design decision concerned the issue of how supervisions should be presented when a user wants to inspect them. There were two different ideas that were discussed with my supervisor as possible solutions to this. The first idea was that all supervisions are displayed together on a single map. In practice, this means that the paths that the user walked and the observations that they registered during every selected supervision will be overlayed together on this map. After discussions with my supervisor, we both saw some positive and negative aspects of this idea. A positive aspect is that this way of presenting the supervisions would make it easier for the user to get a complete picture of which areas they have and haven't supervised, which would make it easier to plan future supervisions. A negative aspect of this idea is that the map could become very crowded if the selected supervisions were performed in the same area, and it may therefore become difficult to separate one supervision from another.

The second idea was to individually display each selected supervision on their own small map. A positive aspect about this solution is that it makes it easier to compare supervisions, as the user could, for example, use the maps to view information about different supervisions' observations at the same time. Another positive aspect is that there is no overcrowding of the map as no

supervisions are overlayed, which is something we discussed as a possible issue with the first solution. On the other hand, a negative aspect of this second idea is that it makes it difficult to see how the different supervisions relate to each other location-wise, as it would require the user to manually interact with the maps and recognize the parallels between the different map areas.

Because none of these two ideas stood out as the clearly superior solution to the issue of inspecting supervisions, both of them were included in the design of the website's paper prototype. This takes into consideration that different users may have different needs, and it will allow the users to choose the method that works the best for them.

Another design decision concerned how to possibly mitigate the negative aspect of displaying supervisions together on a single map. As already mentioned, this way of displaying supervisions together could make the map overcrowded and confusing. To alleviate this issue, a list of the selected supervisions was added above the map, as seen in Figure 58. This list allows the user to toggle the visibility of specific supervisions, which makes it easier for the user to interactively make the map less crowded. Another design decision that should help with the same issue, is that each supervision on the map is drawn using different colors. Using different colors should make the supervisions easier to separate from each other.

Don Norman's "feedback" principle played again a very important role when designing the website's paper prototype. A good example of how feedback has been used can be seen in the supervision list page, as shown in Figure 57. The user is here given feedback of which supervisions they have successfully selected. This feedback is given through the green check mark icon that is present on every selected supervision, and feedback is also given through the unselected supervisions' lack of such an icon.

The principle of "affordance" from Don Norman also played a large role in the website's design. Affordance has been important for every control element in the design, and a good example of this can be seen in the supervisions list in Figure 56. The empty circle on each supervision in the list communicates to the user that the supervisions can be selected by clicking on them.

Don Norman's principle of consistency and Jacob Nielsen's fourth heuristic of "consistency and standards" have again been important for the design. The use of consistency is especially visible in how supervisions are presented on maps. The path and the observations are consistently displayed when the user is inspecting a supervision on a map. All observations on a map can also always be clicked on to reveal more information of the observation.

8.5 User Testing

The website's paper prototype was user tested on five different people. The paper prototype was user tested to get an understanding of how usable it is, and to discover any usability problems or improvements that can be fixed in the next design iteration.

As with the user test of the mobile application, the "Wizard of Oz" testing method was again used for the user test of the website's paper prototype. This testing method was explained in further detail in Section 6.6. A quick recap of the method is that the prototype is printed out on multiple sheets of paper, and a "wizard" changes the sheets whenever the user interacts with it. The user test setup can be seen in Figure 60.

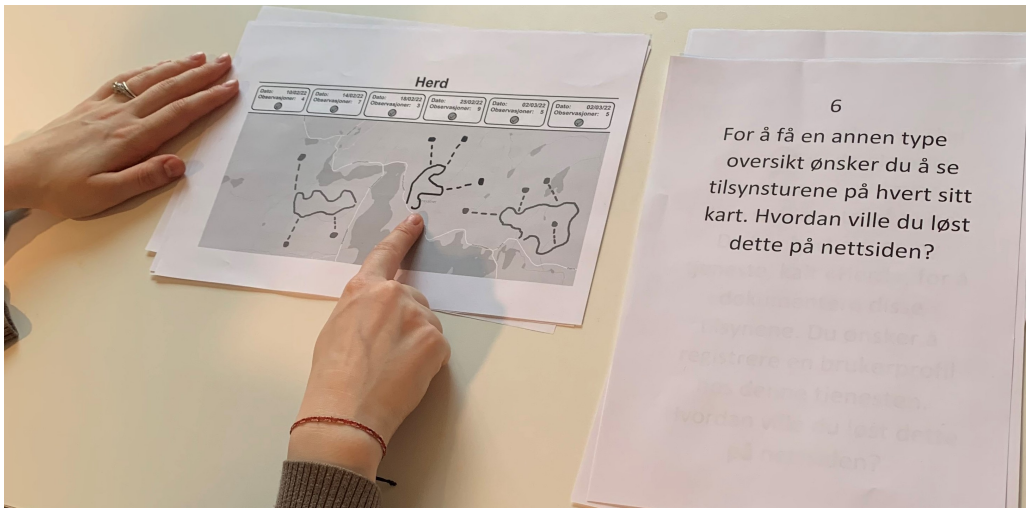

Figure 60: How the website's paper prototype was user tested

The user test followed the same ten testing guidelines as the user test of the mobile application, which can be seen in Section 6.6. The user test itself consisted of the user solving eight different test assignments given to them. These test assignments can be seen in appendix D, and they were created to test all the major parts of the website. After the user had solved all eight assignments, they were asked six different follow-up questions, which can be seen in appendix E. These questions are mostly the same as the follow-up questions that were asked during the user test of the mobile application, and they are meant to give a better understanding of the user's experience with the prototype and how it can be improved.

8.5.1 Results from the User Tests

The website's paper prototype was user tested on five different people, who's ages range from 19 to 24. These people are my room-mates as part of my 15-people student collective. The prototype was user tested only on people that I live with to reduce the risks surrounding the Covid-19 pandemic. Two of these people are familiar with the sheep supervision process as they grew up on a sheep farm.

The user tests of this first design iteration generated important knowledge of how usable the design is, and how it can be improved. The five users were all able to complete the eight test assignments seen in appendix D. The users were overall satisfied with the design, but they also saw areas in which it can be improved.

After the users had finished their test assignments, they were asked what they liked about the design. In addition to the design's intuitiveness being something that the users liked, they also enjoyed the design's minimalist approach. One user commented that they "liked that the website did not annoy me by showing too much stuff at the same time". Another user mentioned that "it was easy to understand what I needed to do to solve the assignment".

Another positive aspect that three of the users mentioned, was the possibility to inspect supervisions in two different ways. One of these users said "it was really nice to be able to see the supervisions together on one map, and I also see how seeing the supervisions on separate maps can be good if the supervisions have been performed in the same place". Another user said that they "like the list of supervisions on the page with the single large map, as it allows me to change the supervisions on the map without having to go back to the previous page".

One issue mentioned by a couple users was related to the wording of two of the buttons seen in Figure 57. The two buttons are the "Vis på ett kart" button and the "Vis på ett kart/tur" button, both of which are used to inspect supervisions. The label of these buttons made it difficult for these users to understand their functionality before they actually attempted to click on them. One of the users said that they "did not understand what kart/tur meant", while another user said that "the first button should specify that the supervisions are shown *together* on a single map".

Another issue was encountered by two users when they were tasked to sort their supervisions. They noticed that the prototype did not include a way to decide between ascending or descending sort. One of the users said that "it would be nice to be able to choose between ascending or descending sort, as both options could be useful in certain situations".

Four of the users also said that they disliked that the four buttons seen in Figure 57 did not appear unless they had selected at least one supervision. One user made the argument that they "would like to know what options I have before I start selecting supervisions", while another user mentioned that they "would not have known that these buttons existed unless I selected a supervision from the list".

The first user also struggled to navigate from the supervisions inspection pages back to the supervisions list page, because of the design missing a "back" button. As this was an obvious flaw in the design, a "back" button was drawn with a pen onto the paper during the first user test, as this would have been an issue for the rest of the users as well.

8.6 Suggestions for Design Improvements

At the end of the user tests, the users were asked to give the design a score from 1 to 10, where 10 means that the design is close to flawless and cannot be further improved. One user gave the design a 7, three gave it an 8, while the last user gave it a 9. This results in an average score of eight out of ten, which shows that there is room for improvements. The users were then asked what had to be added to, or changed with, the design for them to increase the score they gave. Their answers, along with my own thoughts, serve as the foundation for the following improvement suggestions.

- The label of the "Vis på ett kart" button should be changed to e.g. "Vis samlet på ett kart". This makes the button better communicate that the supervisions are shown *together* on the map.
- The label of the "Vis på ett kart/tur" button should be changed to e.g. "Vis på ett kart per tur". This way we avoid any confusion caused by the use of "kart/tur".
- As mentioned by some of the users during the user tests, there should be an option for the user to choose between ascending or descending sorting of the supervisions.
- The buttons on the supervisions list page should always be visible. Instead of being hidden, the four buttons should be disabled when no supervisions are selected. This allows the user to know what their options are without having to first select a supervision.
- The "Vis på ett kart/tur" button gives the same result as the "Vis på ett kart" button when exactly one supervision is selected, and having both buttons enabled in that situation is unnecessary. The "Vis på ett kart/tur" button should therefore be disabled unless at least two supervisions are selected.
- There should be a "back" button on both of the supervision inspection pages. Clicking this button would bring the user back to the supervisions list page.

9 Website - The Design of the Implementation

This section will present the website's second design iteration. This iteration is the actual developed and implemented version of the website, and its design is largely based on the website's paper prototype. This iteration follows the same design quality guidelines that were used for the design of the mobile application, as seen in Section 6.2. This section will start by taking a quick look at how this implemented design was created, followed by a walkthrough of the changes made in this design iteration. A rationale for the design is then given, before the user tests and the results from these are presented. The section ends by giving suggestions for how the design could be further improved. The flowchart for this iteration has not changed from the first iteration, which can be seen in Figure 53.

9.1 How the Design of the Implementation Was Created

All the improvement suggestions that were generated during the user tests of the paper prototype (seen in Section 8.6) have been incorporated into this second iteration. This version of the design was created during the development of the website. Making considerable changes to the design after this iteration would therefore be time consuming, so it was important to thoroughly consider what improvements could be implemented. As was also the case for the first iteration, the design principles of Don Norman [32] and the heuristics by Jacob Nielsen [31] again played a large role in shaping the design.

9.2 Design Changes

Based on the results from the first round of user testing (seen in Section 8.5), multiple improvements were implemented in this second design iteration. With that said, the design is still very similar to how it looked in its first iteration. So instead of giving another walkthrough of the design, this section will look at the changes that have been implemented. To get a thorough picture of the design, I suggest testing the website yourself by visiting the URL that was presented in the preface of this report.

The first significant design change can be seen on the login page in Figure 61. To log in, the user now has to type in their farm number in addition to their e-mail-address and password. Having the farm number be a part of the login credentials allows the users to have different accounts for different farms, which is beneficial for users who perform supervisions for multiple farms.

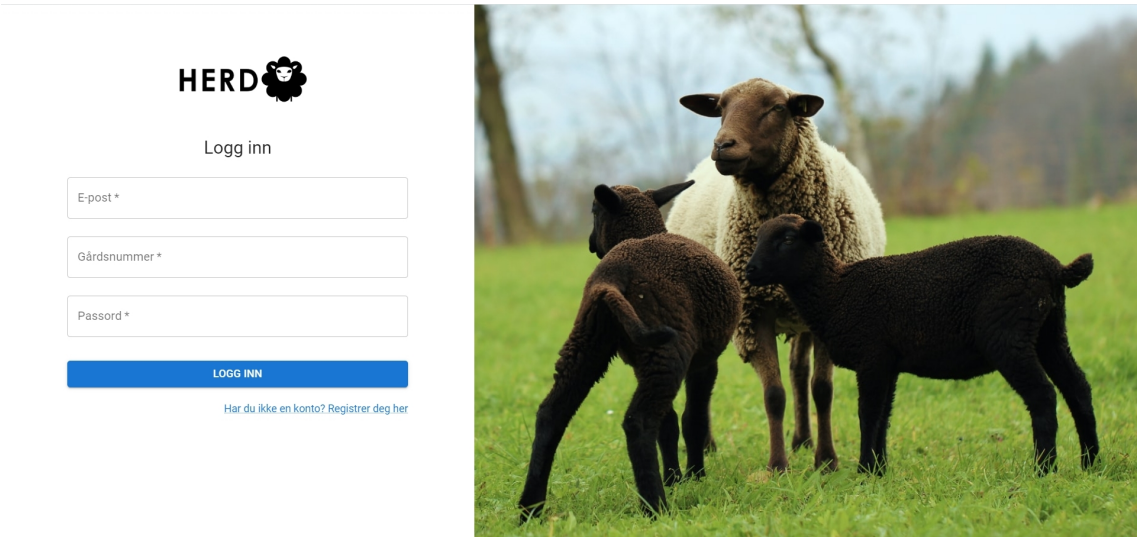

Figure 61: Login page

The register page, seen in Figure 62, has also been changed slightly. The register form is now placed on the left side of the page. When the user switches between the login page and the register page, the forms are changed through a sliding animation. This animation became jarring when the register form was on the right side of the page, which was the reason for moving it to the left.

The picture on the login and register page is a random sheep-themed image fetched from the "Unsplash" API [35]. A new random image is fetched every time the user visits the website. Random sheep images were added to these pages to increase the website's uniqueness in an effort to increase the user experience.

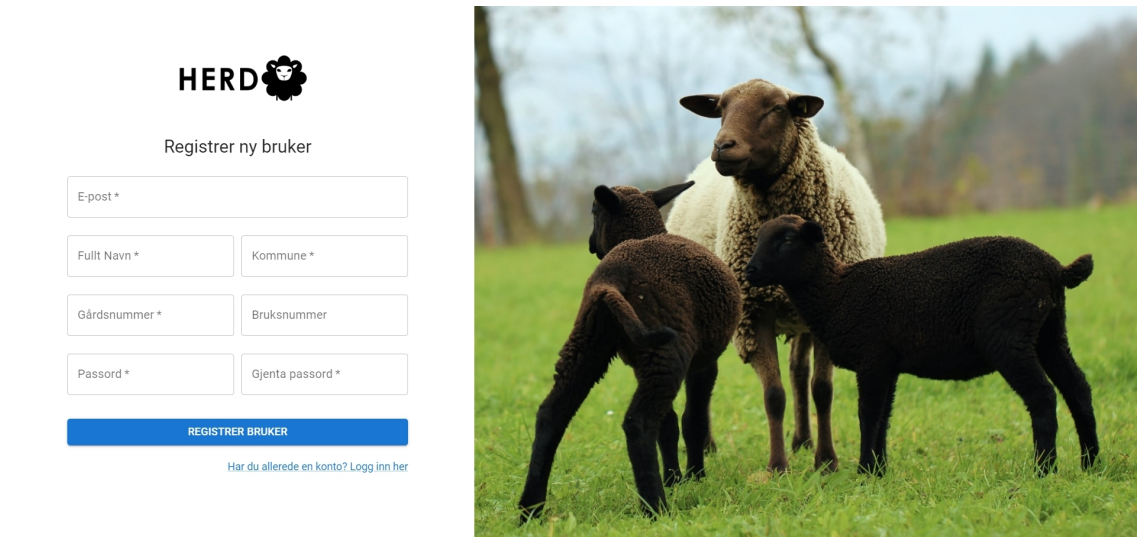

Figure 62: Register page

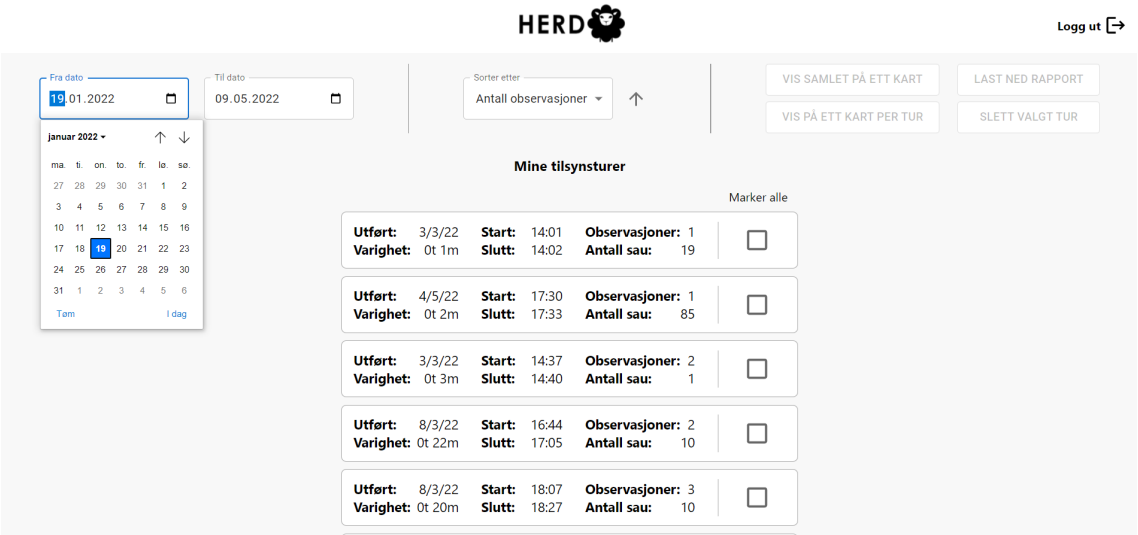

Figure 63: Supervisions list page - No supervisions selected

The supervisions list page has also seen some improvements. As can be seen in Figure 63, an arrow button has been added to the options bar, which the user can click to toggle between ascending or descending sort of their supervisions. An upwards-pointing arrow indicates an ascending sort, while a downwards-pointing arrow means that the sorting is performed descendingly. A log-out button has also been added to this page in the top right corner.

The same page has also been changed so that the four buttons in the top right corner are always visible. If no supervisions are selected, these buttons are disabled, as seen in Figure 63. If a single supervision is selected, one of the four buttons is disabled, as seen in Figure 64. The button that is disabled is the one used for inspecting the selected supervisions on separate maps, and it is disabled because, for a single selected supervision, it would have the same effect as the "Vis samlet på ett kart" button. If two or more supervisions are selected, all four buttons are enabled, as seen in Figure 65.

