NTNU – Trondheim
Norwegian University of
Science and Technology

Visualization of Crowds from Indoor Positioning Data

Jeppe Benterud Eriksen

Master of Science in Informatics
Submission date: May 2015
Supervisor: John Krogstie, IDI

Norwegian University of Science and Technology
Department of Computer and Information Science

Abstract

In recent years, a wide range of Indoor Positioning Systems (IPSs) have been developed through both research projects and as commercial systems. IPSs can be utilized in many different ways, such as providing wayfinding capabilities, tracking of humans and equipment, and for identification of human processes. An area where further investigation is needed is how indoor positioning data collected through an IPS can be used to aid facility managers. The goal of this research is to develop a prototype application that utilizes collected positioning data, and use it to investigate how such data is able to aid facility managers.

The research was conducted according to the design science research methodology, and qualitative research approach was used. The artifact developed is a web application that is able to process large amounts of collected positioning data, and use it to visualize crowd distribution and movements within a building. The application visualizes crowds by generating a heat map of the distribution of crowds on top of a map of Gløshaugen campus at Norwegian University of Science and Technology (NTNU). This application was evaluated using relevant stakeholders, to assess if the utilization of indoor positioning data was perceived as useful by facility managers.

The results from this research presents an investigation of the perceived usefulness of collected positioning data from a facility managers perspective. Potential stakeholders for the prototype application and the collected positioning data is presented, as well as an evaluation of the application with two different groups of stakeholders. The results from the evaluation shows that there is a clear interests in the use of collected indoor positioning data among facility managers.

Sammendrag

I de senere år har en rekke forskjellige innendørs posisjoneringssystemer blitt utviklet gjennom både forskningsprosjekter og som kommersielle systemer. Innendørs posisjonersingssystemer kan utnyttes på mange forskjellige måter, som å tilby wayfinding-tjenester, sporing av mennesker og utstyr, og for identifisering av menneskelige prosesser. Et område hvor ytterligere forskning er nødvendig er på hvordan innendørs posisjoneringsdata samlet inn gjennom et innendørs posisjoneringssystem kan brukes til å hjelpe anleggsledere (facility managers). Målet med denne forskningen er å utvikle en prototype applikasjon som utnytter innsamlet posisjoneringsdata, og bruke denne applikasjonen til å undersøke hvordan slike data er i stand til å hjelpe anleggsledere.

Forskningen ble gjennomført i henhold til *design science research methodology*, og en kvalitativ forskningstilnærming ble brukt. Artifakten utviklet er en webapplikasjon som er i stand til å behandle store mengder innsamlede posisjoneringsdata, og bruke denne dataen til å visualisere fordelingen av folkemengder i en bygning. Applikasjonen visualiserer folkemengder ved å generere et heat map over fordelingen av folkemengder over av et kart over Gløshaugen campus ved NTNU. Applikasjonen ble evaluert med relevante interessenter, for å vurdere om bruk av innendørs posisjonering data ble oppfattet som nyttig av anleggsledere.

Resultatene fra denne forskningen viser en undersøkelse av den oppfattede nytteverdien til innsamlede posisjoneringsdata fra anleggsledere perspektiv. Potensielle interessenter for applikasjonen og posisjonering data er presentert, samt en evaluering av applikasjonen med to ulike grupper av interessenter. Resultatene fra evalueringen viser at det er en klar interesse for bruk av innsamlede innendørs posisjoneringsdata blant anleggsledere.

Problem Description

Since its launch in 2011, MazeMap has provided indoor/outdoor wayfinding capabilities to students and staff at NTNU, Gløshaugen. Using the existing WiFi network at Gløshaugen, MazeMap is able to collect large amounts of positioning data from devices located within the range of the WiFi network. An area that needs to be researched further is how collected positioning data can be used to aid facility managers.

The task is to process position data to give a simple overview of crowds in a building. The project should result in a prototype application that is able to utilize indoor positioning data, and an evaluation of this application with relevant stakeholders. The task is to be done according to a design science research methodology, and the report is expected to be written in English.

Preface

This document contains my master thesis, conducted at the Department of Computer and Information Science (IDI) at Norwegian University of Science and Technology (NTNU). The project was defined in consultation with my supervisor, Professor John Krogstie, and was executed in the fall of 2014 and spring of 2015. I would like to give my sincere thanks John Krogstie for his support and guidance during the project.

I would also like to thank Åsmund Tokheim, Thomas Jelle and Dag Jomar Mersland from Trådløse Trondheim for providing access to the MazeMap application, and for their quick and detailed support on technical matters. Additionally, I would like to thank Dirk Ahlers from the Department of Computer and Information Science, Dag Sverre Rønning from the Student and Academic Division, and Morten Hatling at SINTEF for providing valuable insight on several different matters during the project.

Last, but not least, I would like to thank the Property Management Division at Norwegian University of Science and Technology (NTNU) and Statsbygg for letting me interview them for the evaluation of the application, and my fellow students at Sule for input and moral support throughout the year.

Jeppe Benterud Eriksen

Contents

List of Tables

List of Figures

Abbreviations

AP Access Point.

API Application Programming Interface.

CSS Cascading Style Sheets.

GPS Global Positioning System.

HTML HyperText Markup Language.

HVAC Heating, ventilating, and air conditioning.

IPS Indoor Positioning System.

JSON JavaScript Object Notation.

MAC Media Access Control.

MSE Mobility Services Engine.

MVC Mode-View-Controller.

NTNU Norwegian University of Science and Technology.

PAW Pattern Analyzer for Workspaces.

RFID Radio-frequency identifier description.

RSSI Received signal strength indication.

SPA Single-page application.

TAM Technology Acceptance Model.

UI User Interface.

Chapter 1

Introduction

This chapter will give a short overview of why and how the project was conducted. First, the general background and motivation for the project are described. This section aims to describe where this project is situated in the field and what the key driving forces motivating this research are. Next, a concise problem definition and overview of the project process is given, before the outline of this report is presented.

1.1 Background and Motivation

Since its launch in 2011, MazeMap[1] has provided indoor/outdoor wayfinding capabilities to students and staff at NTNU, Gløshaugen. MazeMap enables its users to find their own location both indoor and outdoor, as well as search for locations on campus, such as lecture halls, reading rooms, toilets, and cafés. Several research projects at NTNU have utilized MazeMap and the data it provides. Biczok et al. [2014] investigated indoor human mobility at campus, using wayfinding requests gathered from MazeMap, while Gao et al. [2015] and Mersland [2013] both resulted in applications that utilized and visualized data provided by the application and the underlying architecture. Another project, utilizing the same dataset, has been conducted in parallel with this one. That project is named *Human Mobility Patterns From Indoor Positioning Systems*, and is conducted by Kristoffer Aulie.

Many other projects within this field, both research related and commercial, have emerged in the recent years, and it is deemed that a long list of venues can benefit from the use of indoor location-based services. This includes universities, shopping malls, hospitals, and airports. The motivation behind this research project is to utilize indoor positioning data in a way that can aid facility managers in their work. The aim is to create an application that utilize indoor positioning data, that can be used to investigate how such data can aid facility managers.

[1] `http://mazemap.com`

1.2 Problem Definition

The goal of this project is to investigate how collected positioning data can be used to aid facility managers, through the development and evaluation of a prototype application. This application must be able to process large amounts of positioning data to give a simple overview of crowd movements within a building. The evaluation of the application should determine if this way of utilizing positioning data can aid facility managers, and thus if the concept of visualizing indoor crowd movement has potential for relevant stakeholders.

1.3 Project Description

This project was carried out over the course of ten months in the fall of 2014 and spring of 2015. The work have been done in connection to work in Wireless Trondheim Living Lab [Andresen et al., 2007].

An extensive background study was conducted to establish the state of the art within the field, ensure the validity and value of the research, and to gather ideas and requirements for the prototype application. An important part of the project have been to identify potential stakeholders for the application that could be used for evaluation of the final prototype. This process have been ongoing throughout the project, and several unstructured interviews and meetings were held both to identify interested parties, and to gather requirements and information that could be used in the development of the application. The application was developed iteratively over the course of four months, with new functionality being added as a result of new information and requirements. The evaluation was conducted through two in-depth interviews, with a demonstration of the final prototype, with two identified groups of stakeholders.

The project was carried out using the design science research methodology. This methodology focuses on the creation of new IT products, also called *artifacts*, that can be used to solve an identified problem. The method is an iterative process that ranges from the very beginning of a research project, with identifying a research problem and motivation, to developing and evaluating the artifact, to communicating the results of the project after the research is finished.

The outcome of this project is a prototype web application, and an investigation on *who* can benefit from the utilization of indoor positioning data, and *how* they might benefit from it. The application was used to demonstrate one way of utilizing collected positioning data, to evaluate the perceived usefulness potential stakeholders had for the concept. The results of this evaluation show that there is a clear interest in the utilization of indoor positioning data among potential stakeholders.

The application developed is attached to this thesis as compressed archive, and can be used following the instructions provided in the archive. A detailed description of the application is given in Chapter 4 and in Appendix B.

1.4 Report Outline

The outline of the rest of this report is as follows:

Chapter 2 - Background is a short literature review, with the goal of generating a solid background, as well as motivation, for the research project.

Chapter 3 - Research Design and Methodology describes the underlying research design and methodology used in the research. This will describe the goal and research questions, and how the research project was conducted.

Chapter 4 - The Application will give a detailed description of the prototype application developed.

Chapter 5 - Problem Elaboration provides a detailed problem elaboration, through the identification of potential stakeholders, and ways they might be able to benefit from the use of positioning data.

Chapter 6 - Evaluation presents the results of the evaluation of the prototype application.

Chapter 7 - Discussion presents a discussion of the results of the evaluation, with a focus on how the results provides answers to the research questions.

Chapter 8 - Conclusion and Future Work concludes the thesis, and briefly discuss potential areas of future work.

Appendix A - Technology Acceptance Model Questionnaire contains the questionnaire presented to the interviewees during the evaluation of the application.

Appendix B - Application Preview contains a short preview of the application, and is meant to supplement the description given in Chapter 4.

Chapter 2

Background

In this chapter, the background study conducted in the first part of the project will be presented. First, description of positioning systems will be given, to provide an overview of different types of technologies and positioning systems that exist. Then MazeMap will be described, as this is the underlying Indoor Positioning System (IPS) that is used in the application developed in this project. The two last sections describe areas where IPSs have been discussed in the literature, with a focus on how they can be used, and what the future potential of such systems is.

2.1 Positioning Systems

A positioning system is a system that is used to determine the location of an object in space. Many different techniques and technologies exist, and this section aims to describe the underlying technology used in such systems. Two main categories of positioning systems exist: indoor and outdoor. This project is based on the use and utilization of MazeMap, an IPS. Even though systems of both categories experience different challenges and difficulties, the principles of positioning systems are often the same regardless if it is for indoor or outdoor use. In this section, different techniques used in positioning systems will be presented, along with a short discussion of the differences between indoor and outdoor positioning systems.

2.1.1 Localization Techniques

All positioning systems must utilize one or more techniques for localizing (i.e. position) the user of the system. According to Fallah et al. [2012], localization methods can be grouped into four different techniques: Dead reckoning, direct sensing, triangulation and pattern recognition. Gu et al. [2009] describes the same specific techniques, although four different categories is presented. Here, the categories proposed by Fallah et al. [2012] will be presented as they include all forms of localization techniques, not just what can be used indoor.

Dead Reckoning

Dead reckoning localization techniques estimates the user's position based on a previously determined position. The estimates are calculated based on odometry readings from different kind of sensors, such as accelerometers, compasses, and gyroscopes. As this is a recursive process, where the next estimated position of the user is based on previous estimations, this technique is often prone to errors that accumulate over time [Noureldin et al., 2013]. These systems are also often called *inertial navigation systems* as they are autonomous systems that determine the location of the user through the use of inertial sensors [Noureldin et al., 2013].

Direct Sensing

Direct sensing is a technique where the position of the user is determined through sensing identifiers or tags installed in the environment. A user has to carry a tag reader, and the position of the user is determined once the reader detects a tag. Within this group, the use of Radio-frequency identifier description (RFID), is the most common technique. RFID tags are then installed in the environment, and the user has to carry a RFID reader. Each tag will transmit its location to the reader, which then, once a tag is detected, will be able to determine the location of the user. Other techniques exist as well, such as the use of infrared light, ultrasound identification, and Bluetooth beacons, which is all based on the principle identifiers installed in the environment.

Triangulation

The triangulation technique uses multiple (three or more) identifiers installed at known locations to position the user. Trilateration uses the distance between the user and at least three known points to determine the location, whereas angulation uses angular measurements [Hightower and Borriello, 2001]. Global Positioning System (GPS) is the most widely used outdoor positioning system, and uses trilateration based on the position of satellites to determine the location of a user [Fallah et al., 2012]. In indoor positioning, signal strength of the signal transmitted by an access point (e.g. a Wireless LAN router, or Bluetooth beacon) can be measured to determine the distance between a user and the access point, and thus locate the user [Li et al., 2006]. Triangulation is illustrated in figure 2.1.

Pattern Recognition

Pattern recognition method compares data from a set of sensors carried by the user with raw data collected earlier, which has been coupled with a map of the given area [Fallah et al., 2012]. This comparison can then be used to determine the location of the user. An example of how the pattern recognition techniques can be used is through *computer vision*-based methods, where a camera is used to "sense" the environment. Images captured by the camera carried by the user is then matched to a database of images from a known location, and the location is determined through this matching.

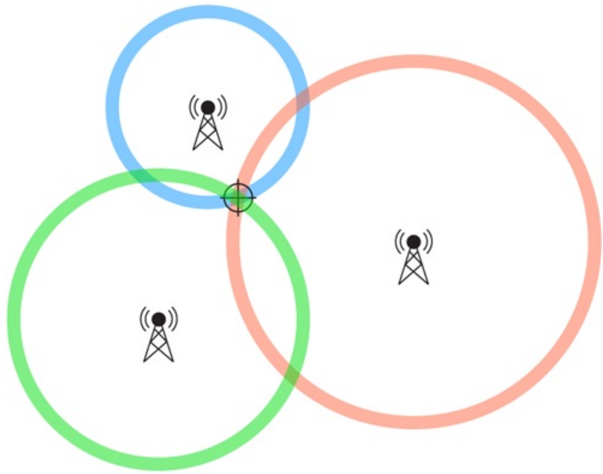


Figure 2.1: Determining user position using Wi-Fi triangulation

2.1.2 Outdoor Positioning Systems

GPS is the most widely used outdoor positioning system in use today [Fallah et al., 2012]. As described in section 2.1.1, GPS uses triangulation based on the known location of four or more satellites to locate the user. The system is developed and maintained by the United States Air Force, and is freely accessible to anyone with a GPS receiver. The accuracy of GPS is reported to be better than 3.5 meters in normal conditions [gps.gov, 2014], and the system is available anywhere on earth where there is an unobstructed line-of-sight to four or more GPS satellites. Because there is a line-of-sight requirement between the satellite and the receiver, however, GPS cannot be used in an indoor environment. GPS is used for a wide range of applications worldwide, including military, civil, and commercial.

2.1.3 Indoor Positioning Systems

An Indoor Positioning System (IPS) is defined as a system that continuously and in real-time can determine the position of something or someone in an indoor physical space, such as a hospital, school, or university [Gu et al., 2009]. These systems differ from outdoor positioning systems, such as GPS, in that they consider only indoor environments.

The two basic approaches to designing an indoor positioning system are to either utilize an existing wireless network infrastructure to locate the target, or to develop an infrastructure from scratch focused primarily on positioning functionality [Liu et al., 2007]. Both approaches have been used in existing systems. The advantage of the first approach is that one avoids expensive and time- consuming deployment of infrastructure. With the growth of the smartphone into consumer markets, using the Wi-Fi network to locate the user is relatively inexpensive as the infrastructure is already deployed most places. These systems, however, often struggles with lower accuracy in the positioning, as the Wi-Fi not initially were developed to support positioning purposes. The advantage of the second approach is that the designers can control the physical specifications of the system, and thus improve the performance and quality of the system. This, however, is often more costly to both develop and implement than utilizing existing infrastructure [Gu et al., 2009]. An RFID based IPS is an example of such a system.

These two design approaches are based on the challenges facing IPSs, with the cost of implementation [Fallah et al., 2012] and the accuracy of the system [Gu et al., 2009] being the two most distinct. Both of these challenges is an effect of the complex nature of an indoor environment. While GPS can require a line-of-sigh to four satellites, this is not a reasonable requirement for an IPS as walls, equipment, and human beings often will obstruct the signals. Anything that obscures the view between the sender and receiver can influence the propagation of electromagnetic waves, and thus degrade the accuracy of the positioning [Gu et al., 2009]. Interference and noise from other sources can also create problems. A system therefore needs to be designed to accommodate for these challenges to provide acceptable an accuracy and affordable implementation. It is also important to note that while an accuracy of 3.5 meters often is acceptable in an outdoor environment, this might mean that the user is placed in the wrong room or floor indoors. A high accuracy is therefore needed, and a trade-off between accuracy and implementation cost therefore needs to be considered.