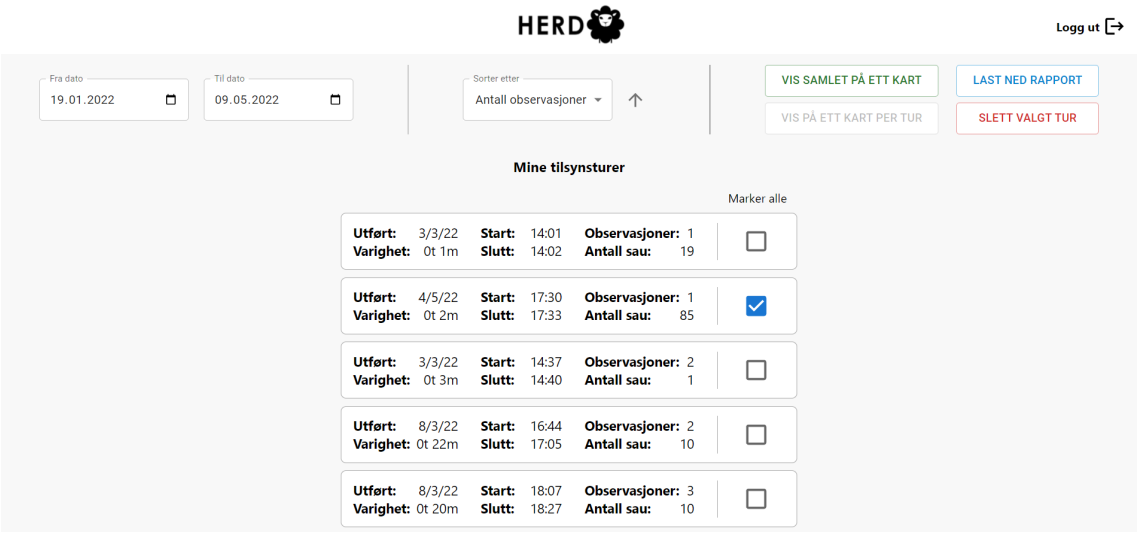

Figure 64: Supervisions list page - One supervision selected

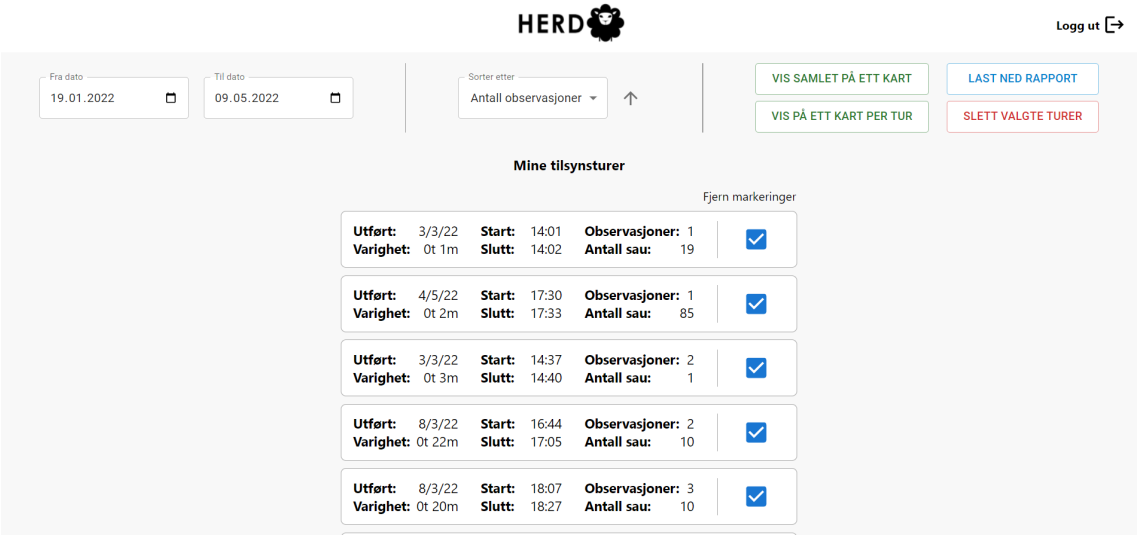

Figure 65: Supervisions list page - Multiple supervisions selected

The page for inspecting supervisions together on a single map has also been updated. As shown in Figure 66, a "tilbake" button has been added in the top left corner, which brings the user back to the supervisions list page when clicked. A log-out button has also been added to the top right corner of this page.

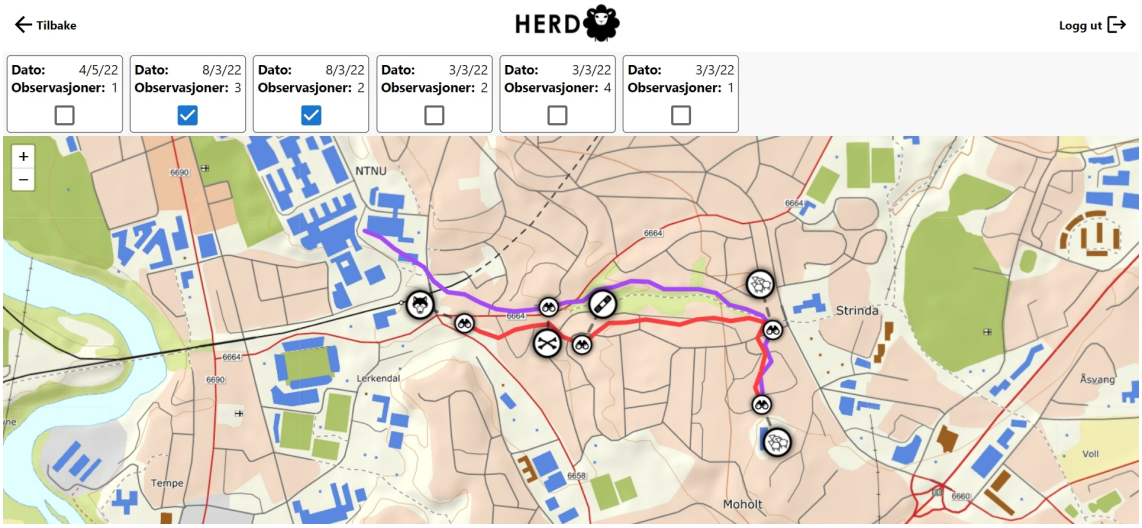

Figure 66: Supervisions inspection page - Single map

The other "supervisions inspection" page, seen in Figure 67, has also been changed slightly. The text boxes that contain the supervisions' date and number of observations are no longer located in the top left corner of each map, but have been moved to the bottom left corners. This change was done to make room for the map's control element for zooming, which is also located in the top left corner. As with the other pages, a back button and a log-out button have also been added to this page.

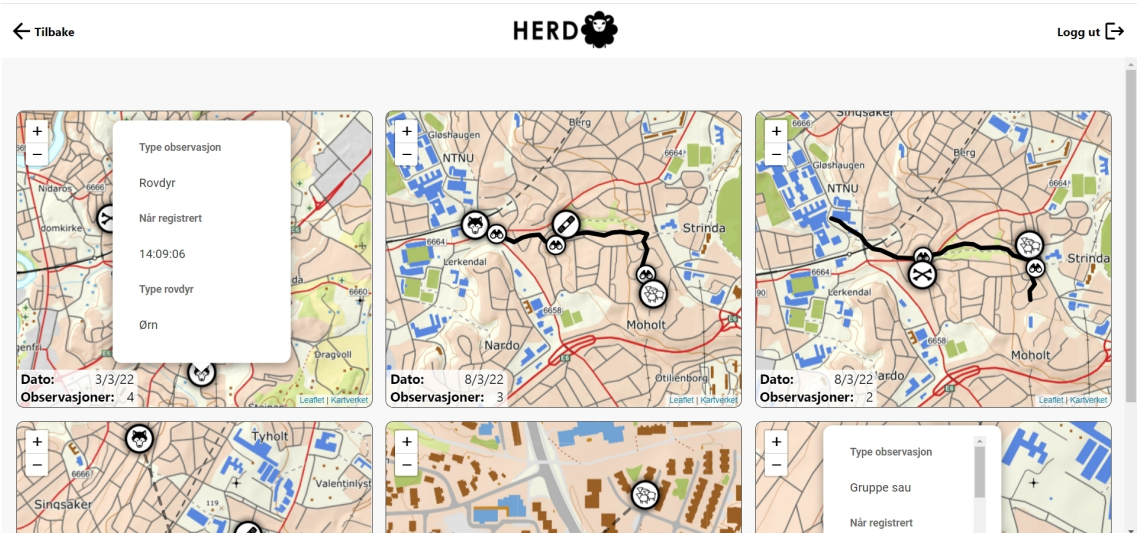

Figure 67: Supervisions inspection page - Multiple maps

When developing the website I realized that generating a report may take a few seconds, so to make sure that the user gets the appropriate feedback when they click on the "Last ned rapport" button, they are now shown the text and animated loading circle seen in Figure 68 while the report is being generated.

Figure 68: Waiting for the report to be generated

The actual PDF report can be seen in Figure 69 and Figure 70. The design of this report was not included in the first design iteration, because at the time it was thought of as separate from the interface that the user interacts with. In hindsight, it could have been beneficial to have included the report as part of the website's paper prototype, so that I could have user tested it before making the actual implementation. When user testing the implemented website, there will be test assignments that test the user's experience with the design of this report.

The first page of the report, seen in Figure 69, is a front page that shows relevant information such as the farm number, the municipality, and the name of the person who performed the supervisions. After the front page, there is a table that summarizes the supervisions, as shown in Figure 70. This table was included in the report to have a more compact and easily readable presentation of

the data, and because it made it easier to present cumulative data of the number of injured sheep, deceased sheep, wolverines, and other observed predators.

Following the table, the report presents the supervisions in more detail, as seen in Figure 70. A screenshot of a map with the path and observations are included for each supervision. After discussions with my Master's supervisor, we concluded that this report should include the supervision's date, start time, end time, the number of injured sheep, the number of dead sheep, the number of wolverines, the number of predators that are not wolverines, the number of healthy adult sheep, the number of lambs, and references to the location of where the supervision was conducted.

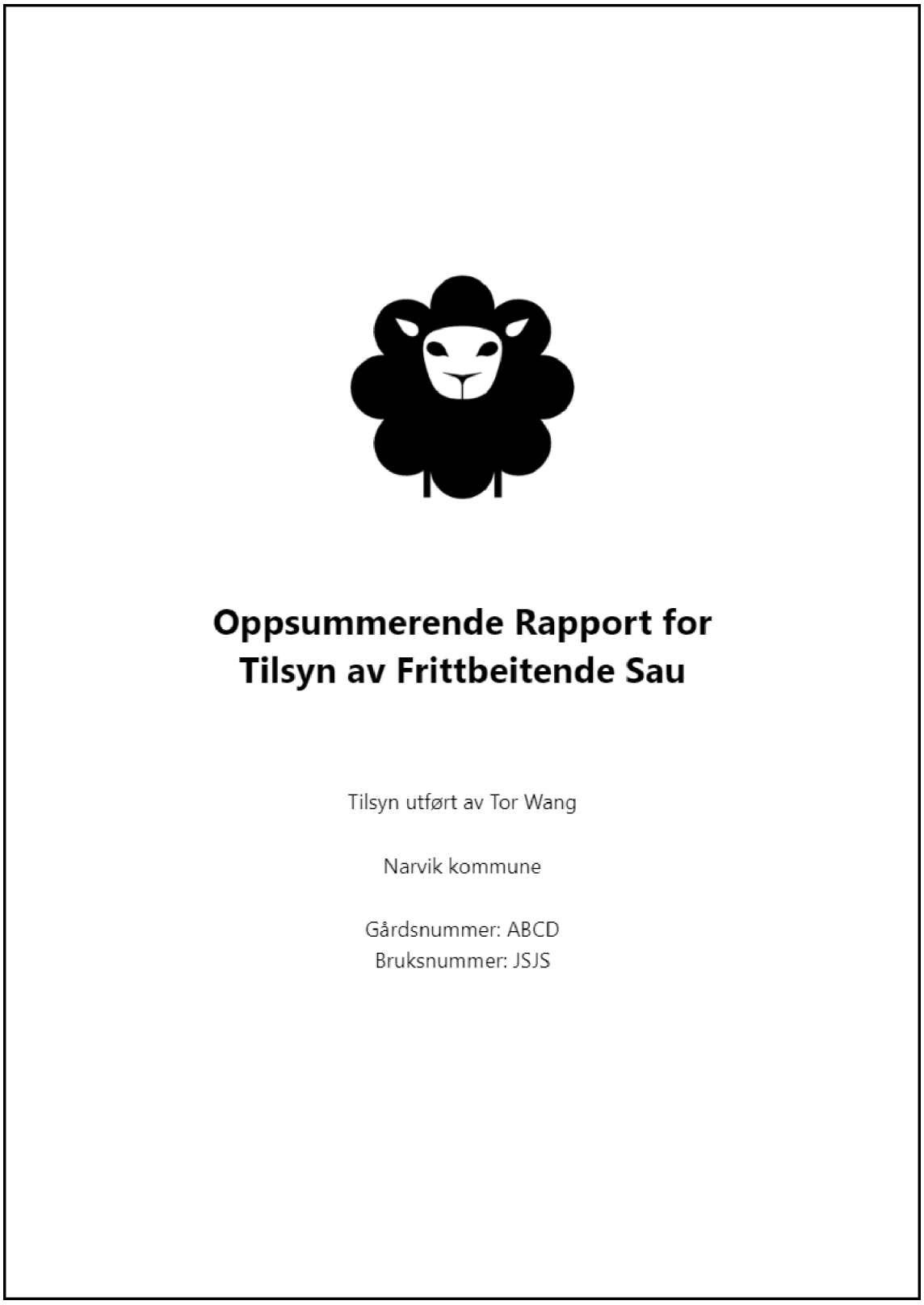

Figure 69: Supervisions PDF report - Page 1 of 2

Tilsynsturer | Tabell

Dato utført	Start-tid	Slutt-tid	Friske voksne sau	Friske lam	Skadde sau	Døde sau	Jerv	Øvrige rovdyr
8/3/22	16:44	17:05	6	3	0	1	0	0
8/3/22	18:07	18:27	6	3	1	0	1	0
Total	***N/A***	***N/A***	***N/A***	***N/A***	***1***	***1***	***1***	***0***

Tilsynsturer | Kart

Dato: 8/3/22
Start: 16:44
Slutt: 17:05

Skadde sau: 0
Døde sau: 1

Antall jerv: 0
Øvrige rovdyr: 0

Friske voksne sau: 6
Friske lam: 3

Startpunkt
Lengdegrad: 10.4309043
Breddegrad: 63.4115595

Sluttpunkt
Lengdegrad: 10.4078239
Breddegrad: 63.4157595

Dato: 8/3/22
Start: 18:07
Slutt: 18:27

Skadde sau: 1
Døde sau: 0

Antall jerv: 1
Øvrige rovdyr: 0

Friske voksne sau: 6
Friske lam: 3

Startpunkt
Lengdegrad: 10.4136156
Breddegrad: 63.413369

Sluttpunkt
Lengdegrad: 10.4308802
Breddegrad: 63.4112608

Figure 70: Supervisions PDF report - Page 2 of 2

9.3 Design Rationale

The most significant changes to the design have already been explained and justified in Section 9.2, so this section will instead focus on how Jacob Nielsen's design heuristics [31] and Don Norman's design principles [32] have again been used to further improve the design in this iteration. These principles and heuristics are important for achieving a design with a high degree of usability.

The principle and heuristic of "feedback" has been used to improve the design. As seen in Figure 68, the users now get an animated feedback message while the report is being generated. This feedback message hopefully prevents the user from believing the system froze while it is working behind-the-scenes on generating the report. The users now also get feedback messages when something goes wrong when logging in or registering for a new account. Figure 71 shows an example of this, where the user gets a feedback message when there is a mismatch in the passwords during the registration process.

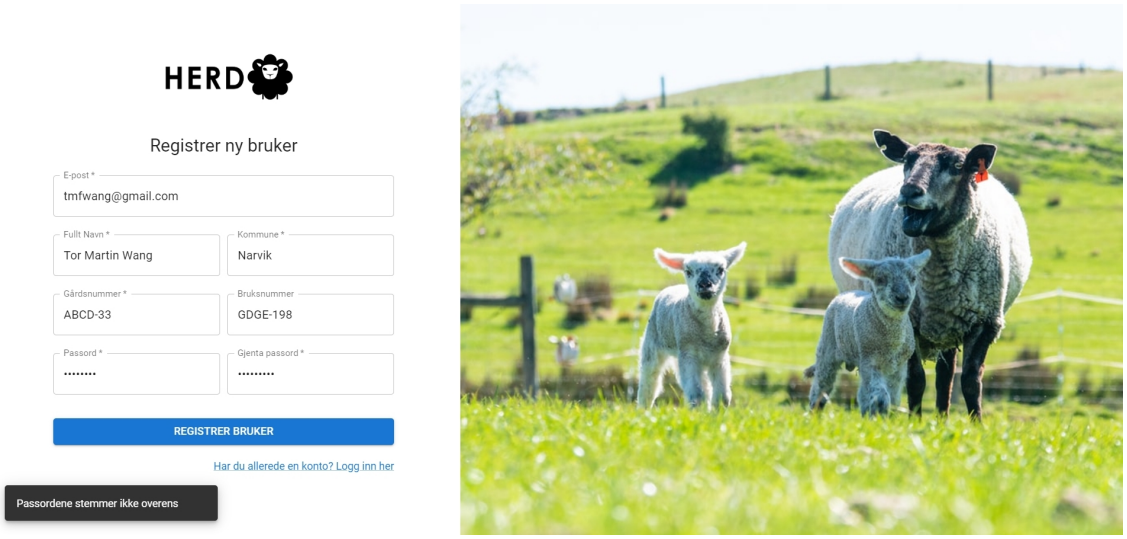

Figure 71: Feedback message when trying to register using mismatching passwords

Don Norman's principle of "visibility" had not been put enough focus on during the first design iteration, as the four buttons seen in the top right corner in Figure 63 were hidden when no supervisions were selected, which led to these options being invisible for the user. This has been fixed in this second design iteration with the use of Don Norman's design principle of "constraints". As seen in the same figure, the four buttons are now always visible, but they have a design which communicates to the user that they are not clickable when no supervisions have been selected.

Jacob Nielsen's fifth heuristic of "error prevention" has also been focused on in this design iteration. This heuristic aims to "either eliminate error-prone conditions, or check for them and present users with a confirmation option before they commit to the action." [31]. An example of this heuristic can be seen in Figure 72, where the user is presented with a confirmation option before committing to the deletion of a supervision. This prevents the user from mistakenly deleting their supervisions.

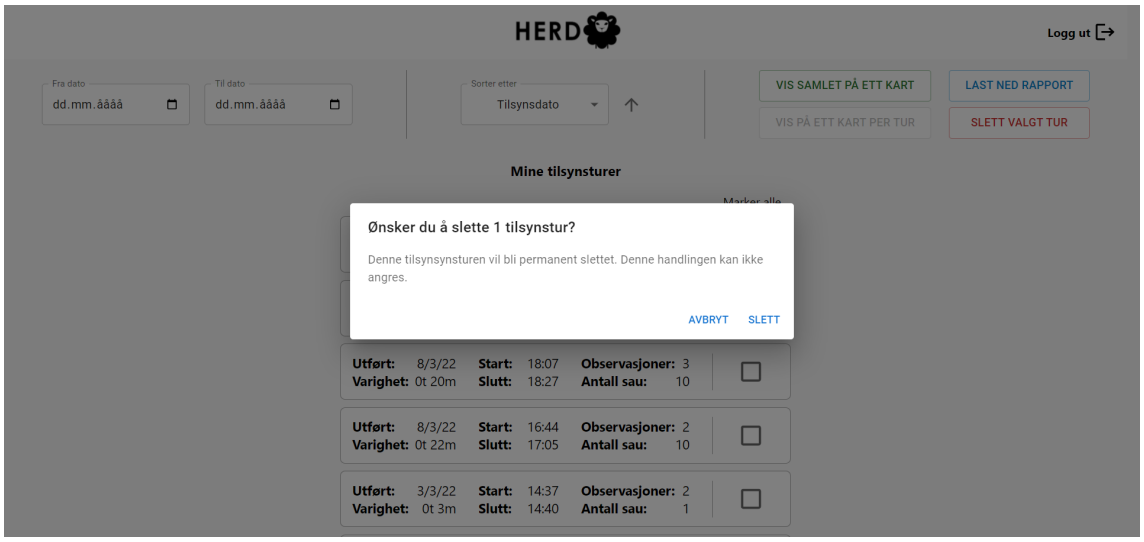

Figure 72: Confirmation message when trying to delete a supervision

Jacob Nielsen's fourth heuristic of "consistency and standards" and Don Norman's principle of consistency is still important in this design iteration. This can be seen in the way the control elements and their actions are consistent throughout the design. There has also again been put much focus on achieving a high level of consistency in how supervisions are presented and interacted with on a map.

The principle of "affordance" is still very important for the design. In addition to making every button look clickable through their design, affordance impacted a specific part of the design seen in Figure 73. In this figure one can see that the window that shows information of an observation has been given a fading bottom. Together with the scroll bar, this fading bottom gives the window the affordance that it can be scrolled to reveal even more information of the observation.

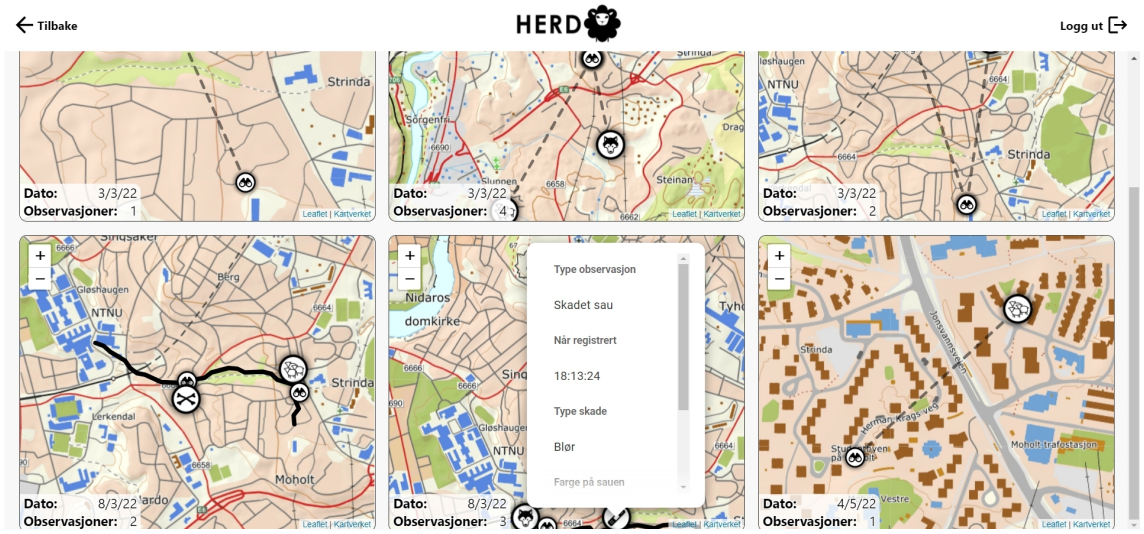

Figure 73: An example of how the fading bottom of the observation window gives the affordance that the window can be scrolled

9.4 User Testing

The implemented website was user-tested on four different people. As was the case with the user testing of the mobile application, none of the people who participated in the user test of the website's paper prototype were part of the user tests of this second design iteration. The reason for this is to preserve the validity of the user test, as these people would already be familiar with the design. The implemented website was user tested to get an understanding of its usability, and to discover any improvements that can be implemented if the project will be continued in the future.

For the user test, the user was given a laptop connected to the internet. The user was also given the URL for the Herd website, which they entered manually in the installed web browser. The test assignments included all eight tasks from the user tests of the website's paper prototype, in addition to three new tasks that were added to test the usability of the generated PDF report. These eleven tasks can be seen in appendix D. During the user test, the test assignment was first read aloud to the user, then it was placed on the table so that the user could read it themselves while solving it, as seen in Figure 74.

Figure 74: Setup of the user tests of the Herd website

The same ten testing guidelines that were presented in Section 6.6 were again followed during this round of user testing. When the user had completed all test assignments, they were asked any questions that arose during the test, and they were asked the same six follow-up questions as in the user test of the paper prototype, as shown in appendix E.

9.4.1 Results from the User Tests

As mentioned, the website was tested on four different people, who's ages range from 22 to 25. These four people were again people that are part of my 15-people student collective. The website was user tested on people I live with due to the risks caused by the Covid-19 pandemic. One of these four people has close family members that work as farmers, and is therefore familiar with the supervision process of sheep.

The user tests were very useful for getting an understanding of how usable the website is, and how it could be improved in the future. The four test subjects were all able to complete the eleven test assignments. All the users were overall very satisfied with the level of usability that they experienced with the Herd website.

The users again mentioned intuitiveness as one of the strong aspects of the design. One user told that "the website was very easy to use and navigate", while another user said that "everything felt logical, and I never got stuck while trying use the website".

Another positive aspect that was brought forward by two of the users, was the design of the generated report. One user said they "really liked that I could create a report of my supervisions". The other user said that "it was really nice to see the two different ways the supervisions are presented in the report. The table was really good for getting a quick overview, and for getting summarized data. The map presentation was also beneficial for getting more in-depth information of each supervision".

Three of the four test users were especially positive about the two different ways of inspecting supervisions. One user said that they "like how I could view the supervisions together on one map, and it was a smart solution to allow me to get more information of an observation by clicking on it on the map". A second user mentioned that they "see the benefits and usefulness of both ways of viewing the supervisions".

Two users also told that they were satisfied with the filtering and sorting functionality on the website. One user said that "filtering was a nice addition that I can see myself using", while another user mentioned that "both the filtering and sorting functionality was great, and I can't think of any way these could be expanded or improved".

Another user noticed a weird page break in the generated PDF report where a supervision's information was split over two different pages, and mentioned that "the page break doesn't really affect anything at all because all the information is still there and fully readable, but if I had to nitpick on anything that could be improved, it would be to fix those page breaks".

One user mentioned that "it would be cool if it was possible to upload and see pictures of the different observations. For example, if I have observed an injured sheep, I would want to take and see a picture of the injury. This would also be useful for observations of dead sheep".

9.5 Suggestions for Design Improvements

As with the other rounds of user testing, the users were also this time asked to give the design a score from 1 to 10, where 10 means that the design cannot be improved in any significant way. Two users gave a score of 9, while the other two users gave it a 10, making the average score 9.5 out of 10. The users were then asked if, and how, the design could be improved. Their responses, along with my own thoughts, serve as the foundation for the following list of improvement suggestions.

- Icons can be added to the four buttons seen in the top right corner in Figure 65. This could improve the buttons' affordances, and make it easier for the user to quickly understand what the buttons' actions are.
- The Herd website could add the support of viewing pictures of the observations. For this feature, the Herd mobile application would also have to be updated so that it supports taking pictures of observations. This feature was considered before the project began, but it was decided that it was outside the current project scope. If the Herd system is to be continued in the future, the ability to take pictures of observations should be added.

- Currently, the supervisions report is generated using a screenshot technique, where the pages in the PDF exclusively consist of images. This can lead to some unwanted formatting on page breaks, and it makes it impossible to select and copy the text in the report. In the future, one could explore the possibility of generating more advanced PDFs with selectable text and more reasonable page breaks.

10 Choice of Technology

This section will explore and justify the most significant technological choices that were made during the development of the Herd system. This includes which platforms the application was developed for, how the website was deployed, which frameworks were used, and what third-party libraries were utilized.

10.1 Version Control

Version control was something that I decided early that I wanted to include in this project. From experience from previous projects, it is very difficult to develop something without proper version control, as it makes it impossible to revert back to a previous version whenever a severe error appears. For this project, GitHub [36] was chosen as the platform for version control. The reasons for this are my previous experience with GitHub, it is free to use, and it is the industry standard for version control.

10.2 Mobile Application

10.2.1 Targeted Platforms

The Android and the iOS platforms are the two dominant platforms in the mobile market, and the Herd mobile application was developed with this in mind. Currently, the mobile application has been fully deployed on the Google Play Store (the application can be downloaded here: [37]), and is therefore available on Android devices. The application is currently not deployed on the Apple App Store, as this requires a Mac computer, which was something I was unable to acquire for this project. The application has been developed using a cross-platform framework that also supports the iOS platforms, so deployment to the Apple App Store should easily be possible with a Mac computer if the project is continued in the future.

10.2.2 Application Framework

When it comes to the choice of a framework for the mobile application, I first thought of using the React Native framework [38]. This is a framework I am familiar with from previous projects, and it supports the cross-platform development that I desired. Upon experimenting more with this framework, it proved challenging to implement the offline map due to React Native's poor support for this kind of functionality. This prompted me to take another look at alternative frameworks that could be used. This is when I discovered the Ionic framework [39]. This framework allows the creation of a "hybrid" mobile application, which is essentially a web app that has been put in a native app shell [40]. This opens up the possibility of using both web technologies like Leaflet maps [41] with offline support, and native technologies like storage, geolocation, and vibration. Ionic also supports cross-platform development, which allows me to develop the application for both Android and iOS devices at the same time.

Ionic supports multiple different frameworks for the web portion of the application, and one of these is "React" [42], which was chosen as the web framework for the hybrid mobile application. The React framework is by far the front-end framework I am most experienced with, which considerably sped up the development process, and it has multiple characteristics and features that were very beneficial for this project. An important factor that contributed to React being chosen, was

how easily it allows implementing maps with offline support, which was one of the largest and most advanced features that had to be implemented in the "web" portion of the hybrid mobile application. I also saw the opportunity to make the development process more efficient by re-using code snippets between the Herd mobile application and the Herd website, and this was made possible by using React as the frontend framework for both of these.

10.2.3 Map

The Leaflet library [41] was used to implement the maps in both the mobile application and the website. This library was chosen because of its focus on making their maps mobile-friendly and highly-interactive. Another major reason for why Leaflet was chosen, was the Leaflet.Offline plugin [43] that expands the core Leaflet map library with offline map support. Using the Leaflet library together with the offline plugin made it possible to implement offline maps that can be used to perform and inspect supervisions. For the actual map images, an API from Kartverket was used, as they provide good quality map tiles through their open and free API [44].

10.2.4 Local Persistent Storage

The "native" app shell in an Ionic application is provided using the "Capacitor" framework [45]. This framework supports the use of different plugins, one of which [46] was used to implement persistent local storage of supervision data. Using a Capacitor plugin to implement local storage was the easiest and most natural choice given the already existing use of Capacitor.

Another Capacitor plugin [47] was used to securely store the login token so that the login session is persistent even after the user closes the application. This plugin encrypts the token value using the platform specific encryption methods [47].

10.2.5 Geolocation

A Capacitor plugin [48] was also used to implement geolocation of the user. This plugin was chosen as it also supported geolocation while the application is backgrounded, such as when the user's phone is locked. To save power on the user's mobile phone, I implemented different types of geolocation depending on whether the app is actively open or not. When the app is actively open, tracking happens more frequently, and the user's orientation is also tracked, which is not the case when the app is backgrounded. This orientation is then used to correctly rotate the user's marker on the map, which helps the user better understand their surroundings when registering observations.

10.2.6 UI Component Library

The Ionic framework comes with its own UI component library, which was actively used throughout the mobile application. This library is designed to be as close as possible to the native control elements that exist on Android and iOS devices. This component library was used to give the Herd application a high-performing native look that feels familiar to the users.

10.3 Website

10.3.1 Website Framework

"React" [42] was also used as the frontend framework for the website. Using the same framework for the website as for the mobile application allowed me to reuse code snippets, such as the majority of the code for the maps, which effectively shortened the required development time for the website. This framework was also chosen because of my thorough experience using it in previous projects.

10.3.2 UI Component Library

To give the website a professional and consistent design, the Material UI component library was used [49]. This component library provides multiple React components and icons that were utilized throughout the Herd website. Using the Material UI component library is also an effective way of speeding up the development process, as I don't have to create all the components from scratch.

10.3.3 Map

"Leaflet" [41] was also used to implement the maps on the website. Leaflet was chosen because it supported all the necessary features, and it made it possible to re-use the Leaflet-specific code from the mobile application.

10.3.4 Deployment

The website was deployed using the platform-as-a-service called "Heroku" [50]. Heroku was chosen because it makes it easy to deploy the website, it is free to use, and it automatically provides encrypted communication over HTTPS. The website is now available on the following URL:

https://master-herd-web.herokuapp.com/

10.4 Backend API

10.4.1 Development Framework

"Django REST" [51] was chosen as the framework for the backend API. Django was chosen because it makes it easy to quickly set up an API, and it is a framework I have previous experience using. The API is used by the users to register and login with user profiles, and to upload supervisions. Both the mobile application and the website make use of the API.

10.4.2 Database

SQLite [52] was chosen as the backend database. This is the default database for a Django project, and it was automatically included in the setup of the API. SQLite was chosen as it makes development very easy. However, it does not allow concurrent write operations to the database, which can be bad for the performance [53], and it should therefore be replaced with another database technology if the project is continued in the future. A suggestion for what database technology to use in the future is given in Section 15.

10.4.3 Deployment

"Heroku" [50] was again used when deploying the API. As with the deployment of the website, Heroku was chosen because it made it easy to quickly deploy the API, it is free, and all communication is automatically encrypted. The following is the base URL of which all API calls are sent:

https://master-herd-api.herokuapp.com/

11 Architecture

In this section, the software architecture will be presented. The architectural drivers, tactics and patterns will first be presented. To describe and communicate the software architecture, this section will also present multiple different architectural views. This method of using architectural views originates from the "4+1" view model, which includes the logical view, process view, development view and physical view [54]. This section can be especially useful for any possible future developers that wish to continue the development of the Herd system, as it gives an understanding of how the system is structured.

11.1 Architectural Drivers

Architectural drivers are considerations that are architecturally significant for the software system [55], and they drive how the software architecture is designed [55]. Both functional and non-functional requirements can typically be part of these drivers [55].

Usability
The main quality attribute for the Herd system is the attribute of usability. Usability became a significant architectural driver, as an intuitive user interface is necessary when creating a system that should be easy to use for users. The importance of usability made it necessary to create a GUI for the Herd system, of which users can easily interact with.

Performance
The secondary quality attribute for the Herd system is performance, and this also drove the design of the software architecture. For example, this impacted the choice of using React as the front-end framework. React makes it possible to only re-render specific components in the dynamic user interface, and therefore avoid re-rendering parts that haven't changed. This way of controlling re-renders can significantly improve the front-end performance.

Offline Maps
The functional requirement that the Herd mobile application needed to support downloading maps for offline use (seen in Section 4.2) significantly impacted the software architecture. Supporting this feature made several different frameworks (for example React Native, which was a front-end framework that was considered for the mobile application) more-or-less unfit for the application, because of their poor support for downloading maps. This resulted in the React framework being used, as this framework supported the implementation of offline maps.

Geolocation
Another functional requirement that had significant architectural impact is the requirement of using and storing the user's location during supervisions. This made it necessary to not only be able to access the mobile phone's GPS, but also be able to have an interactive map that can present the user's location.

Supporting Binoculars
One very important requirement for the Herd application is the requirement of supporting the use of binoculars during certain parts of the observation registration process (as seen in Section 4.3). This had an impact on the architecture, as this requirement introduced some unique needs from the system. These include the need of using the phone's speakers to give auditory feed, using the phone's vibration motors to give tactile feedback, and having a user interface that can be intuitive even when not actively looking at it.

Mobile Application and Website
The fact that the Herd system consists of not only a mobile application, but also an accompanying website, had a large impact on the architecture. One obvious impact stems from the requirement that the mobile application must be able to upload supervision data so that it can be seen and used on the website. Another impact originates from my desire to use the same front-end framework for both the mobile application and the website, as this would make it possible to re-use code from the mobile application when developing the website, making the development process considerably more efficient.

11.2 Architectural Tactics

An architectural tactic is a design decision that decides how a functional requirement or quality attribute will be satisfied [56]. This section will look at which architectural tactics have been used in the Herd system.

11.2.1 Usability Tactics

Supporting System Initiative
The system initiative tactics are the tactics that identify the models that the system uses to predict either the user's intentions or its own behaviour [57]. An example of this can be seen in both the Herd application and the website, as the system maintains a model of the task when the user is registering or logging in. Here the system tries to provide some form of assistance to the user in the form of correctly lower-casing the email address. Email addresses are always lower-case, and the system helps the user correctly enter their email correctly.

Supporting User Initiative
The user initiative tactics are those that improve the usability by allowing the user to take certain actions, to which the system correctly responds [57]. Examples of this are especially apparent when a user is registering a new observation using the Herd application. Here the user is allowed to undo steps in the registration process, and they are allowed to cancel the process completely.