2.1.4 Navigation Systems

A navigation system in this context is a system that can determine the location of the user, and provide wayfinding and navigation functionality. The system must be able to follow the user while navigating in the environment, and continuously plan the best path for the user to follow [Fallah et al., 2012]. In outdoor environments, GPS is the system most commonly used for navigation. Indoor navigation is emerging along with Indoor Positioning Systems, and MazeMap is a good example of such a system. As will be described in section 2.2, MazeMap is able to determine the position of its users, and enables them to easily navigate the given area where the application is offered.

The emergence of Wi-Fi-enabled smartphones is making it possible to offer indoor navigation to almost everyone, and an ever increasing amount of locations worldwide is now offering indoor maps and navigation. An indoor navigation system allows a venue to provide a detailed overview of their environment, and guide their visitors to a desired location. Where a visitor before had to find their location on a map and manually calculate the best way to their destination, it is now possible to offer a system that does this for them. This allows visitors that are unfamiliar with the environment to more easily find and navigate to different parts of the venue. Several different systems utilizing this technology has emerged in the recent years.

2.2 MazeMap

MazeMap is the underlying system enabling indoor positioning at NTNU and a number of other venues. In this section, a thorough description of MazeMap will be given. As this is the underlying IPS used in this project, it is important to describe how it works and what possibilities it provides. In this section, the application and how it works will be explained, along with important privacy concerns regarding the use of the positioning data generated by the service.

2.2.1 The Application

MazeMap[1] is a hybrid indoor/outdoor wayfinding application that can locate a user's position in a given area with an accuracy of up to 5-10 meters [Biczok et al., 2014]. The solution is offered by Wireless Trondheim and was started as an R&D project between Wireless Trondheim and NTNU and launched for the first time in the fall of 2011, under the name CampusGuide. The application uses a combination of trilateration (see section 2.1.1) and GPS to locate the user at selected locations. At time of writing, the service is offered at seven different locations, including NTNU Gløshaugen in Trondheim, The University of Tromsø and St. Olavs Hospital (Trondheim University hospital)[MazeMap, 2014].

On Gløshaugen, MazeMap enables its users to find their own location both indoor and outdoor. Users can search for any location on campus, such as lecture halls, reading rooms, toilets, and cafés, and use the application to find the shortest path from their own location to any given location on campus. MazeMap is also able to detect which floor the user is located on, enabling easy navigation in any building. The user interface of MazeMap is shown in figure 2.2.

2.2.2 Cisco Mobility Services Engine

The underlying service providing location data to MazeMap is called Cisco Mobility Services Engine (MSE). The MSE is a platform that utilizes existing network infrastructure at a location to provide location analytics. The service captures information about every device detected within the coverage area of the network, and determines the discrete time, location and Media Access Control (MAC) address of the device [Little and O'Brien, 2013]. When a WiFi client (e.g. a phone or a computer) is enabled, it continuously transmits probe requests to identify the best Access Point (AP) for the client. These requests are used to identify Received signal strength indication (RSSI) of every AP within range to ensure that the client always is connected to the best one. With the Cisco MSE, the APs connected to the network gather these probe requests and forward them together with the MAC address of the client to the MSE. The MSE then uses the RSSI captured from every AP within the range of the client to triangulate the location of that client. The MAC address is a unique address for every client, and is used for identification.

To ensure that the client always is connected to the best AP, it actively scans the channels of the network for available APs. This scanning works the way that the

[1] `http://www.mazemap.com/`

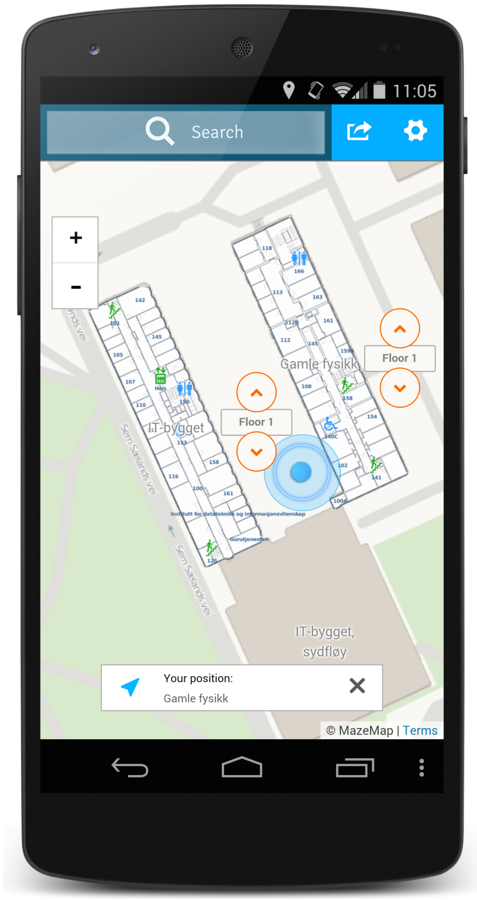


Figure 2.2: MazeMap user interface

client broadcasts a probe request, and then waits to receive any probe responses, or periodic beacons, from the APs on the channel that is being scanned [Cisco Systems Inc., 2013]. The interval of these broadcasts will vary depending on the hardware in the client and the RSSI of the AP [Lee et al., 2012], but they are often sent between every five seconds and a minute. As these probe requests are transmitted once the client has enabled its WiFi, the client does not need to be associated with the network (i.e. logged in) to for its location to be calculated. Given a good Wi-Fi coverage of an area, the Cisco MSE is therefore able to calculate the location and follow the movement of every client within the coverage area of the network. On NTNU, there is more than 1800 APs [Biczok et al., 2014], which means that the user is usually within the range of three or more APs, which is required to accurately triangulate the location. An overview of how Cisco MSE works are given in figure 2.3.

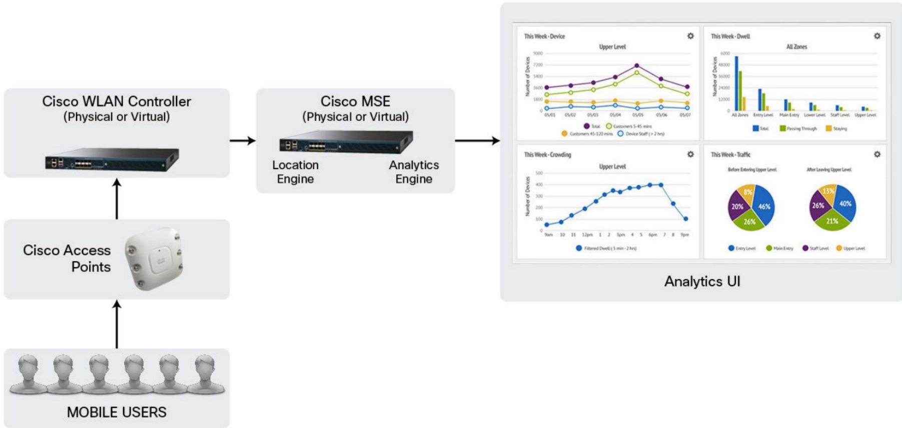


Figure 2.3: Cisco Mobility Services Engine overview (`www.cisco.com`)

2.2.3 Data Collection & Privacy

At NTNU, the location data generated by the Cisco MSE is collected and stored for analysis purposes. Two specific products have been developed to ensure the privacy of the users of MazeMap, and the people located within the range of the wireless network at NTNU Gløshaugen.

To protect the users of MazeMap, an application named GeoPos have been developed. This application ensures that a device running MazeMap only can ask for its own location, and not the location of other devices located within the range of the network. MazeMap communicates with the Cisco MSE through this application, instead of with the MSE directly. Users of MazeMap can therefore not access the location data for other users of the system.

Regarding the users of MazeMap, an application named GeoPos have been developed. This application is developed so MazeMap does not have to communicate with the MSE directly, but through this application. What it does is mainly to ensure that a device only can ask for its own location, and not the location of other devices located within the range of the network. Users of MazeMap is therefore unable to access the location of other users of the system.

The other application developed is an anonymization module that is to ensure that it is impossible for those with access to the stored location data to use it to track a single user over time. As mentioned above, the MSE uses the unique MAC address of a device to identify it. To ensure that it is impossible to associate a MAC address with a specific device, this module hashes the MAC addresses before it returns the location data. By hashing the MAC address, it is very difficult to reconstruct the original address from the hash, and the identity of the device is therefore considered secure. Additionally, the hash of a MAC address is changed once every day to make it impossible to track a single user (using the hash value) over time. Even though a MAC address is not directly registered to the name of the device owner, this is regarded as sensitive data as the MSE makes it possible to use it to track the movement of the device. With this module, a device can be tracked one day before the hash is changed, and it is impossible to associate the MAC address to a specific device. One can therefore follow one random device for 24 hours before the hash is changed, and it is impossible to find the same device again. This module has been approved by The Data Protection Authority of Norway[1].