11.2.2 Performance Tactics

Caching Data
One aspect that could impact the performance is having to wait for replies from the API server. To avoid sending multiple requests to the server, the response data is saved and shared between the different parts and components. This way, we avoid that every component that use the response data send and wait for their own API requests, and we avoid having to send duplicate API requests. This way of caching the data results in a considerable improvement on the overall performance of the system.

Reduce Computational Overhead
Reducing the computational overhead can improve the system's performance. One factor that can cripple the system's performance is when the front-end components are unnecessarily re-rendered. To avoid this problem of re-rendering, the respective built-in React tools were used.

Introduce Concurrency
Concurrency have been introduced several places in order to improve the software's performance. One such place is when a user is using the Herd mobile application to download map tiles for offline use. Downloading a map section typically requires downloading around 400-500 map tiles, resulting in just as many requests to the Kartverket API. If these requests were sent in sequence, where the system waits with sending the next request until it receives the response for the current request, the waiting time for the user would be considerably long. Instead, concurrency is introduced, and all these map tiles are downloaded in parallel, effectively decreasing the time required for downloading them.

The use of asynchronous requests throughout the application also introduces some form of concurrency. By using asynchrony, the system can fetch or send relevant data to the API while the user at the same time can continue interacting with the user interface. This way, the perceived responsiveness and performance of the system can be increased.

11.3 Architectural and Design Patterns

This section will have a look at some of the architectural and design patterns that have been implemented in the Herd system. An architectural pattern "expresses a fundamental structural organization or schema for software systems", while a design pattern "provides a scheme for refining the subsystems or components of a software system, or the relationships between them" [58]. Some patterns, like the client-server pattern, were actively decided to include in the system, while other patterns are introduced together with the frameworks that have been used.

11.3.1 State Pattern

The state pattern is "a behavioral design pattern that allows an object to alter its behaviour when its internal state changes" [59]. React has been used for both the mobile application and the website, and with it comes support for components to have their own internal state. An example of this can be seen when a user is using the mobile application to perform a supervision. When the user here initiates a registration of an observation, an internal state changes so that a registration modal is presented to the user.

11.3.2 Client-Server Pattern

The client-server pattern is a network architectural pattern that includes a server that communicates with clients [60]. A good example of this in the Herd system is the REST API that has been developed. This API has been deployed on a server using a platform called Heroku. The clients (i.e. the users) communicate with this API both when they use the mobile application and when they use the website. The API server allows the users to not only register and login with a user profile, but also allows them to upload and download their supervision data.

11.3.3 React Hook Pattern

React version 16.8 introduced the React Hooks API, and it drastically changed how components are made in React [61]. The React Hook design pattern makes React features such as state, refs, props and lifecycle available to functional components [61]. The Hook pattern has been used in almost every component in both the mobile application and the website, and it has made the code considerably more reusable between the two.

11.4 Logical View

The logical view of both the Herd website and the Herd mobile application can be seen in Figure 75 and Figure 76 respectively. The function-based front-end components in the React framework closely resemble typical class-based objects, and the logical views are therefore presented in the form of class diagrams. The logical views show all the components that have been created and how they are connected to each other, along with their variables and functions.

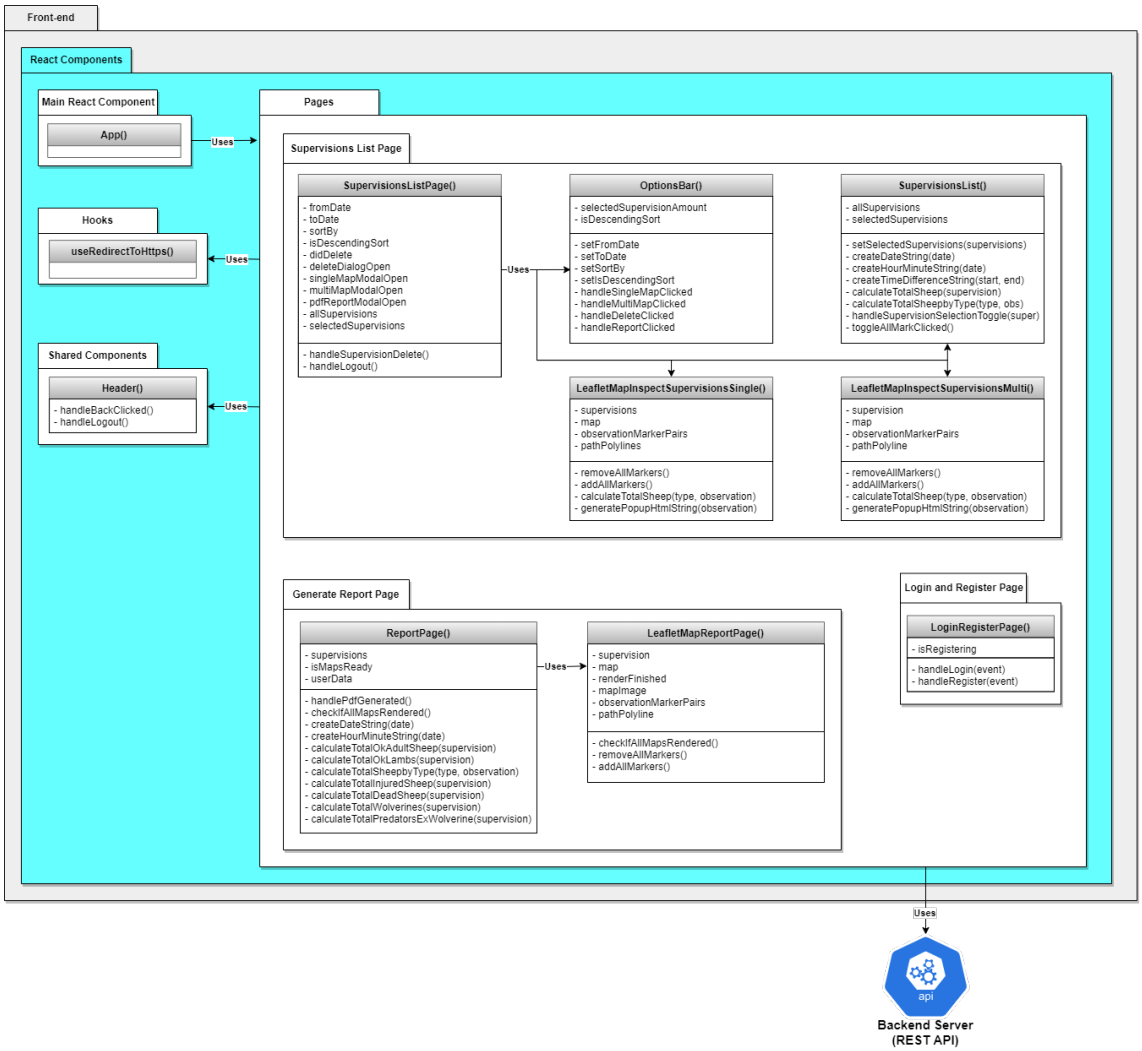

Figure 75: Class diagram for the website's architecture.

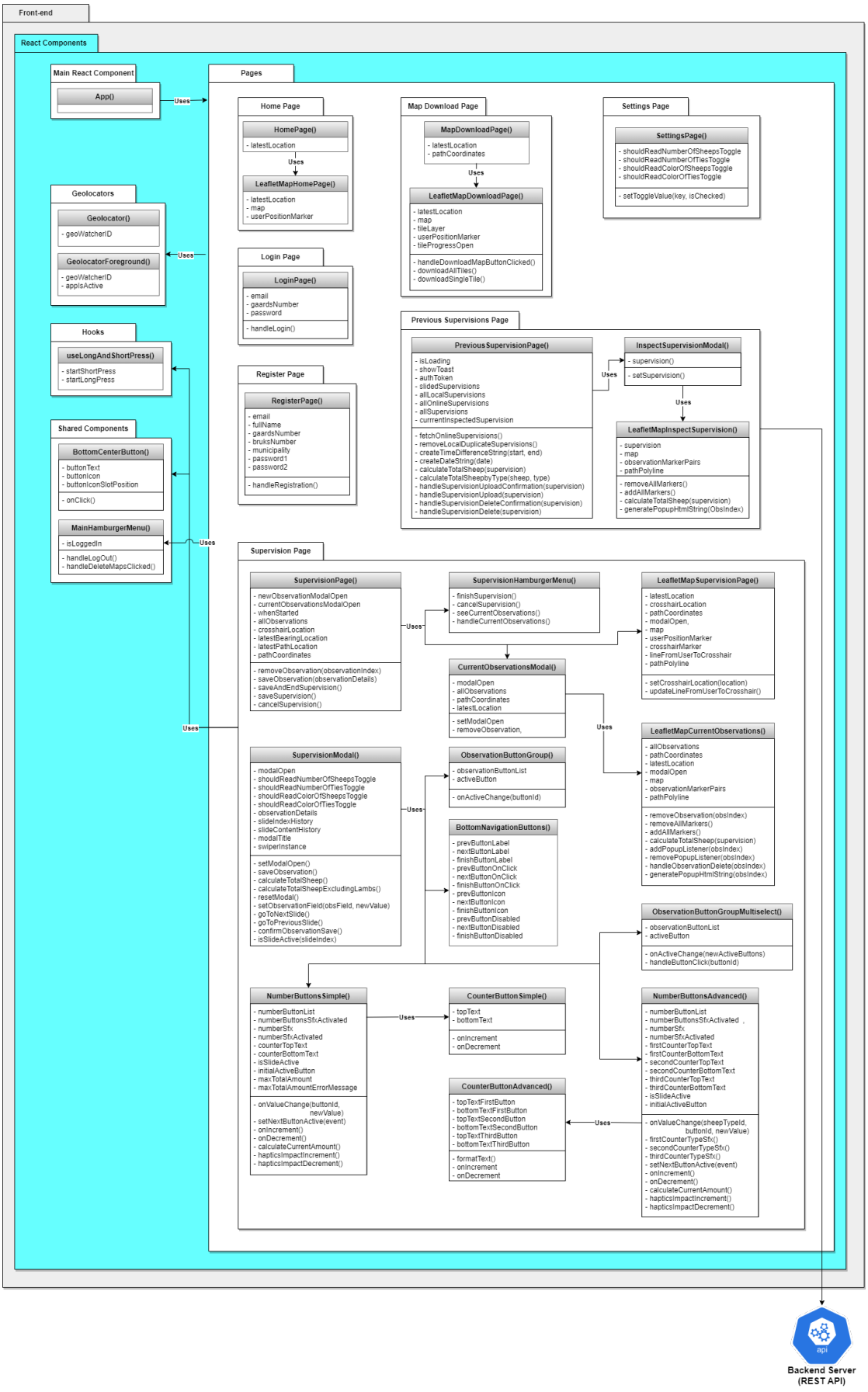

Figure 76: Class diagram for the mobile application's architecture.

11.5 Process View

The process view shows the system at runtime, and communicates how different parts of the system handles concurrency and synchronization [54]. Four different sequence diagrams have been created for the process view. The diagram in Figure 77 shows how a user can make their map support offline use by downloading, in parallel, map tiles from the "Kartverket" API. Figure 78 shows a user performing, registering and uploading a supervision. Figure 79 communicates the sequence of a user being presented with the previously-conducted supervisions. The last diagram, seen in Figure 80, shows the sequence of a user generating a PDF report of their supervisions by using the Herd website.

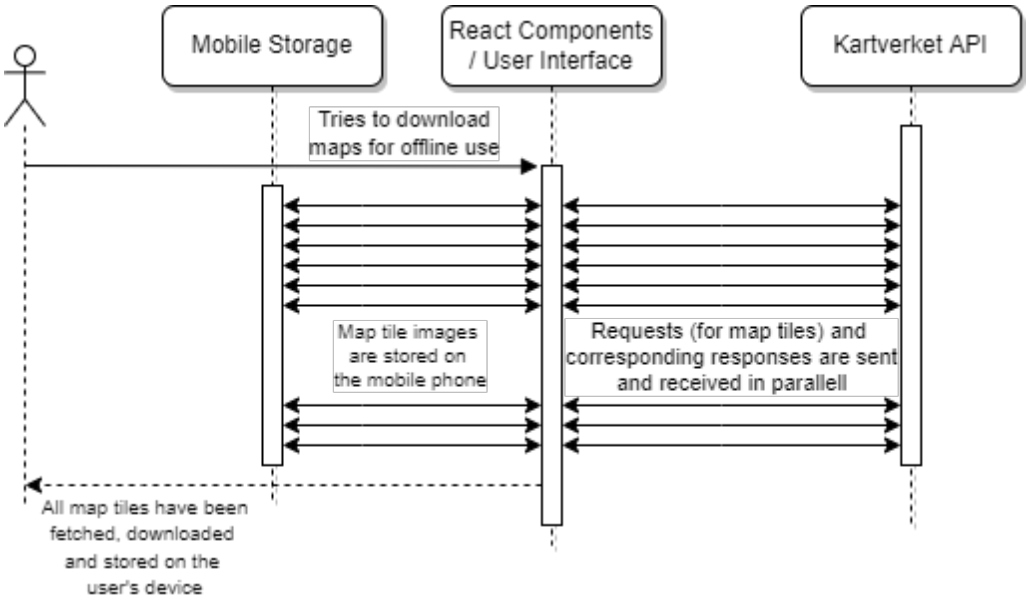

Figure 77: Sequence diagram of a user downloading map tiles for offline use

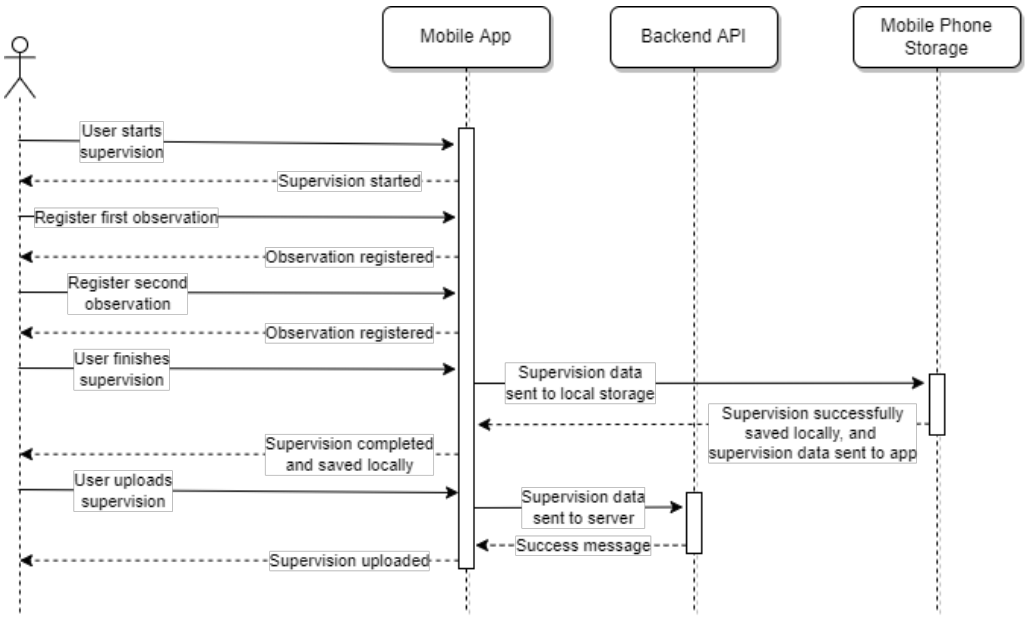

Figure 78: Sequence diagram of a user performing, registering and uploading a supervision

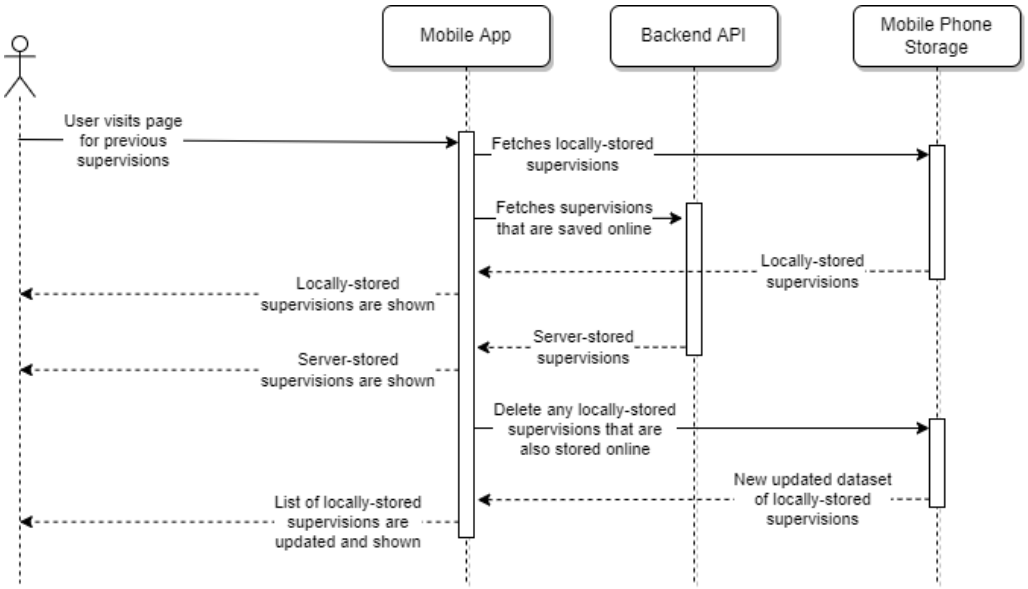

Figure 79: Sequence diagram of a user being presented, in the mobile application, with their previously-conducted supervisions

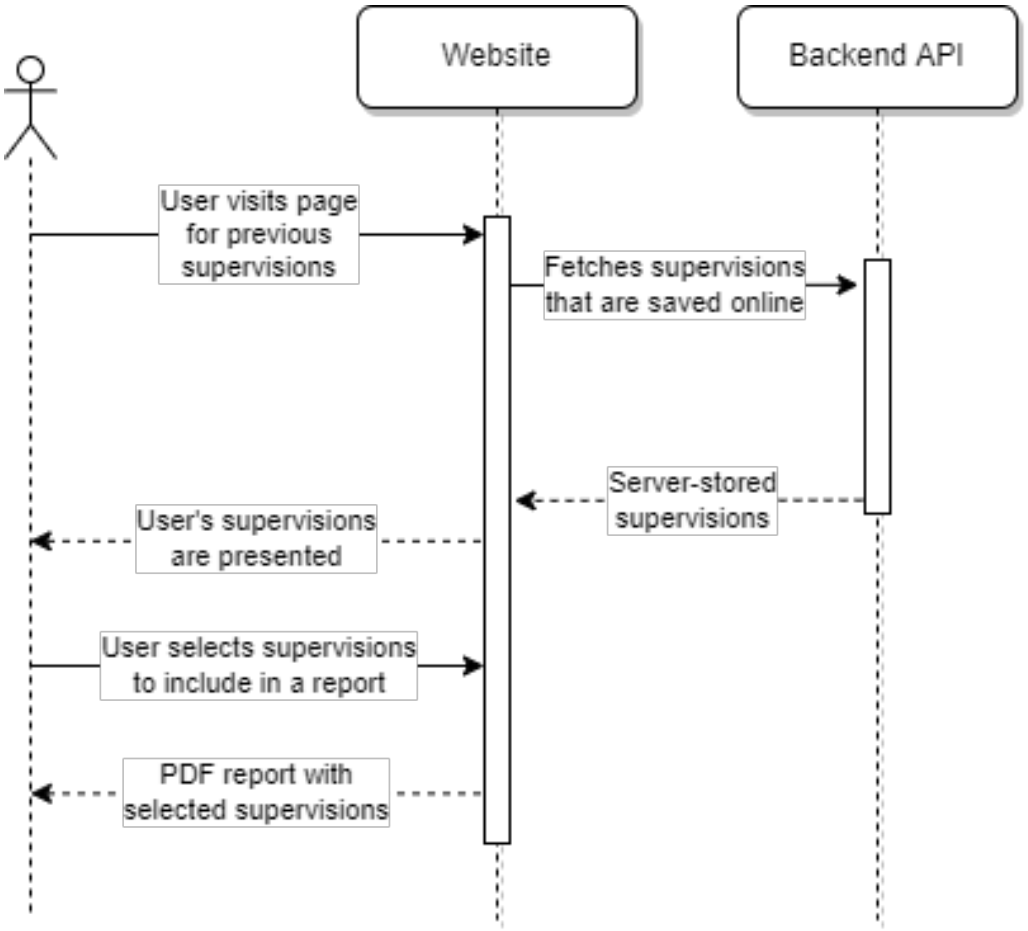

Figure 80: Sequence diagram of a user using the website to fetch and generate a PDF report of their previous supervisions

11.6 Development View

The development view is responsible for communicating the software in its development environment [54]. This view is useful for getting an overview of the overall structure of the system, which can be very helpful when planning and allocating time for the actual development and implementation of the software. The development view is presented in the form of a package diagram, as seen in Figure 81, and it shows how both the mobile application and the website are divided into separate pages

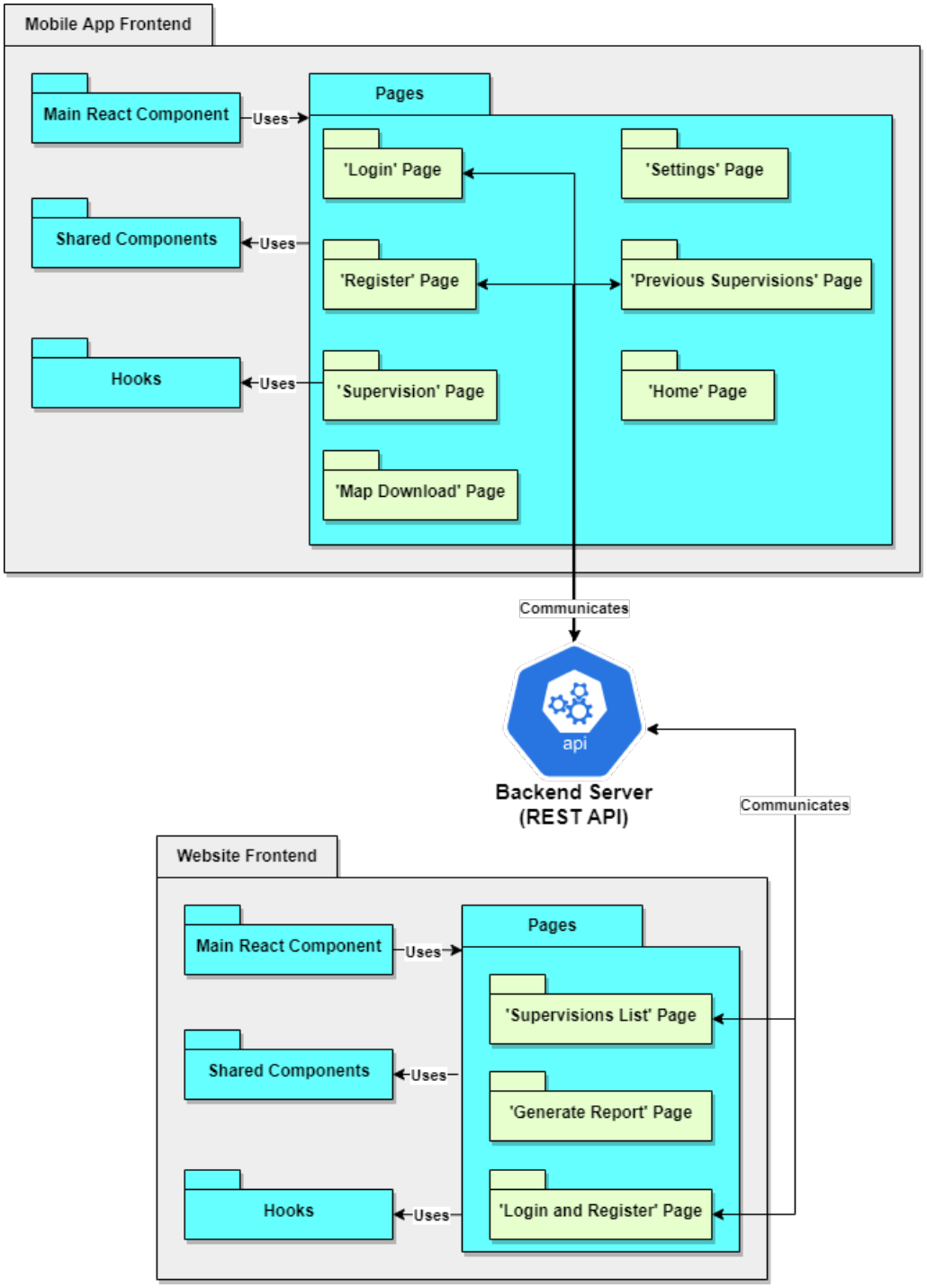

Figure 81: Package diagram for the Herd system

11.7 Physical View

The physical view can be seen in Figure 82 in the form of a deployment diagram. The deployment diagram shows how the website, mobile application and backend API are deployed and connected. As can be seen in this diagram, both the website and the backend API have been deployed on Heroku-servers using NGINX. It also shows that the communication between the website and the API, and between the mobile application and the API, are performed using HTTP messages.

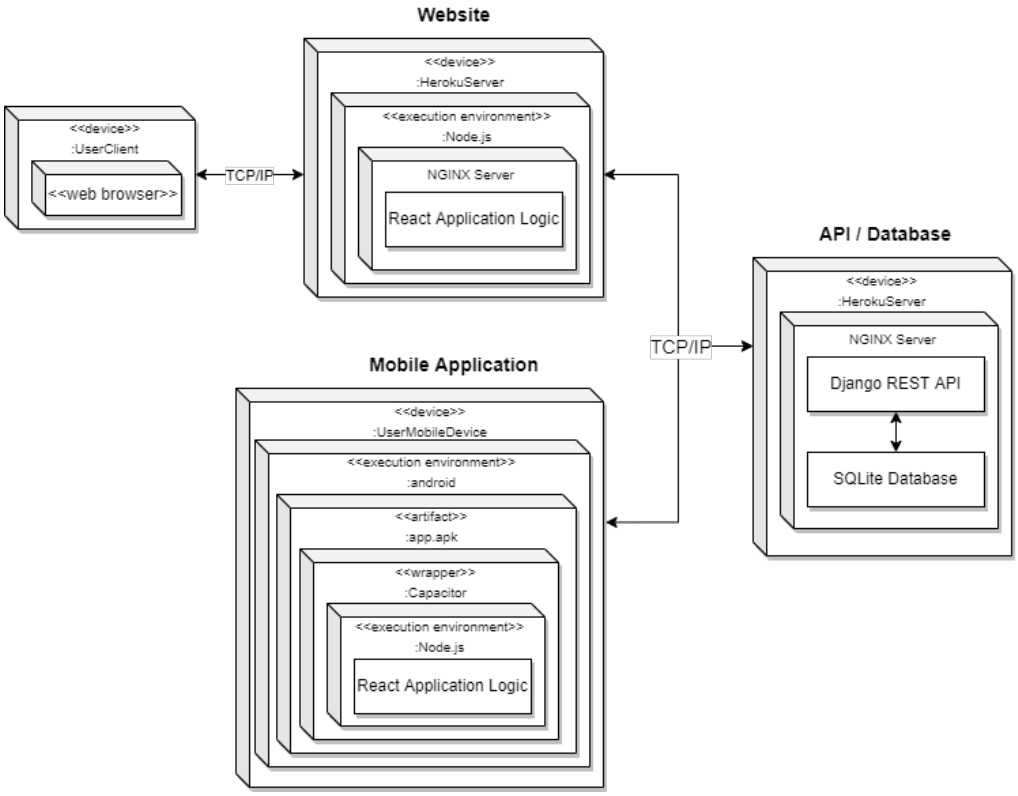

Figure 82: Deployment diagram for the Herd system

12 Testing

This section will look at the test plan for the complete Herd system, and it will present the test reports from the internal testing of the functional and non-functional requirements of the Herd mobile application and the Herd website.

12.1 Test Plan

Because the Herd system is not planned to be commercially launched during this Master's project, a decision was made early to prioritize user testing instead of unit testing. A large part of this project was to develop a design with a high degree of usability, so this was put more focus on than implementing unit tests. If more time was available, unit tests would have been created for both the mobile application and the website. Unit tests are good for discovering bugs with the system, and to discover if any future feature implementations unknowingly make unwanted changes to the rest of the code base. Because of the lack of unit tests, it has been important to perform thorough manual testing of the system during development, to ensure that the features work as expected. The overall test plan is presented in Table 25.

Table 25: Test plan

Type of test	**Description**	**Measure**	**When**	**Test subjects**
User test (App - iteration one)	The paper prototype of the mobile application is user tested to discover usability problems and possible improvements that can be made in the second design iteration	The users are able to solve the test assignments with a high degree of satisfaction	After the mobile application's paper prototype has been created	Family members with limited knowledge of sheep supervisions
User test (App - iteration two)	The implemented mobile application is user tested to measure the design's usability and to discover improvements that can be made in a possible future iteration	The users are able to solve the test assignments with a high degree of satisfaction	After the mobile application has been developed	Room mates with varying knowledge of sheep supervisions
User test (Website - iteration one)	The paper prototype of the website is user tested to discover usability problems and possible improvements that can be made in the second design iteration	The users are able to solve the test assignments with a high degree of satisfaction	After the website's paper prototype has been created	Room mates with varying knowledge of sheep supervisions

User test (Website - iteration two)	The implemented website is user tested to measure the design's usability and to discover improvements that can be made in a possible future iteration	The users are able to solve the test assignments with a high degree of satisfaction	After the website has been developed	Room mates with varying knowledge of sheep supervisions
Manual testing	The mobile application and website are manually tested to ensure that features are working properly	The implemented features are working as intended	After any code change, especially after any new features have been developed and implemented	Tor Martin Wang (Me)
Functional testing	The system is demonstrated frequently to my supervisor	Planned functionality is implemented	During weekly supervision meetings	Svein-Olaf Hvasshovd (Master's supervisor)
Functional requirement tests	The functional requirements for both the website (Section 4.4) and the mobile application (Section 4.2) have been fulfilled	The functionality is implemented and it is working correctly	At the end of the project	Tor Martin Wang (Me)
Non-functional requirement tests	Non-functional requirements for the website (Section 4.5) and the mobile application (Section 4.3) are fulfilled	The expected response measures for the non-functional requirements are met	At the end of project	Tor Martin Wang (Me) with external user

12.2 User Testing

Each of the two iterations of both the Herd website and the Herd mobile application were user tested, resulting in four rounds of user testing in total throughout this project. The user tests have been crucial in discovering usability problems and possible ways to further improve the design. The two rounds of user tests of the mobile application are documented in Section 6.6 and Section 7.5 respectively, while the two rounds of user tests of the website are shown in Section 8.5 and Section 9.4 respectively.

12.3 Manual Testing

Manual testing was part of the development process of both the mobile application and the website. Before any code was merged into the main branch on GitHub, the affected parts of the application/website were thoroughly tested manually. This was a good approach for discovering any issues or oversights with the implemented feature before it was added to the rest of the code base. The features were also manually tested after they were merged, in order to detect any problems that could have been introduced by the merge.

12.4 Functional Testing

I frequently demoed both the website and the mobile application for my Master's supervisor Svein-Olaf Hvasshovd during our weekly meetings. This was done to ensure that my supervisor's vision and my own vision were aligned, and to be certain that the functionality that I was making was correctly implemented. Because the discussions during these demos were often related to the implementation of the different functional requirements, they can be seen as a type of functional testing.

12.5 Test Reports

This section presents the test reports of the website's and the mobile application's functional and non-functional requirements that were given in Section 4. These reports have been created to give an overview of the system's fulfillment of the requirements, and to document how these were tested. The test reports for the mobile application's and the website's functional requirements are shown in Table 26 and Table 27 respectively. The test reports of the mobile application's non-functional requirements are presented starting from Table 28 going to Table 36, while the test reports of the website's non-functional requirements are presented starting from Table 37 going to Table 43.

12.5.1 Test Reports for the Mobile Applications's Functional Requirements

Table 26: Test reports for the mobile application's functional requirements

Executor	**Date**	**Requirement ID**	**Time used**	**Evaluation**	**How the requirement was tested**
Tor Martin Wang	17/5/2022	FR1.0	26 seconds	Success	Open the hamburger menu, and click register. Fill out information and confirm.
Tor Martin Wang	17/5/2022	FR1.1	23 seconds	Success	Open the hamburger menu, and click register. Fill out all information except the email, and confirm that the email is required by the application.
Tor Martin Wang	17/5/2022	FR1.2	20 seconds	Success	Open the hamburger menu, and click register. Fill out all information except the password, and confirm that the password is required by the application.
Tor Martin Wang	17/5/2022	FR1.3	19 seconds	Success	Open the hamburger menu, and click register. Fill out all information except the full name, and confirm that the full name is required by the application.
Tor Martin Wang	17/5/2022	FR1.4	21 seconds	Success	Open the hamburger menu, and click register. Fill out all information except the farm number, and confirm that the farm number is required by the application.

Tor Martin Wang	17/5/2022	FR1.5	17 seconds	Success	Open the hamburger menu, and click register. Check that the registration form includes a field for the cadastral number.
Tor Martin Wang	17/5/2022	FR1.6	19 seconds	Success	Open the hamburger menu, and click register. Fill out all information except the municipality, and confirm that the municipality is required by the application.
Tor Martin Wang	17/5/2022	FR2.0	28 seconds	Success	Open the hamburger menu, and click log in. Fill in the e-mail address, the farm number, and the password for an existing user, and log in.
Tor Martin Wang	17/5/2022	FR3.0	9 seconds	Success	While logged in, open the hamburger menu and click log out.
Tor Martin Wang	17/5/2022	FR4.0	41 seconds	Success	Open the hamburger menu, and click log in. Fill in the e-mail address, the farm number, and the password for an existing user, and log in. Force-close the app, then open the app and confirm that you are still logged in.
Tor Martin Wang	17/5/2022	FR5.0	15 seconds	Success	Open the hamburger menu, start a new supervision, and confirm that a map is available to use.
Tor Martin Wang	17/5/2022	FR5.1	27 seconds	Success	Zoom out the map on the front page and confirm that the entire Norwegian map is available.
Tor Martin Wang	17/5/2022	FR5.2	68 seconds	Success	Confirm that pinch-zooming is possible on the map on the front page. Open the hamburger menu, start a new supervision, and confirm that pinch-zooming is possible on this map. During the supervision, open the hamburger menu, click the option to inspect the current observations, and confirm that pinch-zooming is possible on this map. Finish the supervision from the same hamburger menu, go to the page for previously-conducted supervisions, click the most recent supervision, and confirm that pinch-zooming is possible on this map as well.
Tor Martin Wang	17/5/2022	FR5.3	62 seconds	Success	Repeat the steps from the test of FR5.2, but instead verify that the maps can be panned using dragging/scrolling.
Tor Martin Wang	17/5/2022	FR6.0	34 seconds	Success	Open the hamburger menu, click the option for downloading maps, and then click the download button.

Tor Martin Wang	17/5/2022	FR6.1	47 seconds	Success	Repeat the steps for the test of FR6.0. Confirm that different map sections can be downloaded and combined for offline use. The map files are too small for them to reach the maximum storage capacity of the mobile phone.
Tor Martin Wang	17/5/2022	FR6.2	14 seconds	Success	Open the hamburger menu, click the option for deleting downloaded maps and confirm.
Tor Martin Wang	17/5/2022	FR6.3	73 seconds	Success	After having downloaded maps, open any map in the application. Then check the phone's data usage statistics to confirm that no map tiles were downloaded.
Tor Martin Wang	17/5/2022	FR7.0	9 seconds	Success	Open the hamburger menu, and click the option for starting a supervision.
Tor Martin Wang	17/5/2022	FR7.1	16 seconds	Success	Open the hamburger menu, click the option for starting a supervision, then open the hamburger menu again and click the option for finishing the ongoing supervision.
Tor Martin Wang	17/5/2022	FR7.2	15 seconds	Success	Open the hamburger menu, click the option for starting a supervision, then open the hamburger menu again and click the option for finishing the ongoing supervision.
Tor Martin Wang	17/5/2022	FR7.3	18 seconds	Success	Open the hamburger menu, click the option for viewing previous supervisions, and confirm that the start time and end time were registered (These are not directly displayed in the application, but can be indirectly confirmed as being registered by the fact that the supervision duration is presented)
Tor Martin Wang	17/5/2022	FR8.0	61 seconds	Success	Turn off internet on the mobile phone, and then conduct a supervision.
Tor Martin Wang	17/5/2022	FR8.1	44 seconds	Success	Ensure that you are not logged in, then conduct a supervision.
Tor Martin Wang	17/5/2022	FR9.0	29 seconds	Success	Go to the page of previous supervisions and click one of them to see that the path was recorded.
Tor Martin Wang	17/5/2022	FR9.1	13 seconds	Success	Start a new supervision from the hamburger menu, and confirm that the position is displayed on the map.
Tor Martin Wang	17/5/2022	FR9.2	76 seconds	Success	Start a supervision from the hamburger menu, lock the phone before walking a couple hundred meters, and then confirm that the path was recorded while the phone was locked.