2.3 Use of Indoor Positioning Systems

As mentioned in section 2.2.2, the Cisco MSE is able to determine the location and movement of every device within the coverage of the given network. Given the unique identification of a device, it is therefore possible to follow the movement of a single device as it moves around the NTNU campus. Many similar systems have been proposed through both research projects and commercial products, utilizing IPSs and position data from both humans and equipment. In this section, an overview of existing technology and research projects utilizing IPSs in different ways will be given, in an effort to outline state of the art within the field. This is not an exhaustive literature review, but a general overview of important projects where IPS and location data have been put to use. A large number of systems and projects exists, and in this section the ones deemed most important will be presented.

2.3.1 Navigation

As described in section 2.1.4, an Indoor Navigation System is a system that can determine the location of the user, and provide wayfinding and navigation functionality. Indoor navigation is one way of utilizing an IPS, and several systems exist. MazeMap, which is now offered for free at seven different locations in Norway, is one example of such a system. Google, who have provided outdoor map technology through Google Maps since 2005, launched Google Indoor Maps in November 2011. Since then, more than 10 000 venues wold wide, such as airports, museums, and shopping malls, have uploaded their floor plans to Google [Google, 2014]. Using a combination of Wi-Fi signal strength, phone sensor data, GPS (if available), and cell tower information, Google Maps is able to determine the location of the user with an average accuracy of 6 meters, and offer navigation in an indoor environment [Google I/O, 2013].

Meridian Mobile App Platform[2], is an application platform that enables venues to easily deliver location-relevant information to their visitors, such as indoor navigation, with turn-by-turn directions, mapping, and context-aware notifications in their own applications [Aruba Networks, 2014]. This allows a venue to implement indoor maps and navigation in their own custom applications, without having to develop the functionality themselves. In the same manner as MazeMap, Meridian powered applications uses the existing WiFi infrastructure of a venue, together with

[1] `www.datatilsynet.no`
[2] `www.meridianapps.com`

the Cisco MSE (see section 2.2.2) to provide location services to its users. Many different venues worldwide have implemented the platform in their own customized applications, such as Macy's department store in New York [Mashable, 2012] and Boston Children's Hospital [Boston Children's Hospital, 2014]. At both of these locations, the customized application is available for Android and iPhone, offering step-by- step navigation and search for specific locations within the environment.

2.3.2 Research Projects

[Fallah et al., 2012], [Gu et al., 2009], and [Liu et al., 2007] all present comprehensive studies of numerous IPSs, including both commercial products and research-oriented solutions. A long list of existing systems can be extracted from the studies. Tracking of assets, inventory, and personnel is usually the main purpose of the system, which is deemed to be useful in a wide range of industries. Healthcare and hospital settings, logistics, and fire and evacuation situations are mentioned as possible areas of application [Liu et al., 2007].

Hospitals have been among the first to make use of IPSs, and several different systems have been tested and put to use. Case studies show that the use of RFID-based IPSs in hospital environment can help locate inventory faster, as well as cut annual losses [Wicks et al., 2006]. By tagging equipment with RFID tags, the use of IPS can help prevent theft, as well as help the staff locate equipment faster. At A Coruña Hospital Emergency Service, an RFID system for tracking of patients and drugs was developed and tested [Martínez Pérez et al., 2012]. This system had several tasks, and among them locating and identifying the patients through the use of RFID and an IPS. The system was positively evaluated by the staff of the hospital, and deemed to have a very high success rate if it were to be introduced in a clinical routine. In an extensive study on the adoption of RFID in healthcare, Yao et al. [2012] claim that the use of IPS can help hospitals, among other things, to track patients and assets, reduce theft loss, and improve patient workflow efficiency. Such a system can therefore help hospital staff save time searching for equipment, and monitor entire wards of patients more effectively.

The data generated by an IPS can also be used for a wide range of applications. In Stahl et al. [2009], an RFID-based IPS were used to try and understand outpatient clinic behavior. An RFID system was used to track both staff and patients of two different clinics, and enabled the researchers measure and monitor process measures in these clinics, through analysis of the data gathered. They claim that the use of IPS successfully can measure important clinic process measures in live clinical outpatient settings, and capture behavioral differences across different clinics.

2.3.3 Commercial Systems

Commercial IPSs have also been developed. Ekahau Real-Time Location System[1] is a system that allows for tracking of both people and equipment within an organi-

[1] www.ekahau.com

zation. The system is focusing on hospitals and health care institutions, and aims to provide business intelligence and location analytics by tracking the location assets, such as staff, patients, and equipment, as well as inventory levels [Ekahau, 2014]. Sonitor Technologies[1] is a company developing real time location system solutions. They have developed an IPS using ultrasound to automatically track the real-time location of movable equipment and people in complex indoor environments, such as hospitals [Sonitor Technologies, 2015].

Beestar Insight[2] is a similar system aimed for higher education. This system is an active RF-based real-time locating platform that allows tracking of people and assets within room accuracy [Beestar, 2014]. Coupled with grade statistics and administration systems, Beestar Insight automates attendance tracking and combines the attendance with grade statistics to provide personalized dashboards to visualize the performance of students. It also enables the organization to visualize the utilization of buildings through the tracking of staff and students [StartupsFM, 2013].

2.3.4 Projects at NTNU

Several projects on IPSs have been conducted at NTNU, utilizing the data collected through MazeMap. In Biczok et al. [2014], they use positioning data collected through MazeMap to show spatial and temporal distribution of geo-location and wayfinding requests from MazeMap, construct an aggregated human mobility map of the NTNU campus, and identify strong logical ties between locations on campus. The mobility map can be used to visualize potential bottlenecks and hotspots on campus, and shed light on the human mobility patterns on the selected location.

In his master thesis, Mersland [2013] utilize MazeMap data in an analytics application. The goal of this service was to visualize room utilization on given locations on campus, to help the administration to better understand how rooms *actually* is used, and thus help better utilization. Location data connected to the largest lecturing halls on campus is analyzed, and a user interface with visualizations of both live and historical data is presented to the user in a proof-of-concept web application. A screenshot from a part of this application is presented in figure 2.4, visualizing the number of people detected in a lecturing hall through several days. Another thesis was delivered by Tran and Thingstad [2014], where live data from MazeMap was used to help students find unoccupied seats in reading rooms. The product of this project was a mobile application that utilized live location data connected to reading rooms on campus, visualizing the occupancy of each room. The goal of this application was to help students find unoccupied reading areas, a task that can be difficult and tiresome, especially during the examination period.

Pattern Analyzer for Workspaces (PAW) [Andreassen et al., 2013] was one of the projects that were part of Customer Driven Project at NTNU in the autumn of 2013. In the PAW project, SINTEF was the customer, and the project was part of a larger project coordinated by SINTEF, called "K2 - Workplace of the

[1] `www.sonitor.com`
[2] `www.beestar.eu`

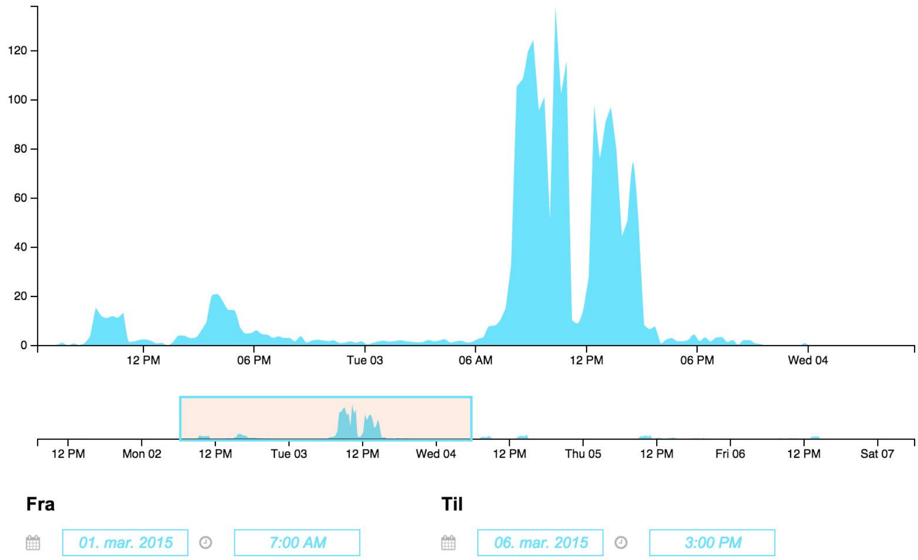


Figure 2.4: A screenshot from a part of the proof-of-concept web application developed by Mersland [2013]. The graph is representing the occupancy of the selected room.

future". K2 stands for "Kontor2.0" (Office 2.0), and is a project that aims to create the workplace of the future through the integration of physical solutions, new technologies, and work practices [SINTEF, 2012]. PAW was a part of this project, and resulted in a prototype of an analysis tool for analyzing movement data within a building, along with a simple simulator to supply it with sample data. This tool allows the user to look at graphic and tabular representations of the work environment, and use this to analyze movement data of workers in an office building. It can therefore help managers gain knowledge of how their space is used. The aim of the K2 project is to improve the workplace in order to provide the best possible conditions for value creation in an organization. The goal with PAW was to create a tool that utilized movement data in a way that could help achieve this, and thus improve the workplace. The current version of PAW uses location data obtained from manually counting the number of people located in each room at regular intervals. The system have been implemented in relation to the design of a new main office for a bank and an entrepreneur company, and in a consulting company that develops services around the application. Figure 2.5 is a screenshot from PAW, showing the default view on the room use report. In addition to different types of graphs, it is also possible to generate a heat map showing the occupancy of each room, or a list of all rooms with connected usage data.