Tor Martin Wang	17/5/2022	FR9.3	24 seconds	Success	Start a supervision from the hamburger menu, then confirm that the path is being displayed on the map.
Tor Martin Wang	17/5/2022	FR10.0	32 seconds	Success	Start a supervision from the hamburger menu, then register an observation.
Tor Martin Wang	17/5/2022	FR10.1	41 seconds	Success	Start a supervision from the hamburger menu, register an observation, then inspect the observation by choosing the "See observations" option from the hamburger menu.
Tor Martin Wang	17/5/2022	FR10.2	42 seconds	Success	Start a supervision from the hamburger menu, register an observation, then delete the observation via the inspection page that opens by choosing the "See observations" option from the hamburger menu.
Tor Martin Wang	17/5/2022	FR11.0	19 seconds	Success	Go to the "previous supervisions" page from the hamburger menu, and slide a locally-stored supervision to the left and click upload.
Tor Martin Wang	17/5/2022	FR12.0	31 seconds	Success	Start a supervision from the hamburger menu, and confirm that the location of what is being observed is being registered with the cross on the map.
Tor Martin Wang	17/5/2022	FR12.1	17 seconds	Success	Go to the page for previous supervisions via the hamburger menu, click a supervision and see that the user's position was registered for every observation.
Tor Martin Wang	17/5/2022	FR12.2	20 seconds	Success	Go to the page for previous supervisions via the hamburger menu, click a supervision, then click an observation and see that registration time was recorded.
Tor Martin Wang	17/5/2022	FR13.0	19 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, and then choose the observation type.
Tor Martin Wang	17/5/2022	FR13.1	18 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, and then confirm that the different observation types are present. Observations of lambs and ewes were moved to the observation type of "group of sheep".
Tor Martin Wang	17/5/2022	FR14.0	23 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "group of sheep" and confirm that the observed amount can be registered.

Tor Martin Wang	17/5/2022	FR14.1	24 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "group of sheep" and confirm that the wool color can be registered.
Tor Martin Wang	17/5/2022	FR14.2	21 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "group of sheep" and confirm that the tie color can be registered.
Tor Martin Wang	17/5/2022	FR14.3	19 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "group of sheep" and confirm that the owner mark color can be registered.
Tor Martin Wang	17/5/2022	FR15.0	26 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "injured sheep" and confirm that the owner mark color, tie color and the type of injury can be registered.
Tor Martin Wang	17/5/2022	FR16.0	28 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "dead sheep" and confirm that the owner mark color, tie color and the cause of death can be registered.
Tor Martin Wang	17/5/2022	FR17.0	21 seconds	Success	Start a supervision from the hamburger menu, click the button for registering an observation, choose "predator" and confirm that the type of predator can be registered.

12.5.2 Test Reports for the Website's Functional Requirements

Table 27: Test reports for the website's functional requirements

Executor	**Date**	**Requirement ID**	**Time used**	**Evaluation**	**Comment**
Tor Martin Wang	18/5/2022	FR1.0	14 seconds	Success	Log in, and confirm that the only the logged-in user's supervisions are shown
Tor Martin Wang	18/5/2022	FR2.0	18 seconds	Success	Log in, set a before-date in the options menu, and confirm that the supervisions were filtered correctly.
Tor Martin Wang	18/5/2022	FR2.1	17 seconds	Success	Log in, set an after-date in the options menu, and confirm that the supervisions were filtered correctly.
Tor Martin Wang	18/5/2022	FR3.0	18 seconds	Success	Log in, set a sort term in the options menu, and confirm that the supervisions were sorted correctly.
Tor Martin Wang	18/5/2022	FR3.1	19 seconds	Success	Log in, toggle the sort order in the options menu, and confirm that the supervisions were sorted correctly.
Tor Martin Wang	18/5/2022	FR4.0	23 seconds	Success	Log in, select a supervision, click delete, and confirm.
Tor Martin Wang	18/5/2022	FR5.0	22 seconds	Success	Log in, select multiple supervisions, and then click the button for inspecting them together on a single map.
Tor Martin Wang	18/5/2022	FR5.1	21 seconds	Success	Log in, select multiple supervisions, and then click the button for inspecting them on multiple maps.
Tor Martin Wang	18/5/2022	FR6.0	26 seconds	Success	Log in, select a supervision, click the button for inspecting the selected supervision on a map, then click an observation on the map and confirm that its information is displayed.
Tor Martin Wang	18/5/2022	FR6.1	20 seconds	Success	Log in, select a supervision, click the button for inspecting the selected supervision on a map, and confirm that the path is displayed on the map

Tor Martin Wang	18/5/2022	FR7.0	19 seconds	Success	Log in, select a supervision, click the button for generating a report and confirm that a report is generated and downloaded.
Tor Martin Wang	18/5/2022	FR7.1	11 seconds	Success	Open the generated PDF report, and confirm that the path and observation locations are shown on a map for each supervision.
Tor Martin Wang	18/5/2022	FR7.2	7 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' date.
Tor Martin Wang	18/5/2022	FR7.3	8 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' total number of observed lambs.
Tor Martin Wang	18/5/2022	FR7.4	8 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' total number of observed healthy adult sheep.
Tor Martin Wang	18/5/2022	FR7.5	7 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' total number of injured sheep.
Tor Martin Wang	18/5/2022	FR7.6	8 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' total number of dead sheep.
Tor Martin Wang	18/5/2022	FR7.7	7 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' start time.
Tor Martin Wang	18/5/2022	FR7.8	6 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' end time.
Tor Martin Wang	18/5/2022	FR7.9	9 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' total number of observed wolverines.

Tor Martin Wang	18/5/2022	FR7.10	8 seconds	Success	Open the generated PDF report, and confirm that the report includes each supervisions' total number of observed predators excluding wolverines.

12.5.3 Test Reports for the Mobile Applications's Non-Functional Requirements

UR1 - The user should, in less than 2 minutes, be able to learn how to start and finish a supervision (Table 28)

Table 28: Test report for UR1

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to conduct a supervision
Expected response measure	User is able to start and finish a supervision in less than 2 minutes
Observed response measure	User is able to start and finish a supervision in less than one minute
Evaluation	Success
Comment	User quickly understood how to start and finish a supervision

UR2 - The user should, in less than 10 minutes, be able to learn how to register all types of observations (Table 29)

Table 29: Test report for UR2

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to register all types of observations during a supervision
Expected response measure	User is able to register all types of observations during a supervision in less than 10 minutes
Observed response measure	User is able to register all types of observations during a supervision in less than 2 minutes
Evaluation	Success
Comment	The user used a few seconds to realize that observations of lambs and ewes are registered using the "group of sheep" observation type. Once the user realized that, the observation registration processes proceeded smoothly.

UR3 - The user should, in less than 10 seconds, be able to cancel the registration of an observation (Table 30)

Table 30: Test report for UR3

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to cancel the registration of an observation
Expected response measure	User is able to cancel the registration of the observation in less than 10 seconds
Observed response measure	User is able to cancel the registration of the observation in less than 6 seconds
Evaluation	Success
Comment	The user quickly understood that they could click the cross button to cancel the registration process

UR4 - The user should, in less than 1 minute, be able to learn how to inspect previously-conducted supervisions (Table 31)

Table 31: Test report for UR4

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to inspect a previously-conducted supervision
Expected response measure	User is able to inspect the previously-conducted supervision in less than 1 minute
Observed response measure	User is able to inspect the previously-conducted supervision in less than 20 seconds
Evaluation	Success
Comment	The user quickly understood how to inspect a previously-conducted supervision

UR5 - The user should, in less than 1 minute, be able to learn how to download a map (Table 32)

Table 32: Test report for UR5

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to download a map section for offline use
Expected response measure	User is able to download the map section in less than 1 minute
Observed response measure	User is able to download the map section in less than 40 seconds
Evaluation	Success
Comment	The user quickly understood how to download their desired map section

UR6 - The user should, in less than 30 seconds, be able to learn how to delete downloaded maps (Table 33)

Table 33: Test report for UR6

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to delete their downloaded map sections
Expected response measure	User is able delete their downloaded map sections in less than 30 seconds
Observed response measure	User is able delete their downloaded map sections in less than 15 seconds
Evaluation	Success
Comment	The user quickly understood how to delete their downloaded map sections

UR7 - The user should, without errors and while using binoculars, be able to register lambs, ewes and sheep in general, and their wool and tie color (Table 34)

Table 34: Test report for UR7

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to, while using binoculars, register lambs, ewes and sheep in general, and their wool and tie color
Expected response measure	User is able make a registration that does not have any errors
Observed response measure	User is able make a registration that does not have any errors
Evaluation	Success
Comment	During the registration process, the user made a mistake which included counting an ewe instead of a lamb, but the user was able to quickly correct their mistake without having to take their eyes away from the binoculars. In the end, the user was able to, while using binoculars, register the correct observation without any errors.

PR1 - The user's location should be established and displayed to the user in less than 10 seconds (Table 35)

Table 35: Test report for PR1

Executor, Date	Tor Martin Wang, 19.05.2022
Environment	Run time
Stimuli	User opens the front page
Expected response measure	The user's position is shown on the map in less than 10 seconds
Observed response measure	The time it takes to show the user's position on the map varies, but it is always less than 10 seconds
Evaluation	Success
Comment	The time it takes to show the user's location is dependant on how fast the mobile GPS hardware can give a location. The location is therefore shown more quickly when outside, and more slowly when inside a building that can interfere with the GPS signals. The application is meant to be used when outside, where the the user's location was always retrieved and shown in just a few seconds.

PR2 - The application should upload a locally-stored supervision in less than 5 seconds (Table 36)

Table 36: Test report for PR2

Executor, Date	Tor Martin Wang, 19.05.2022
Environment	Run time
Stimuli	User clicks the button to upload a locally-stored supervision
Expected response measure	The supervision is uploaded in less than 5 seconds
Observed response measure	The supervision is uploaded in less than 1 second
Evaluation	Success
Comment	The API is deployed using Heroku [50], which makes the API go to sleep when it has not been used for a while. If that is the case, the API needs to be waken up before the request can be processed, and this can take around 10-15 seconds. This is controlled by Heroku, and is outside the control of the application and the API. When the API is awake, the supervision upload always takes less than 1 second.

12.5.4 Test Reports for the Website's Non-Functional Requirements

UR1 - The user should, in less than 1 minute, be able to learn how register for a user profile (Table 37)

Table 37: Test report for UR1

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to register for a new user profile
Expected response measure	User is able to register for a user profile in less than 1 minute
Observed response measure	User is able to register for a user profile in less than 30 seconds
Evaluation	Success
Comment	The user quickly understood how to register for a new user profile

UR2 - The user should, in less than 30 seconds, be able to learn how to filter their supervisions by start- and end-date (Table 38)

Table 38: Test report for UR2

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to filter their supervisions between a start date and end date
Expected response measure	User is able to filter their supervisions in less than 30 seconds
Observed response measure	User is able to filter their supervisions in less than 15 seconds
Evaluation	Success
Comment	The user quickly understood how to filter their supervisions so that only the supervisions that were performed within a certain date interval were shown

UR3 - The user should, in less than 30 seconds, be able to learn how to sort their supervisions (Table 39)

Table 39: Test report for UR3

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to sort their supervisions
Expected response measure	User is able to sort their supervisions in less than 30 seconds
Observed response measure	User is able to sort their supervisions in less than 10 seconds
Evaluation	Success
Comment	The user quickly understood how to sort their supervisions by the different sort terms, in both ascending and descending order

UR4 - The user should, in less than 1 minute, be able to learn how to delete a supervision (Table 40)

Table 40: Test report for UR4

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to delete a supervision
Expected response measure	User is able to delete their supervision in less than 1 minute
Observed response measure	User is able to delete their supervision in less than 8 seconds
Evaluation	Success
Comment	The user very quickly understood how to delete their supervision

UR5 - The user should, in less than 1 minute, be able to learn how to inspect their supervisions on a map (Table 41)

Table 41: Test report for UR5

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to inspect their supervisions on a map
Expected response measure	User is able to inspect their supervisions in less than 1 minute
Observed response measure	User is able to inspect their supervisions in less than 30 seconds
Evaluation	Success
Comment	The user very quickly understood how to inspect their supervision. They experimented using both methods of inspections, both on a single map and on multiple maps. They also understood that observations on the map could be clicked to reveal more information about them.

UR6 - The user should, in less than 1 minute, be able to learn how to generate a supervision report (Table 42)

Table 42: Test report for UR6

Executor, Date	External user, 19.05.2022
Environment	Run time
Stimuli	User wants to generate a PDF report of their supervisions
Expected response measure	User is able to understand how to generate the PDF report in less than 1 minute
Observed response measure	User is able to understand how to generate the PDF report in less than 10 seconds
Evaluation	Success
Comment	The user very quickly understood how to generate a report of their supervisions

PR1 - A report of 10 supervisions should be generated in less than 20 seconds (Table 43)

Table 43: Test report for PR1

Executor, Date	Tor Martin Wang, 19.05.2022
Environment	Run time
Stimuli	Selects 10 different supervisions, and then clicks the button to generate a PDF report
Expected response measure	The PDF report is generated in less than 20 seconds
Observed response measure	The PDF report is generated in less than 5 seconds
Evaluation	Success
Comment	The report is generated more quickly than required

13 Discussion

13.1 Evaluation of the Solution

In this section, the Herd system will be discussed and evaluated, with specific focus on the quality of both the design and the code.

13.1.1 Evaluation of the Herd Mobile Application

I am very pleased with what has been achieved with the mobile application. The application supports all the major functionality that were included in the project scope, and it is effectively functional for conducting and documenting sheep supervisions.

I am also very satisfied with the choice of technology, especially the choice of framework. The Ionic framework [39] worked even better than expected, and even though this is a "hybrid" application [40], the Ionic UI component library was used extensively, which has given the application a good native feeling. The choice of a good framework resulted in there being excellent support when implementing the required features and functionalities.

One aspect that I feel I could have put more focus on during the design of the application is the choice of colors. Most of the application is designed to have a white color, and while I'm happy with how it ended up looking, it would have been interesting to explore different color palettes that could give the application its own unique look. A more thoughtful color palette could possibly also give the users more associations to sheep, which is at the center of the application's purpose.

Another aspect that I could have considered to put more focus on is the creation of automated tests. I did not write any automated tests for the mobile application, and this was a conscious choice so that I instead could spend more time implementing new features and functionality. This led to a mobile application that is full of useful features, but the lack of automated tests means that there could be undiscovered bugs and mistakes in the implementation of these features. Automated tests themselves also work as a type of documentation of how the software is supposed to behave, and the lack of these tests can make it more difficult for possible future developers that want to continue developing the application. The automated tests could ensure that the existing functionality still behaves correctly, even when possible new features are being added by future developers.

13.1.2 Evaluation of the Herd Website

I am also very pleased with the end-result of the Herd website. The website supports all the features that were included in the project scope, and the design is satisfactory. I am especially pleased with how the supervisions, and their observations, can be inspected interactively on maps.

Because of time limitations in this project, the method used for generating the PDF supervisions reports on the website is non-ideal. Currently, the PDF is being generated by combining screenshots of website components that are being rendered in the background outside the user's view. The fact that the PDF is comprised of screenshots can result in some unwanted page breaks, and it means that the text in the report cannot be selected and copied by the user.

Automated testing was again not prioritized, as the time was rather spent on developing functionality that fulfilled the requirements. As discussed in Section 13.1.1, having automated testing could have helped document the code and how it is supposed to behave, which could help possible future developers that want to continue the development of the Herd system.

13.1.3 Evaluation of the Herd API

The Herd API is the part of the Herd system that was put the least focus on when compared to either the website or the mobile application. While the API works exactly as required, there are some aspects that could have be done differently. For example, more of the built-in functionality of the Django framework could have been used. This would have possibly sped up the development process, and it would have made the code more closely aligned with what is considered best practice for Django REST APIs.

As with the mobile application and the website, there were no tests written for the API, as the implementation of new functionality was prioritized. Having automated tests, as already explained in Section 13.1.1, would be beneficial if future developers are to continue working on the project.

13.2 Review of the Research Questions

This section will answer the following three research questions that were first presented in Section 2.1.

- What changes could the digitalized system introduce to the sheep supervision process?
- How can the mobile application support the use of binoculars during the observation registration process?
- How usable is the digitalized system for documenting sheep supervisions?

13.2.1 Research Question #1

The first research question is about which changes, both positive and negative, the Herd system could bring to the process of documenting sheep supervisions. My supervisor, professor Svein-Olaf Hvasshovd, mentioned during one of our weekly meetings that one of the large problems with the current paper-based method of documenting the sheep supervisions is the lack of a common structure or standard for how to write these paper notes. This can lead to unstructured or inaccurate reports of farmers' observations during supervisions. This is one area where the structured digital Herd system could introduce a positive change. A digital documentation tool, like what the Herd system provides, could improve the effectiveness, efficiency and accuracy of both the supervision process, the registered observation information, and the generated reports.

The Herd system also makes it possible to track and store the path that the user walked. This makes it possible for the users to inspect their previous supervisions and use the path data to more easily plan where to conduct future supervisions. This ability to use the Herd system to plan supervisions could in turn make the supervision process more efficient, effectively saving the user valuable time.

A large advantage of the Herd system is the automatic generation of a summarizing supervisions report. Currently, the users have to manually create the report based on the paper-based notes that they write when they are conducting their supervisions. With the Herd-system, this extra work is removed completely, as the users can use the website to easily generate and download a PDF report, which they then can use as documentation that the supervisions were conducted correctly.

As has been mentioned throughout this report, the Herd application was developed with the support of binoculars in mind. It is very difficult for the users to combine the use of binoculars

together with the current way of documenting the supervisions using pen and paper. The user tests in Section 7.5 have shown that the mobile application has been successful in introducing the support for binoculars during the registration process.

Another issue with the current method of using pen and paper to document sheep supervisions, is that the paper is very susceptible to rain and bad weather. Most mobile phones now are water resistant, so the Herd application can still be used outside even when it is bad weather. This allows the users to be less dependant on good weather when performing their supervisions.

One of the strengths of the Herd system may also be one of its greatest weaknesses at the current moment. The application provides structure to the data that is being registered, but it also does not currently allow the registration of any data that does not fit this pre-defined format. Here is where the pen and paper has its strengths, as it allows the registration of all kinds of data. If the Herd system were to be used in its current format, there may be details from the observations that the user wants to document, but that are impossible to register because of missing support from the application. This disadvantage could be removed if a future iteration of the Herd application allows the user to enter their own text when making observation registrations. Such a change should be carefully considered before being implemented, as it could possibly damage the advantage of having all the data saved in a structured format.

13.2.2 Research Question #2

To answer the second research question, which is about how the mobile application can support binoculars, it would be beneficial to take a look at the page from the Herd mobile application shown in Figure 83. This page is one of the pages that were specifically designed to support the use of binoculars, and is the result of two design iterations and one round of user testing. The goal is that the user should be able to register the information on this page without needing to take their eyes away from the binoculars.

Figure 83: A page in the Herd mobile application where the design has been created specifically to support binoculars

The first measure that was taken to support the use of binoculars was to have a considerably large button for counting the different colors, and to use this same button to decrement the value (by long-pressing it). This button was made large and given the dual functionality of both incrementation and decrementation in order to make it easier for the user to successfully utilize it without having to look at the screen. The user tests from Section 6.6 and Section 7.5 showed that this was successful in its task of making incrementations and decremantions screen-independant.

Another measure that was implemented is the use of haptic feedback. On this same page, the user's mobile phone vibrates quickly with a low intensity when an incrementation is made, and vibrates quickly with a high intensity when a decrementation is made. This haptic feedback does not only notify the user that their action was registered, but the different vibration intensities also communicate to the user whether the value was incremented or decremented. This sort of feedback is valuable in the situation where a user is using binoculars and is unable to look at the screen.

A swiping functionality has also been implemented as a measure for supporting the use of binoculars. On the parts of the registration process where the user may want to use binoculars, the application allows the user to swipe downwards to change the selected color, as seen in for example Figure 45. This allows the user to change the selected color without having to actually look at the screen.

Auditory feedback is also a really important measure for the application's support of binoculars. Unless the user has disabled auditory feedback in Herd's settings page, the mobile phone will read out loud the new value whenever it is incremented or decremented, and the phone will also read out loud the new selected color whenever swiping is used to change it. This auditory feedback allows the user to keep track of the selected color and the size of the count without having to look away from their binoculars.

When you combine all these measures, you end up with a design that successfully supports the use of binoculars, as was the result of the user tests in Section 7.5. Even if the users were to make a mistake during the registration while using binoculars, the measures that have been implemented support the user in undoing these mistakes without having to look down on the screen. There are of course improvements that can still be made, as the user tests in Section 7.5 showed that for example not all users were immediately aware of the swiping method for changing the active color.

13.2.3 Research Question #3

The third research question is about how usable the Herd system is for documenting sheep supervisions. Usability is defined as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" [4]. The user tests of the mobile application (presented in Section 7.5) and the user tests of the website (presented in Section 9.4) showed that the users did not have any considerable issues with the system, and were able to effectively and efficiently complete every task that they were given during the tests. The user tests also indicate that the system has reached a high degree of satisfaction, with an average score of 9.6/10 for the mobile application and an average score of 9.5/10 for the website.

If the Herd project is to be continued in the future, it will be important to get a more detailed answer to this research question. Even though the system was tested on users both with and without knowledge of the sheep supervision process, it will be necessary to conduct real field-tests of the mobile application, where it is used by real farmers that try to use the application to document supervisions of real sheep. This will give a more complete picture of the usability of the system, as this will bring the user tests closer to what the definition of usability defines as the "specified users" in the "specified context of use" [4]. The Herd system was not user tested on current sheep farmers because of two reasons. The first reason was the desire to mitigate the risks surrounding the Covid-19 pandemic, which made it both easier and safer to conduct the user tests on my room mates. The second reason is that the sheep in Norway are only out on graze from mid-May to mid-September, which is outside what is effectively the entire duration of this project.

14 Conclusion

During this project, both a mobile application and an accompanying website have been developed and user tested. The project started by examining any current digital solutions for documenting sheep supervisions, along with taking a look at the background of grazing sheep in Norway. The functional and non-functional requirements were then elicitated together with my supervisor. The pre-study for the design was then performed, which included the creation of user personas and user scenarios. After this, the paper prototype of the mobile application was created and user tested, followed by the development and user test of the actual functional mobile application. The paper prototype of the accompanying website was then created and user tested. Following this, the actual functional website was developed and user tested.

The user tests of the Herd system shows that it has achieved a high degree of usability, with a design that is both effective and efficient, with a considerable level of user satisfaction. One of the large tasks in this project was to develop a design that supported the use of binoculars during certain parts of the observation registration process. The user tests have shown that this has been a success, as all users were able to correctly register the information while using binoculars.

The testing of the functional and non-functional requirements shows that they have all been fulfilled by the Herd mobile application and the Herd website. Even so, there is still more work that could be performed if the Herd project is to be continued in the future. These additional future tasks are presented in Section 15.

15 Future Work

I am proud and pleased with the product that I have developed, and that it fulfills all the functional and non-functional requirements that were included in the project scope. With that said, there are still more ways the Herd system can be improved, and that is why this section will present the suggested work that should be performed if the Herd project is to be continued in the future. This includes changes, improvements and new features that could be implemented to further increase the usability and usefulness of the Herd system. The following list presents the suggested future work tasks.

- The suggested design changes that were presented in Section 7.6 should be implemented. These changes would further improve the usability of the Herd mobile application.
- The suggested design changes that were presented in Section 9.5 should be implemented. These changes would further improve the usability of the Herd website.
- Automated tests should be written for the mobile application, the website, and the API. Having automated tests would be beneficial if the development of the Herd system is to be continued in the future, as they would ensure that the current features still work correctly even when new features are being implemented.
- Together with my supervisor, Svein-Olaf Hvasshovd, we agreed that security was not a priority in this project, which led me to implement only what I would say is the minimum requirement for security in a system like this (i.e. the logged-in user can access only their own data, passwords are being hashed by the API, and all communication is encrypted using HTTPS). If the Herd system is to be commercially launched in the future, a good understanding of the threat landscape should be established. That is why a threat analysis, using for example the STRIDE threat model [62], should be performed in the future.
- As a result of security not being a priority, there may be existing security vulnerabilities that should be mitigated if the project is continued in the future. That is why I suggest that the future developers perform penetration testing [63] of both the Herd website and the Herd mobile application. This kind of testing will allow them to discover possible security vulnerabilities, which they then should mitigate by making improvements to the codebase.
- The Herd system should be user tested by real farmers that try to use the application to document supervisions of real sheep. This will give a more detailed answer to how usable the system is, which is important to know before a possible commercial release in the future.
- The database technology should be changed from the current SQLite technology. SQLite does not support concurrent write operations [53], and this could have a negative impact on performance if a lot of users adopt the Herd system and use it simultaneously. The Herd system should change its database technology to one that supports concurrency, for example PostgreSQL [64].
- The color scheme could be looked more into in the future. The color scheme could for example be changed to give the users stronger associations to sheep and farms, which would strengthen the branding of the Herd system.
- The Herd system should allow users to edit their profile information. This was not included in the current scope of the project, but it should be added in the future. Editing of user profiles is an important feature for when the user's information have changed, or if the user wants to correct a mistake they made during the registration process.

- A "reset password" feature should be added to the Herd system. This feature was not included in the project scope, but it is important to have before a commercial launch. One way this feature could be implemented is to have the user click a link in an email sent to them, which brings them to a page where they can set a new password. This feature will allow users to continue using their accounts even if they forget their password.
- A feature should be added to validate the user's email address. The user could for example have to click a link in an email that is sent by the Herd system when they register for a new user profile. This is not only a security feature that prevents fake accounts from being mass-generated, but it also verifies that the user has access to the provided email address, which can be crucial in for example a situation where the user needs to reset their password.
- Seeing as supervisions of a farm's sheep are often carried out by different people throughout the grazing period, the Herd system should have some support for this. The Herd system could for example support the creation of a supervision team that consists of multiple supervisors. This would allow supervisors to coordinate their supervisions, and generate reports that include supervisions from multiple users.
- Currently, the Herd system includes the farm number as a third login credential. The farm number was added as a login parameter so that users who supervise multiple farms can create multiple accounts with the same email address and password, as long as the farm number is different. In hindsight, the Herd system could have a better, more intuitive, solution for users who supervise multiple farms. The user could for example, when they initiate a new supervision, choose which farm they are conducting a supervision for, and the website and mobile application could have the possibility to filter these supervisions based on which farm they were performed for.
- The list of previously-conducted supervisions in both the Herd website and the Herd mobile application should support pagination or dynamic loading. When the list of previous supervisions grows large, the lack of pagination or dynamic loading could possibly hurt the performance of the application.
- The list of previous supervisions in the Herd mobile application (seen in Figure 50) should have the same options for sorting and filtering supervisions as the Herd website. This would make it easier for the users to locate their desired supervisions even when the list of supervisions grows considerably large.
- The Herd mobile application should support adding photos to registrations of observations. Photos are a good tool for documenting what has been observed, and a future version of the Herd system should support this.
- Currently, when a user inspects their supervisions together on a single map on the Herd website (seen in Figure 66), they are able to toggle the visibility of entire supervisions. It could be beneficial for the user to have an even deeper control over what is presented on this map. The user could for example only wish to display all injured or deceased sheep on the map, in order to figure out which areas pose extraordinary danger to their sheep. A feature where the user can toggle the visibility of different types of observations on this map could therefore be considered in the future.
- The possibility to communicate with the tracking devices from Telespor [17] or FindMy [16] (which were looked at in Section 3.2) should be explored. Supervisions could become more efficient if the sheep's location, provided by the tracking devices, could be displayed on the map in the Herd mobile application.

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Appendix

A Mobile Application User Tests - Test Assignments

1. You are a farmer that is going to perform one of the weekly supervisions of your grazing sheep. You have downloaded a new mobile application called Herd, that you will use to document this supervision. The first thing you want to do is to register for a new user account. How would you do this using the mobile application?

2. You are planning to conduct a supervision in an area without cellular service, and you therefore have to first download a map section for offline use. How would you do this using the mobile application?

3. You now want to start the new supervision. How would you do this using the mobile application?

4. You are now outside performing your supervision, and you spot a group consisting of 2 white/grey sheep, 3 black sheep, and 4 brown sheep. These are far away, so you are unable to see the color of the sheep's ties or owner marks. You wish to register this observation. How would you do this using the mobile application?

5. You now spot 1 white/grey ewe and 1 brown ewe. These are close enough for you to see that they both have a green owner mark, and that the color of the ties are red on the first sheep and green on the other. You wish to register this observation. How would you do this using the mobile application?

6. You now see 5 brown lambs and 2 black ewes. These are far away, so you are unable to spot the color of the sheep's owner's marks or ties. You wish to register this observation. How would you do this using the mobile application?

7. You now spot multiple sheep located far away, but to be able to see the color of the sheep you need keep your sight in the binoculars while at the same time you register the observation. Said in other words, you have to register the color of the sheep without actively looking at the application. To prepare, you can explore the application before you start using the binoculars. How would you do this using the mobile application?

8. You now observe a lynx. You wish to register this observation. How would you do this using the mobile application?

9. You now spot a white/grey sheep that is bleeding. You wish to register this observation. How would you do this using the mobile application?

10. You now see a sheep that has died from a falling accident. You wish to register this observation. How would you do this using the mobile application?

11. Your supervision is now over, but before you finish it, you wish to get an overview of all the observations you registered. How would you do this using the mobile application?

12. You now wish to finish the supervision. How would you do this using the mobile application?

13. To save storage on your mobile phone, you wish to delete the map sections you downloaded earlier. How would you do this using the mobile application?

14. (Extra task - Only part of the second user test) You want to upload the supervision you just finished to the cloud. How would you do this using the mobile application?

15. (Extra task - Only part of the second user test) You now want to delete the supervision you just uploaded. How would you do this using the mobile application?

B Mobile Application User Tests - Follow-Up Questions

1. What are your thoughts on how the prototype supported the use of binoculars?
2. Was there anything in particular that you liked about the prototype?
3. Was there anything in particular that you disliked about the prototype?
4. Was there anything you felt were missing or could be improved about the prototype?
5. On a scale from 1 to 10, where 10 is best, how would you rank the prototype as it is now?
6. What would have to be done to increase the score you just gave?
7. Do you have any other thoughts you want to share?