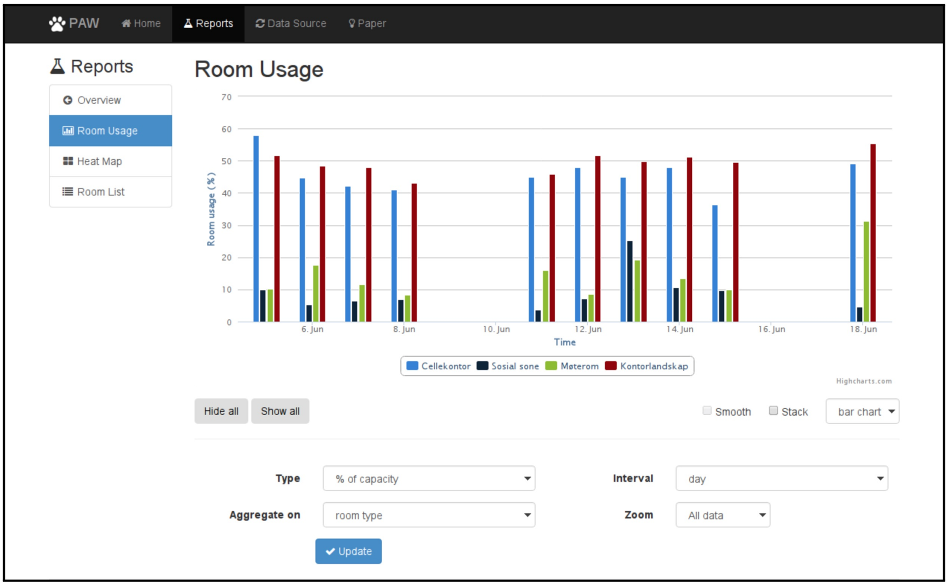


Figure 2.5: A screenshot from PAW, fetched from Andreassen et al. [2013].

2.4 Potential Use

In this section, areas where different actors might be able to benefit in some way from an IPS, and general areas of application, identified in the literature will be described. Biczok et al. [2014] argue that a long list of indoor venues could benefit from the use of indoor location-based services, including hospitals, shopping malls, museums, and airports. Industry forecast of location-based services predicts a huge marked growth and revenue [Gartner, 2012], [Li et al., 2006]. Four main categories for areas of potential have been identified, and is presented below.

2.4.1 Process Improvement and Safety

As mentioned in section 2.3.2, hospitals and healthcare have been among the first to make use of IPS and the data it provides. In a comprehensive literature review on the use of RFID in healthcare, Yao et al. [2012] identify a large number of potential usage areas for such systems in this business. They present a long list of hospitals that have utilized RFID for tracking of both assets and humans, and argue that the use of RFID in healthcare offer major advantages that includes enhanced patient safety, reduced cost, and improved efficiency. They identify tracking of both assets and humans to be the most widely used application for RFID in hospitals, which enables staff to locate both equipment, patients, and employees faster and more easily. Based on this, they argue that the use of an IPS in hospitals and healthcare has potential. Martínez Pérez et al. [2012] expect the use of an IPS to help in lowering the number of adverse events in the treatment of patients, as well as waiting and treatment times in a hospital setting. In an extensive study to explore the potential value of data generated through an RFID-based IPS, Amini et al. [2009] conclude that RFID-based systems can help in a number of ways in health care, as well as in other industries. They argue that the data generated by such a system in general can provide the ability to monitor throughput and process efficiencies, and thus lead to an improved understanding of existing processes. This allows for re- engineering and improvement of the observed processes. In healthcare, the opportunities offered by such a system range from providing real-time tracking of patients, medications and medical equipment, to reporting of process-related statistics.

In [Stahl et al., 2009], the authors argue that the RFID-based IPS they tested successfully fulfilled its initial promise of being able to capture system behavior in the environment they tested it in, and that IPSs has a lot of potential. Compared to traditional observation methods, IPS has the ability to unobtrusively gather large amounts of data from its environment, which can make it easier to observe and evaluate existing and ongoing processes. Potential usage areas mentioned by Stahl et al. [2009] is to identify room utilization patterns, which can be used to improve scheduling, and to provide infrastructure to support ongoing process improvement.

2.4.2 Space Utilization

At universities, and in education in general, teaching space and reading areas is often considered a scarce resource. According to Jan Sverre Rønning from the Student Academic Division at NTNU, room utilization is a considerable problem at NTNU. Even though all available rooms usually is booked at all times, sampling conducted by the administration shows that between 20 and 30 percent of the rooms are unoccupied, even though they are booked. Additionally, it is common that lecturers state that they need teaching space for more students than actually attend the course, and that the course therefore could be held in a much smaller room. Studies in England shows similar results, and state that space utilization of the available space often is as low as 20-40% [Beyrouthy et al., 2007]. The data collected through an IPS at a university or similar institution, can help the administration determine how the available space is utilized. Gathering data and visualizing how the area is *actually* used could open up for possibilities for automatic analysis of space utilization, which can help educational institutions save time and money. Management of location resources is difficult and time consuming in all public buildings, and the use of IPS can help the administration of such buildings better organize and manage these resources.

2.4.3 Commercial Use

IPSs is deemed to have potential for commercial products. At Google I/O 2013, Google's annual developer conference, the speaker talked about Google Indoor Maps, and their vision for the future of indoor maps and localization [Google I/O, 2013]. They present an example for contextual awareness for related to search, explaining that their users expect different search results depending on his or her location; if the user is located at Home Depot and search for "painting", the expected results will be related to wall paint. At The Louvre, however, Mona Lisa is likely to be the expected top result. According to Klepeis et al. [2001], Americans spend 87% of their time indoors, and Google therefore deems ability to accurately locate the users in indoor environments as important for their service to work as expected by the users.

Skyhook[1] is a Boston company that specializes in providing location services to its users. Skyhook uses Wi-Fi-signals to locate the user, and allows developers to create location-enabled applications using their location framework. The framework is able to establish the location of the user both indoor and outdoor, and use this to determine the *context* the user is in. This is similar to the Meridian Mobile App Platform that is described above, which enables developers to integrate location services into their own applications. The goal of these application services is to enable developers to give the users of the application the right services at the right time, and thus be able to tailor the content of the application according to the context the user is in at that very moment. Similar ideas have been utilized by Google through Google Now[2], that aims to give you the information you need based on the context you are in. Google Now has become an integral part of the Android operating system, and provides the user with notifications and information based on the context the user is in. Examples include reminders that activate once you enter a specific location, like a store or other specific area, relevant suggestions for things to and visit in the area are located, and traffic messages and travel time from your location to e.g. home or work.

The use of contextual aware applications is deemed to hold a large business potential, which easily can be utilized by venues that want to direct potential customers attention to the right place. The location of the user is an important part of the overall context he or she is in, and indoor positioning systems can therefore aid contextual aware applications. Shopping malls will be able to provide advertisement to their visitors depending on their location and context, and thus provide advertisement tailor-made for each customer. Shopkick[3] is an application that aims to help its users discover products and deals in nearby stores. By providing its users with advertisement and offers based on the users location, e.g. when a user is close to a specific store, Shopkick has been able to boost the sales of its partners [TechCrunch, 2013].

In addition to contextual aware advertisement, public venues can use the data provided by an IPS to study how their visitors move, identifying potential bottlenecks, where they stop for rest, and points of interest [Biczok et al., 2014]. This can again be used for smart placement of stores, identification of shopping patterns, and informed pricing plans for tenants. Previously, shopping patterns have been inferred from cash register data [Berry, 1998] or by following selected customers through the store. With a system that is able to automatically detect and register crowd movement, however, it could become possible for public venues to

[1] `www.skyhookwireless.com`
[2] `www.google.com/landing/now/`
[3] `www.shopkick.com`

automatically analyze the movement of their visitors, which could provide valuable previously unknown information.