C Mobile Application - Design of the Implementation

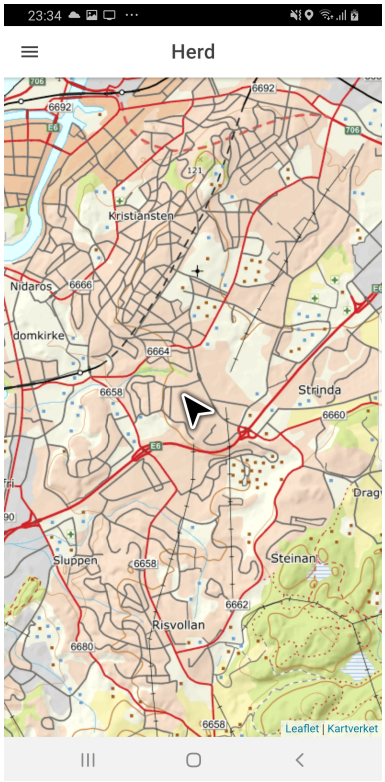

Figure 84: Start menu

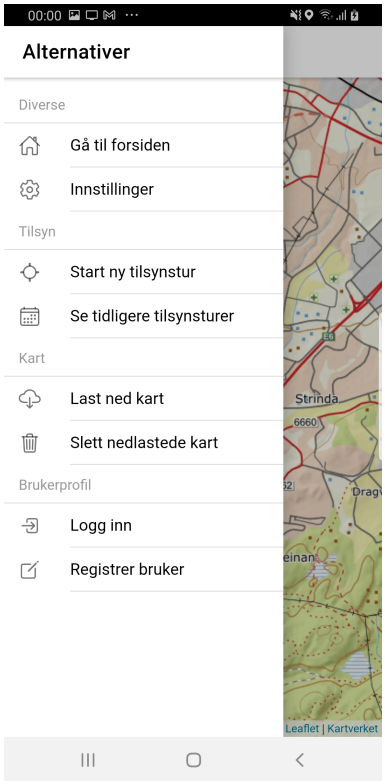

Figure 85: Hamburger menu when not logged in

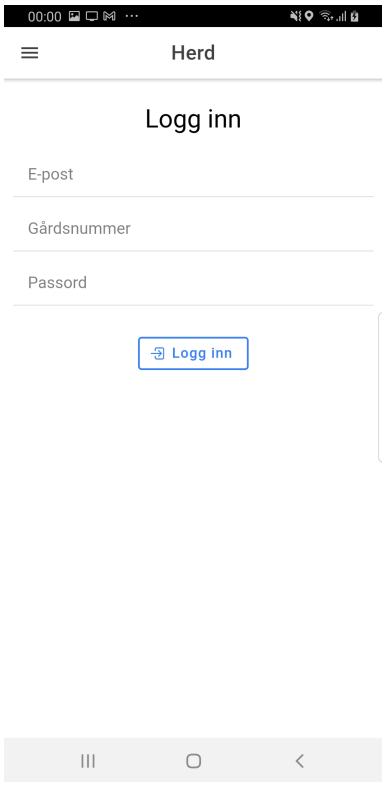

Figure 86: Login page

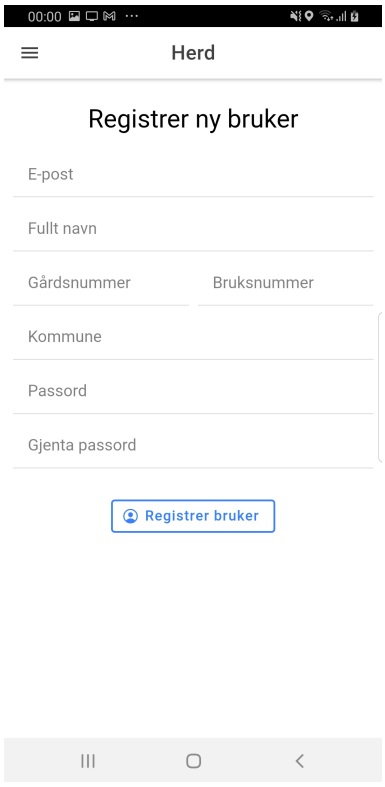

Figure 87: Register page

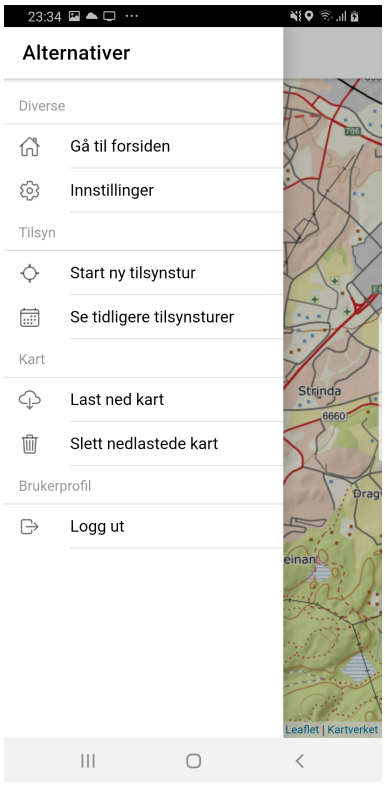

Figure 88: Hamburger menu when logged in

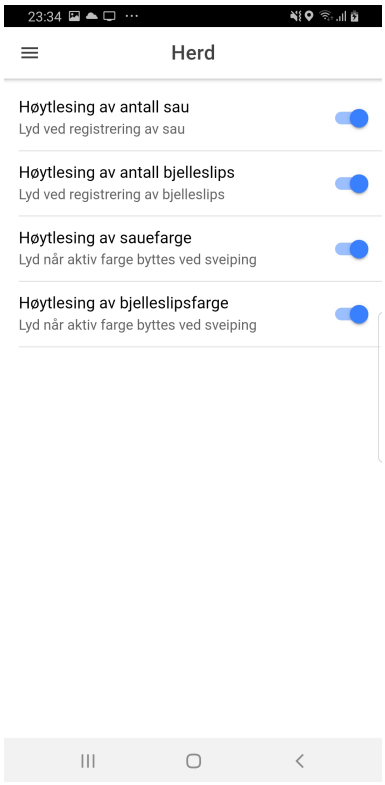

Figure 89: Settings page

Figure 90: Ongoing supervision page

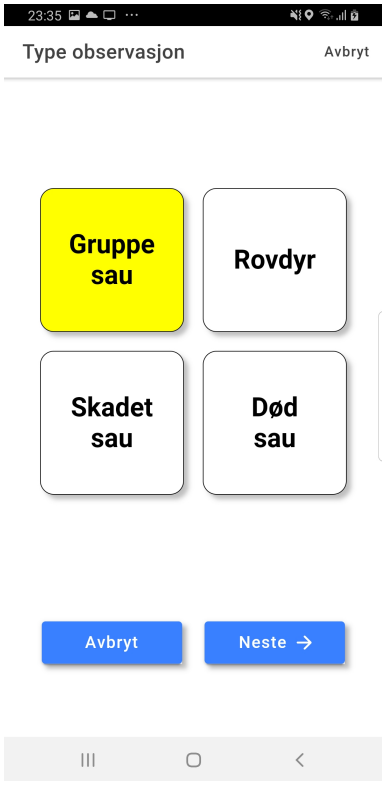

Figure 91: Registering the observation type

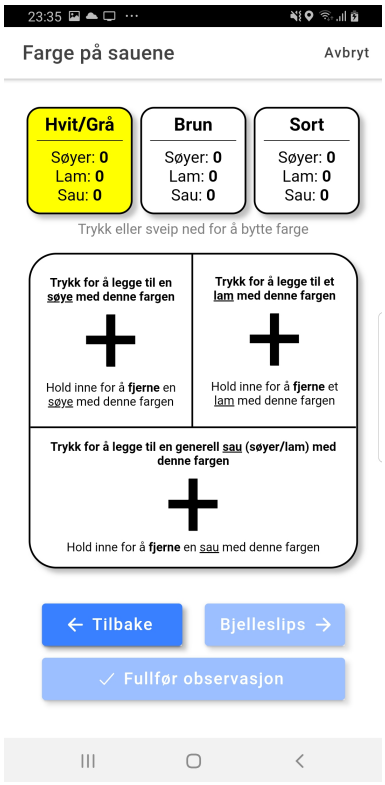

Figure 92: Registering the different sheep and their wool color

Figure 93: Registering the color of the sheep ties

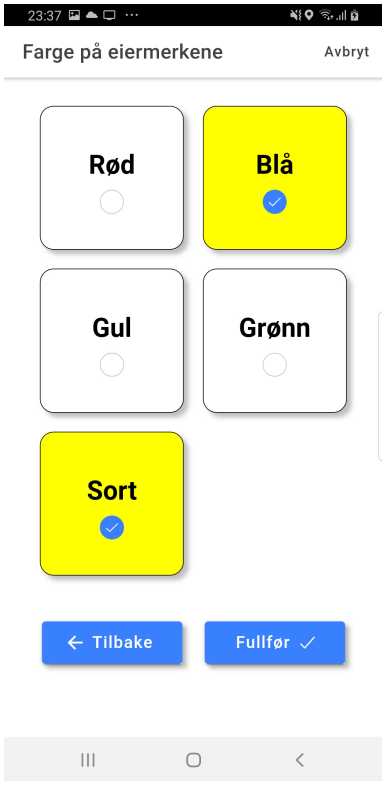

Figure 94: Registering the color of the owner marks for a group of sheep

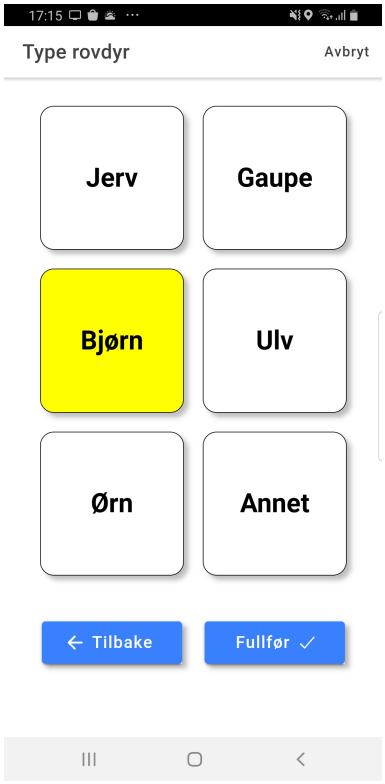

Figure 95: Registering the type of predator

Figure 96: Registering the type of injury

Figure 97: Registering the color of an injured sheep

Figure 98: Registering the color of an injured sheep's owner's mark

Figure 99: Registering the suspected cause-of-death of a deceased sheep

Figure 100: Registering the color of the deceased sheep

Figure 101: Registering the color of the deceased sheep's owner's mark

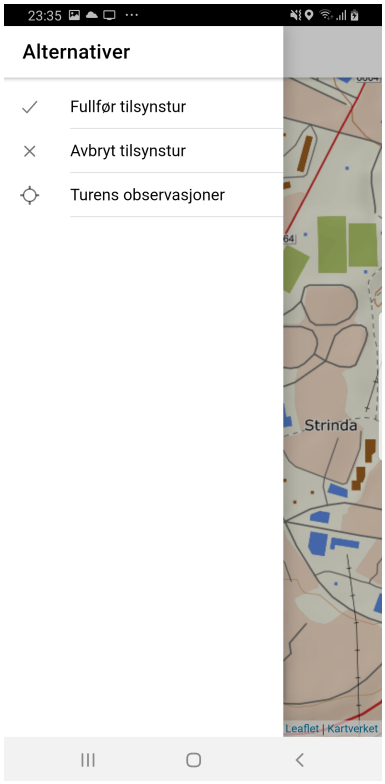

Figure 102: Hamburger menu during an ongoing supervision

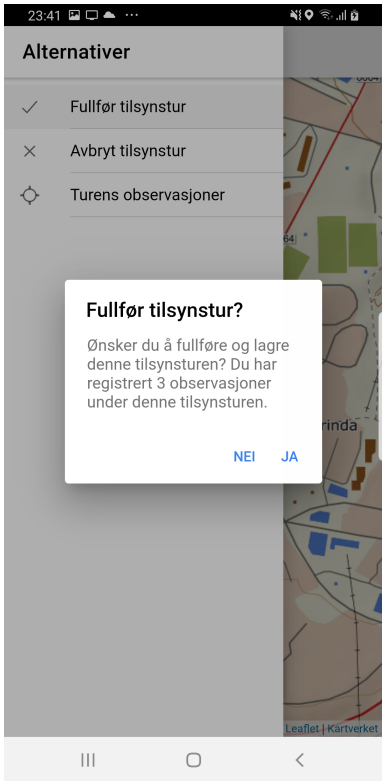

Figure 103: Confirmation message when trying to finish a supervision

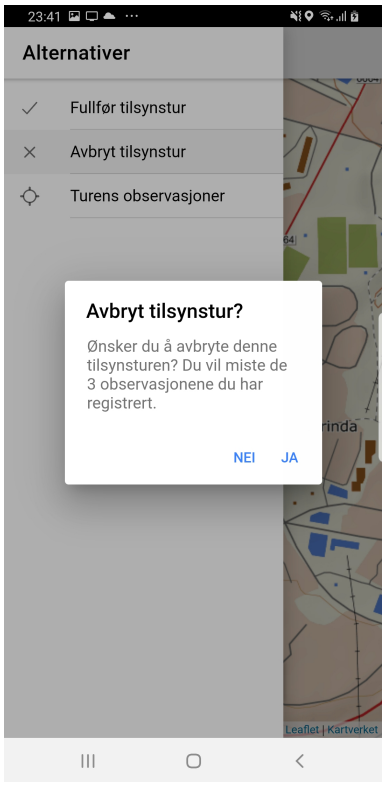

Figure 104: Confirmation message when trying to abort a supervision

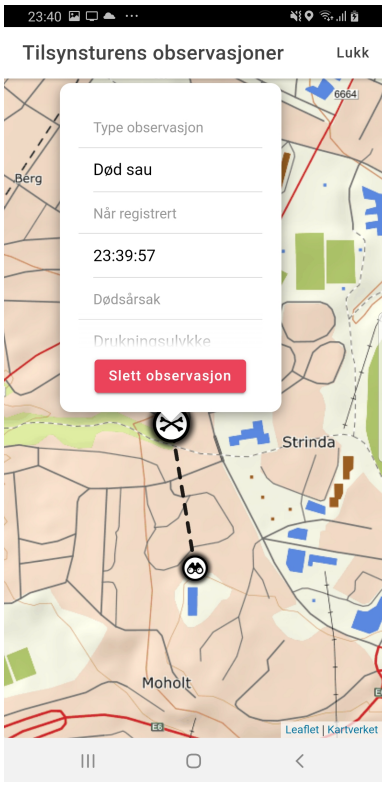

Figure 105: Inspecting a supervision's observations

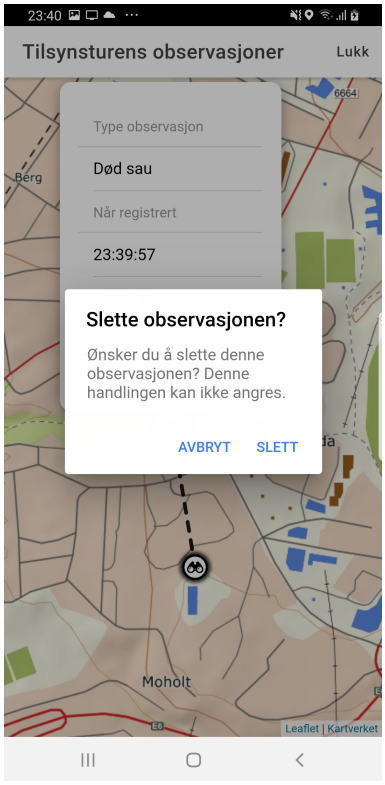

Figure 106: Confirmation message when trying to delete an observation in an ongoing supervision

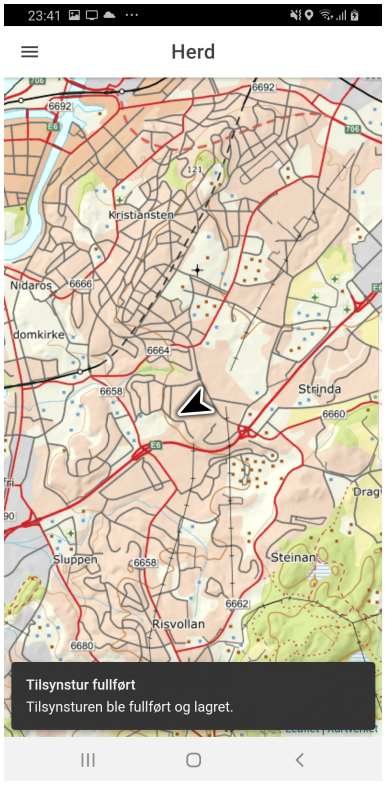

Figure 107: Feedback message when a supervision is completed

Figure 108: List of previous supervisions

Figure 109: Slide menu for a locally-stored supervision

Figure 110: Feedback message when a supervision is successfully uploaded

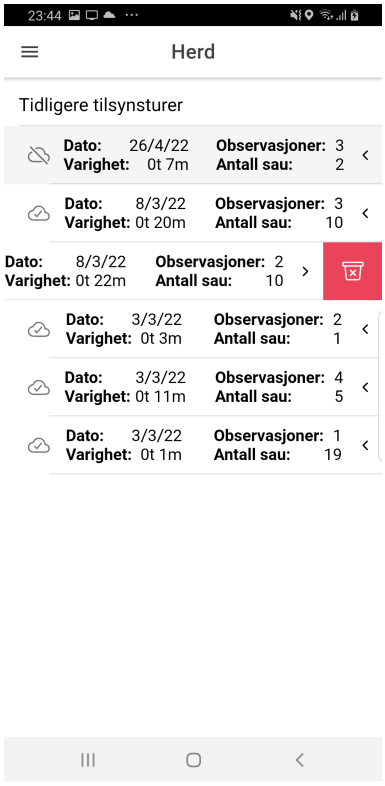

Figure 111: Slide menu for a server-stored supervision

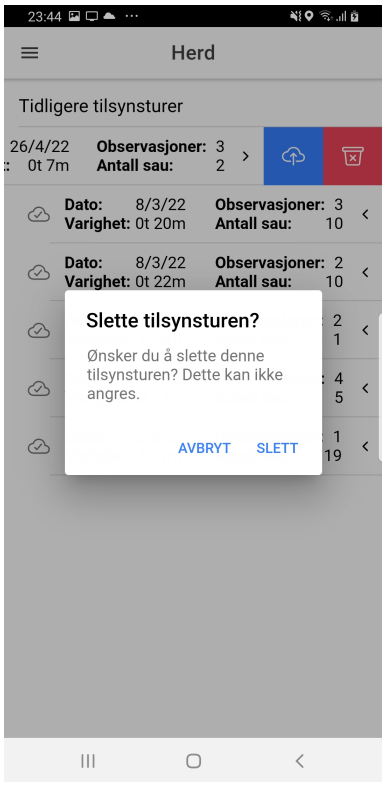

Figure 112: Confirmation message when trying to delete a supervision

Figure 113: Page for downloading map sections for offline use

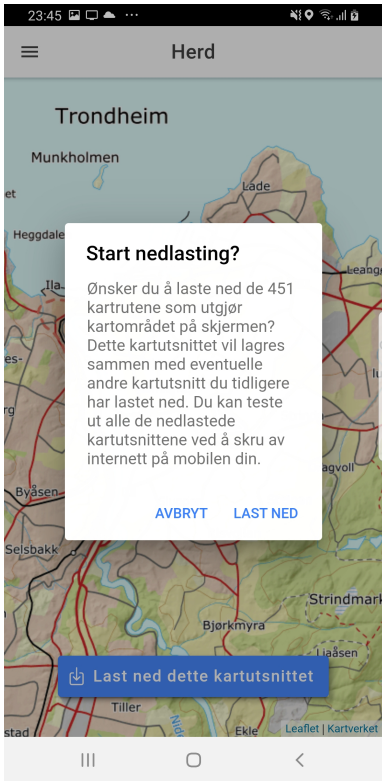

Figure 114: Confirmation message for downloading map section

Figure 115: Feedback of the map download progress

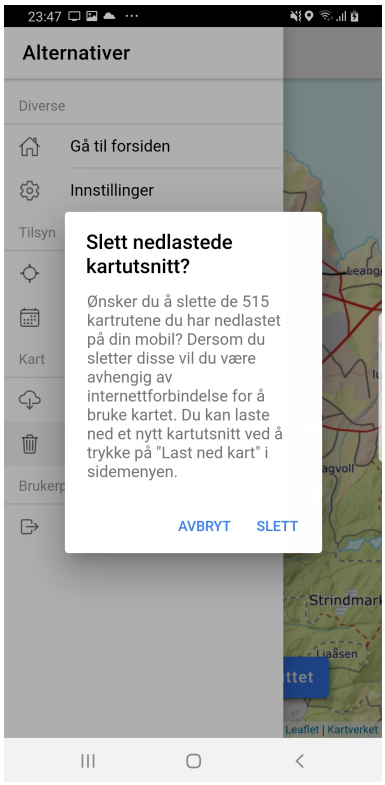

Figure 116: Confirmation message for deleting downloaded map sections

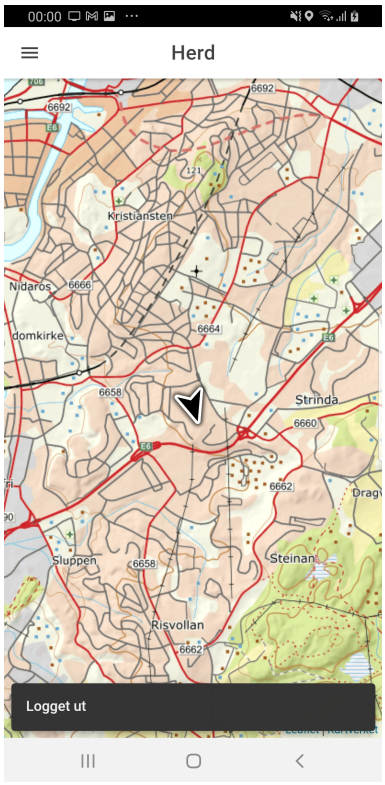

Figure 117: Feedback message when logging out

D Website User Tests - Test Assignments

1. You are a farmer that is going to conduct one of your weekly supervisions of your grazing sheep. You have heard of a new service called "Herd" that can be used to document these supervisions. You wish to register a user profile at this service. How would you do this using the website?
2. Some weeks have passed, and you have now used the Herd mobile application to conduct and upload several supervisions. You now wish to see that these supervisions are visible on the Herd website. How would you do this using the website?
3. You now wish to delete the most recent supervision. How would you do this using the website?
4. You now wish to download a report of the three most recent supervision. How would you do this using the website?
5. (Extra task - Only part of the second user test) To get an understanding of the dangers your sheep are subjected to during the grazing period, you wish to figure out how many injured or deceased sheep were observed during these three most recent supervisions. How would you do this using the generated report?
6. (Extra task - Only part of the second user test) You now wish to figure out the time the most recent supervision was started and finished. How would you do this using the generated report?
7. (Extra task - Only part of the second user test) You now wish to figure out how many healthy adult sheep were observed during the third most recent supervision. How would you do this using the generated report?
8. To get a better overview of your supervisions, you want to display the three most recent supervisions together on a single map. How would you do this using the website?
9. To get a different perspective you now wish to display your three most recent supervisions individually on separate maps. How would you do this using the website?
10. You now wish to see a list of only the supervisions that were conducted this month. How would you do this using the website?
11. You now wish to sort all your supervisions by their duration. How would you do this using the website?

E Website User Tests - Follow-Up Questions

1. Was there anything in particular that you liked about the prototype?
2. Was there anything in particular that you disliked about the prototype?
3. Was there anything you felt were missing or could be improved about the prototype?
4. On a scale from 1 to 10, where 10 is best, how would you rank the prototype as it is now?
5. What would have to be done to increase the score you just gave?
6. Do you have any other thoughts you want to share?

Tor Martin Frøberg Wang

Master's thesis

NTNU
Norwegian University of
Science and Technology