2.4.4 Occupancy Prediction and Energy Consumption

Building occupancy is an important factor in the energy use of a building, but is hard to predict due to its spatial stochastic nature. In the U.S., 40% of the energy consumption is from buildings, whereas 48% of this is from Heating, ventilating, and air conditioning (HVAC)-systems [Li et al., 2012]. Research on energy consumption have shown that energy savings of up to 10 to 15% is possible by regulating the HVAC-systems based on the number of people in the given area of the building [Sohn, 2010]. This technique is called demand-driven or demand-controlled ventilation, and uses data on the occupancy of the building to regulate the systems. This is a potential usage area for IPS, as these systems automatically monitors the occupancy of buildings. Using the detailed data provided by and IPS, it is possible to tailor the HVAC-system in a building to adapt itself to the amount of people in a given area, instead of assuming maximum occupancy. It is also possible to use the same data in predicting future occupancy through simulations.

Chapter 3

Research Design and Methodology

This chapter will describe the research design and methodology used in this research project. First, the goal and research questions will be described, before the general approach to the research is presented. This will include a description of the design science research methodology, and of the choice of using qualitative research approach for evaluation. Then, the entire research process will be summarized, to provide an overview of how the research was conducted. The planning and execution of the evaluation of the application will then be presented, before the collection and analysis of data is described.

3.1 Goal & Research Questions

The aim of this project is to investigate how the use of indoor positioning data is able to aid facility managers, through the development and evaluation of a prototype application. Given this problem description, the goal of this research is as follows:

Goal Investigate how collected positioning data can be used to aid facility managers.

Given this goal, two research questions guided the research. The first research question concerns identifying stakeholders that can be used in the research, while the second focuses on researching how these stakeholders can benefit from the utilization of indoor positioning data.

RQ1 Who can benefit from the use of indoor positioning data?

To be able to achieve the goal of the research it was important to identify facility managers that could be used in the research, and for evaluation of the prototype application. The first research question, RQ1, therefore aims to identify potential stakeholders that have interest an in the field of indoor positioning data, and that can be classified as "facility managers". The second research question is more directly connected to the goal of the research, and aims to use the stakeholders identified for evaluation.

RQ2 How can indoor positioning data be utilized in order to aid facility managers?

This is an open ended question that aims to investigate how specific facility managers can be able to benefit from the use of indoor positioning data. The question is deliberately vague to enable the researcher to perform a wide investigation without narrowing the research area before the research was conducted. The desired result of this question is therefore not necessarily a concrete list of possible usage scenarios for indoor positioning data, but an investigation that can shed light on both current and future possible areas of application. This investigation should provide insight on how identified facility managers might be able to benefit from the use of the data, that can be used in future research projects on the same topic.

3.2 Research Approach

The use of a qualitative research approach have been an important factor in the execution of this project, and in this section, the general research approach will be described. First, an overview of the design science research methodology is presented, to provide an overview of the activities conducted as part of the research. Then a general description of qualitative research is presented, before the choice of using a qualitative research approach is briefly discussed.

3.2.1 Design Science Research Methodology

The design science research process is fundamentally a problem-solving paradigm [Hevner et al., 2004]. Using the design science approach in information systems research, the researcher focuses on developing new IT products, also called *artifacts*, that can be used to resolve an identified problem [Oates, 2006a]. The focus of this research method is therefore to create new knowledge through the creation of novel or innovative artifact [Vaishnavi and Kuechler, 2004]. Hevner et al. [2004] defines the methodology as follows: "Design Science ... creates and evaluates IT artifacts intended to solve identified organizational problems". The resulting artifact can be anything from an algorithm to a process model, and can therefore include such things as a new software application, a search algorithm or a web application. What is important is that the artifact should be able to solve the identified problem better than existing solutions, or support solutions that have not before been addressed [Peffers et al., 2006]. To evaluate the artifact, the researcher observes how well the artifact supports a solution to the problem through a demonstration. This demonstration can take many forms, depending on the nature of the problem and the artifact, and can include such methods as performance measures, simulations, or client feedback [Peffers et al., 2007].

In this project, to ensure that the research was conducted in a proper manner, the design science research methodology proposed by Peffers et al. [2007] was followed. This methodology consists of six activities: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication. These steps are described below. This research methodology is an iterative process, where the researcher can choose to iterate back during the research if the result of the evaluation of the product is unsatisfactory. The model is depicted in figure 3.1.

Activity 1: Problem identification and motivation The groundworks for the research is laid through defining a specific research problem and justifying the value of a solution. This motivates both the researcher and the audience to pursue and accept the solution, and helps the audience understand the researchers reasoning, and understanding of the problem.

Activity 2: Define the objectives for a solution Using the problem definition, the researcher defines the objectives and goals for a solution. These can, for example, describe how the new artifact is expected to address and solve problems that have not before been addressed.

Activity 3: Design and development The researcher determines the artifacts desired architecture and functionality, and develops it.

Activity 4: Demonstration The artifact is demonstrated by using it to solve one or more instances of the problem. This is done through an appropriate activity, such as experimentation, case study, or proof.

Activity 5: Evaluation The artifact is evaluated through observing and measuring how well it supports a solution to the problem. After the evaluation is finished, the researcher decides whether to iterate back to Activity 3 to improve the artifact, or continue to communication and communicate the research.

Activity 6: Communication The research and entire project is documented to researchers and other relevant audiences through a publication, thesis or other relevant documentation.

3.2.2 Qualitative Research

Qualitative data includes as non-numeric data, such as words, images, and sounds, that is found in such things as interview tapes, researchers' diaries, or documents [Oates, 2006c]. This is the main type of data generated through for example interviews or case studies and is used to understand and explain social phenomena [Myers and Avison, 1997]. While quantitative research deals with "hard" data, such as numbers, qualitative research deals with "soft" data, such as text, speech, or images. In qualitative research, the researcher is supposed to be close to the

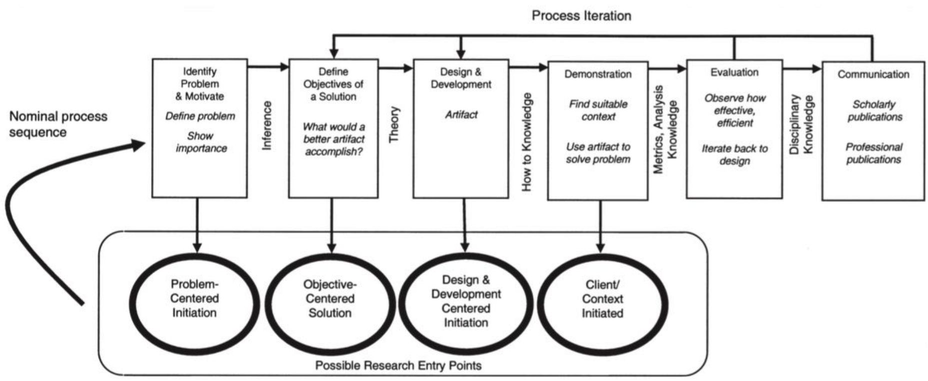


Figure 3.1: Design Science Process Model (Peffers et al. [2007])

subject, to explore their thoughts and feelings, but at the same time make sure that he or she does not influence them with personal opinions.

In this project, the goal was to investigate how collected positioning data can be used to aid facility managers, through the development and evaluation of a prototype application. Keeping this in mind, the goal is not to implement an application that can be used directly, or put into production, but to develop a prototype that is able to demonstrate a concept. To be able to investigate how this concept is able to aid facility managers, and at the same time discuss future potential, usage areas, and improvements, it was deemed necessary to be able to talk directly with relevant subjects within the area of building management. Qualitative research methods are designed to help researchers understand people, and the social and cultural contexts within which they live [Myers and Avison, 1997], and a qualitative research approach was therefore desirable. Using unstructured and semi-structured interviews allowed the researcher to demonstrate the prototype at different levels of completion, and explore the feelings and opinions the subjects had regarding the concept. Discussion regarding the application and concept have been an important part of the project, which is something that is difficult to achieve through quantitative research.

3.3 Research Process

The research project was conducted following the six activities suggested by Peffers et al. [2007], described in section 3.2.1, and depicted in figure 3.1. In this section, the research process will be described, with the goal of providing an outline of the execution of the project.

3.3.1 Background and Motivation

The first two activities in the design science research methodology consist of problem identification and motivation, and the definition of objectives for a solution. To enable these activities to be performed, a background and foundation for the research needed to be built. It was important to the researcher to get an overview of the research area in order to be able to identify relevant research problems, and to ensure that the research could provide novel insights within the field. Knowledge about the technology used in IPSs, such as localization techniques and the gathering of data, was also needed.

This overview was obtained by a gradual, iterative process consisting of searching for and reading relevant literature, talks with potential stakeholders, and guidance from the supervisor. These activities were performed interchangeably, as one often provided information that could be used in another. Once an adequate understanding and overview of the research field had been obtained, the background was documented, presented in Chapter 2. How the search for literature was conducted is presented in section 3.5.3.

Based on the new understanding of the research field, the motivation and objectives for a solution could be identified. The problem definition for the project was to investigate how collected positioning data could be used to aid facility managers, through the development and evaluation of a prototype application. Based on this description, the initial goal for the application, and the goal and research questions for the research project, was defined. The application was to utilize the positioning data by generating a heat map on the map of Gløshaugen campus, to visualize the distribution of crowds. This goal is further described in section 4.1.1, with the description of the application. The heat map would give an overview of where the people inside a building was located, and thus provide knowledge about its use. This definition laid the groundworks for the application, and enabled the project to move forward to the development of the first prototype. Defining the initial goal and research questions for the research helped determine the purpose of the project, and made it possible to work towards a final goal. It is still important to note that the questions and goal at this point was open for smaller modifications based on feedback and experiences gained during the project. The application is presented in Chapter 4, and the final goal and research questions for the project in section 3.1.

3.3.2 Design & Development

The design and development of the application consists of the third and fourth activity in the design science research methodology: *design and development* and *demonstration*.

Some research on relevant web technology was needed before the development of the application could begin. Even though the researcher had basic knowledge in web development prior to this project, some of the technology had to be learned from scratch before it could be used. Even though researching and learning new tools and technology is a time-consuming task, it was deemed necessary for creating a satisfactory application.

Once an adequate overview of available technology and tools had been obtained, the development of the application could start. At this point, the core functionality of the application had been decided and described in general terms. In order to better understand how different parts of the functionality best could and should be implemented, and thus describe it specifically, mockups of the application was drawn. These were hand-drawn sketches, which aimed to demonstrate how the application would look once developed. These sketches were used by the researcher in developing the application, and to get feedback from the supervisor. During the development, when possible improvements of the design were discovered, new mockups were generated. Figure 3.2 depicts four different versions of the design. These sketches illustrates the main page the application, and it is here possible to see the development and changes in the design. Sketch v0.4 (bottom right corner in figure 3.2) gives an overview of the final design of the main screen. Similar sketches were made for all parts of the application.

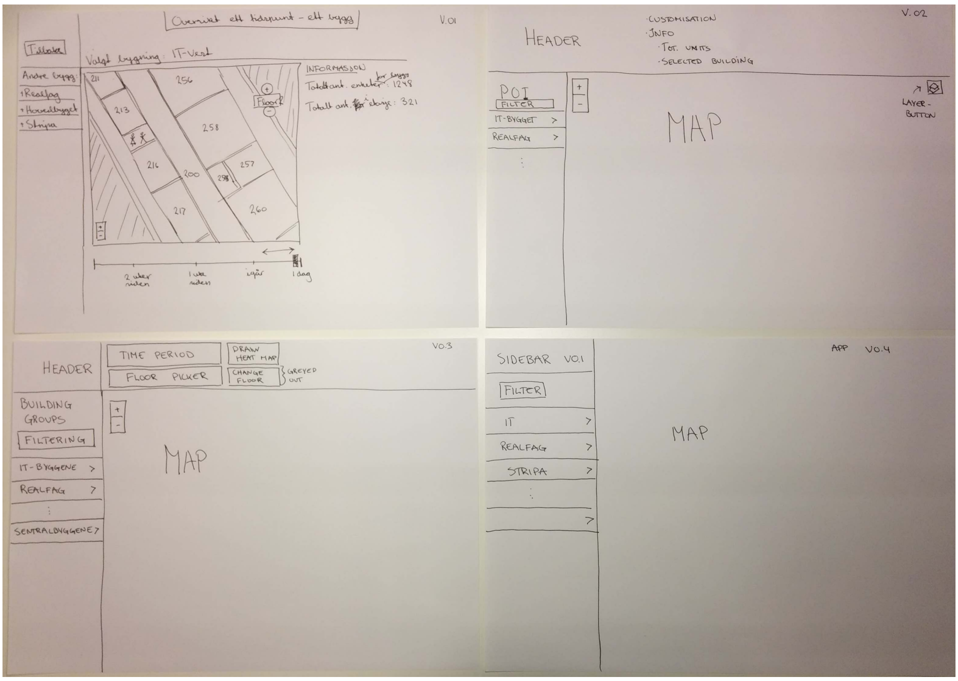


Figure 3.2: Sketches of four different versions of the application

The development went through four iterations, where each iteration resulted in a pre-release, i.e. a version, of the application. The completion of each of these iterations marks an important milestone in the development of the application, as certain vital parts of the application would be finished in each iteration.

First Iteration The goal of the first iteration, and thus the first version of the application, was to get the heat map to work. In this version, it is possible to draw a heat map for all of Gløshaugen on a selected floor, and the heat map was generated using data from all of Gløshaugen at once. The completion of this iteration marked an important milestone in the project as it made it possible to demonstrate the application to the supervisor, and proved that it would indeed be possible to develop the application according to plan.

Second Iteration In the second iteration, large parts of the core functionality of the application were added. This made it possible to demonstrate the application and concept to potential stakeholders. This resulted in the first demonstration of the application, before Christmas 2014. The goal of this meeting was to demonstrate the application, and get the first real feedback on the concept.

Third & Fourth Iteration Initially, the third iteration was going to be the last one. In this iteration, the possibility to select a desired time and time period to fetch data from was added, which was the last part of the planned core functionality. In a meeting with potential stakeholders February 12., however, this version of the application was demonstrated, and it became clear that another iteration was needed. In the fourth and final iteration, functionality for visualization over time was added, based on feedback from the potential users of the application. This version was later used in the final evaluation process. An overview of the functionality of each version is given in table 3.1.

Version	Description
v0.1	First version of the application. Possible to draw a heat map for all of Gløshaugen on a selected floor plan. Possible to manipulate the options of the heat map from UI
v0.2	Most of core functionality is implemented. Possibility to draw heat map for a selected building group and selected floor. Map automatically pans to the selected building group. Statistics of the data used in the heat map. Improvements in UI.
v0.3	All of the initially planned core functionality implemented. Possibility to select a desired time and time period to fetch data from. More data statistics. UI improvements.
v0.4	Functionality for visualizing crowd movements over time added. Large UI improvements.

Table 3.1: Summary of each of the versions of the application

3.3.3 Identification of Stakeholders & Evaluation

To enable a proper evaluation of the application, relevant stakeholders needed to be identified. This identification was ongoing for large parts of the project, with the goal of connecting with stakeholders that could be used for evaluation. Once the application was ready for demonstration, a document with an overview of the application and its functionality was created and attached in conversations with potential stakeholders. This document is similar to the one presented in Appendix B. The results of the identification process are presented in Chapter 5 as a problem elaboration. This chapter explains the most important meetings conducted throughout the project, the resulting potential stakeholders identified, and the two groups of stakeholders that were contacted for evaluation.

The evaluation of the application is the fifth activity in the design science research methodology, and was conducted using two relevant groups of stakeholders identified. Two in-depth interviews were performed, with a demonstration of the application, that provided data that was used for the final evaluation. How the evaluation was conducted is explained in more detail in section 3.4, and the data collection methods used is explained in section 3.5.

3.3.4 Communication

Once the evaluation of the application was finished, the results was documented. This documentation process is part of the sixth and final activity in the design science research methodology, and should result in a thesis or other relevant documentation. Some parts of the thesis had been written during or after specific parts of the research had been performed, like the background in Chapter 2, but the main part of the thesis was documented after the evaluation was finished. This documentation process resulted in this thesis, and aims to communicate the results of the research.

3.4 Evaluation

As described in the problem definition (section 1.2), the evaluation of the application should determine if this way of utilizing positioning data is able to aid building managers, and thus if the concept of visualizing indoor crowd movement has a potential for potential stakeholders. The evaluation process should therefore result in an assessment that can be used both by the researcher, and in future projects, to decide if the use of indoor positioning data for visualization is helpful for facility managers. The evaluation is based on two in-depth interviews, and in this section, the planning and execution of these interviews will be presented.

3.4.1 Planning

To achieve the desired result, it was decided to use a qualitative data collection method. Several aspects played important roles in the planning and execution of the evaluation, and it was important that the process was able to provide answers to the research questions. Using a qualitative data collection method, such as interviews, it is possible for the researcher to explore the feelings and thoughts of the subjects better than in a quantitative data collection method, such as surveys or questionnaires. The methods used for data collection will be described further in section 3.5. Using a semi-structured interview when meeting stakeholders allowed the researcher to properly demonstrate and explain the application to the subjects, before a conversation regarding its usefulness and possible usage areas was held. For the subjects to be able to decide in what way this way of utilizing positioning data is able to aid them in their work, it was deemed important that they were able to properly understand how the application worked and what its goals were. Using semi-structured interviews as data collection method, it was possible for the subjects to ask all the questions they had, and for the researcher to explain and elaborate on areas that were unclear, and at the same time lead the interview in the desired direction. It also allowed for a discussion of the future potential of the concept, and how to specialize and tailor a solution for a specific stakeholder, which was important for the evaluation.

Another important aspect of the execution of the evaluation is the relatively narrow nature of the research field. Even though IPSs and the utilization of the data they generate has received a lot of attention in the recent years, the application created in this project is not something that is interesting and useful for everyone. This played a role in the decision to use a qualitative data collection method: it was desirable to talk to a few selected relevant stakeholders, as opposed to a wider range of less relevant sources. An effort was therefore put into contacting the two groups of stakeholders that were deemed the most relevant, and conducting a thorough qualitative data collection on these, instead of a more shallow collection on a larger number of possibly relevant stakeholders. As described above, this also allowed for a deeper discussion of both the concept and the application, and its future potential. The identification and selection of stakeholders is connected to the first research question, defining who can benefit from the use of indoor positioning data, and will be described in Chapter 5.

3.4.2 Execution

The data collection for the evaluation was conducted in the form of a semi-structured interview with representatives from the group of stakeholders that was deemed the most relevant: NTNU Property Management Division, and Statsbygg. From NTNU Property Management Division, which is responsible for the management, maintenance, and development of NTNUs properties, three representatives were present during the interview. From Statsbygg, which is the Norwegian government's key advisor in construction and property management affairs, four representatives were present. Having more than one representative from each group of stakeholder present during the interviews was desirable, as it was deemed to allow for a better conversation about the concept. The interviews was conducted as a group interview, where questions and explanations were given to the entire group instead of only one subject.

Both interviews lasted about an hour, and was recorded by the researcher.

Having the interviews recorded was desirable, as it allowed for a deeper and more thorough examination of the conversation after it was finished. This made it possible to extract better and more data from the interviews, as it was possible to listen to the exact conversation upon transcribing it. It also allowed for a better interview, as the researcher could concentrate on the interview instead of taking notes of everything that was being said. The notes taken could therefore focus on capturing thoughts and ideas the researcher had, that would not appear on the recording.

At the end of the interviews, the subjects were asked to fill out a Technology Acceptance Model (TAM) questionnaire. This questionnaire was used as a supplement to the data collected from the interviews, in an effort to help identify the perceived usefulness of the application and concept. The technology acceptance model, along with the questions on the questionnaire will be described in section 3.5.2.

The results from the evaluation interviews, and thus the evaluation of the application and concept, will be discussed in detail in Chapter 6.

3.5 Data Collection

It is sometimes useful to distinguish between primary and secondary sources of data [Myers and Avison, 1997]. Primary sources of data are those data which are unpublished and which the researcher has gathered throughout the research. Secondary sources refers to any materials, such as books, articles, and journals, that have been previously published. In this research project, interviews have been the main source of primary data. As will be described below, two types of interviews have been conducted for data collection, along with a Technology Acceptance Model (TAM) questionnaire. The structured literature review, laying the groundworks for the background described in Chapter 2, is a secondary source of data. In this section, the data collection methods used in the research will be described.

3.5.1 Interviews

Interviews have been the main source of primary data used in this research. In meetings with potential and identified stakeholders, the degree to which the interview have been structured by the researcher in advance has varied depending on the goal and topic of the meeting. Early in the project, the goal of meeting with potential stakeholders were mostly to search for problem areas and motivation for the project, and explore the research field. In these settings it was important that the interviewees got to talk freely, as potential problem areas and topics could have been unknown to the researcher prior to the interview, and it therefore could have been difficult to prepare the “correct” questions. In the evaluation interviews, a higher degree of structure was prepared. The topic of these meetings was more defined prior to the interview, enabling the researcher to prepare questions and an agenda.

Throughout the project, the interviews of stakeholders have always been informal, and has generally been regarded by the researcher as meetings or discussions, rater than interviews. This also comes from the exploratory nature of the meetings, where the goal usually have been to gain understanding of a given topic, rather than check or confirm theories or facts. The two types of interviews are described below, along with how they were prepared and used.

Unstructured Interviews

In this type of interview, the researcher has less control than in more structured forms of interviews, and lets the interviewees develop their ideas, and talk freely about events, behavior, or beliefs [Oates, 2006b]. The interviewer has prepared the topic that is to be discussed, and lets the conversation flow freely. This type of interview has the primary goal of "discovery" rather than "checking", and can therefore be useful in the design science research methodology on both generating data for requirements and eliciting user feedback on a finished design [Oates, 2006b]. The questions asked by the interviewer comes primarily from "in the moment experiences" as means of clarification or further understanding of the topic that is discussed [Turner, 2010].

All the meetings leading up to the evaluation interviews were conducted as unstructured interviews, and used to gather different kinds of data relevant to the research. Early in the project, the meetings were used to gather background information and requirements, to help build a solid foundation for the project. As the application was ready for demonstration, they were used for feedback on its functionality and use, and to help identify potential stakeholders that could be used for evaluation. Open-ended questions usually were prepared prior to these meetings, to help guide the conversation if needed.

Semi-structured Interviews

Semi-structured interviews are similar to unstructured ones, but gives the interviewer more control over the interview process. The interviewer have a list of themes to be covered, and questions to be asked, but is willing to change the order of the questions depending on the flow of the conversation [Oates, 2006b]. The interviewees should still be able to "speak their mind", and elaborate on and introduce new topics they think is relevant to the issue being discussed. At the same time, the interviewer has more control than with unstructured interviews, as he or she has prepared topics and questions prior to the interview.

The semi-structured interviews were divided into three parts: (1) *Explanation of the application and the positioning data*, (2) *Demonstration of the application*, and (3) *Conversation*. Each part is described below. Dividing the interviews in this way allowed the researcher to properly introduce himself and the research project, building a foundation before the actual evaluation began. The interviewees then got to know the project, and the application, before they were engaged in a conversation concerning the usability of the concept.

Explanation of the application and positioning data Prior to the interviews, the interviewees was sent a short preview document of the application, to enable them to prepare themselves before the meeting if they wanted to. This preview is similar to the one presented in Appendix B, and was created to give a short overview of the concept to stakeholders unfamiliar with the project. To enable the interviewees to properly understand the concept, an explanation of the application and the underlying data was given at the beginning of the interview. This also enabled the interviewees to ask about areas that were unclear.

Demonstration of the application After the underlying concept had been explained, the application was demonstrated to the interviewees. All the core functionality was demonstrated and explained to provide an overview of how it worked in practice.

Conversation After the demonstration, a conversation regarding the application and concept was held. The interviewees were informed of the goal of the project and its topic before the interview, and was therefore informed of the topic of the interview. No concrete questions were prepared for the interview, but the conversation was directed toward general discussion of the concept and application, and possible areas of application, concerns, ideas, etc.

3.5.2 Technology Acceptance Model

The Technology Acceptance Model (TAM) was first introduced by Davis [1989], and is used to describe and predict user acceptance of information technology. The aim of this model is to predict how users come to accept a new technology, and it posits that the behavioral intention to use a system can be explained by the following two beliefs:

Perceived Usefulness: the degree to which a person believes that using a particular system would enhance his or her job performance.

Perceived Ease of Use: the degree to which a person believes that using a particular system would be free of effort.

As depicted in figure 3.3, the perceived usefulness and perceived ease of use the users of a system has, leads to their behavioral intention to use it. In this project, the focus has been to identify the perceived usefulness: how useful do the potential users of the application think it is? As the application developed is only a prototype, the focus was put into creating a functional system that was able to utilize the data in a given way, to see if this is perceived as useful by its potential users. Even though some effort was put into creating a usable and user-friendly application, this was never the main goal. Given this, the Technology Acceptance Model (TAM) was used as a basis for the data collection and evaluation, even though it was not utilized completely. As described in section 3.4, the interview subjects was asked to fill out a questionnaire with 12 questions at the end of the interview. As the subjects were only given a relatively short demonstration of the application, and thus was unable to test and use it themselves, some of the subjects expressed difficulty in answering the last six last questions regarding perceived ease of use. These were therefore made optional.

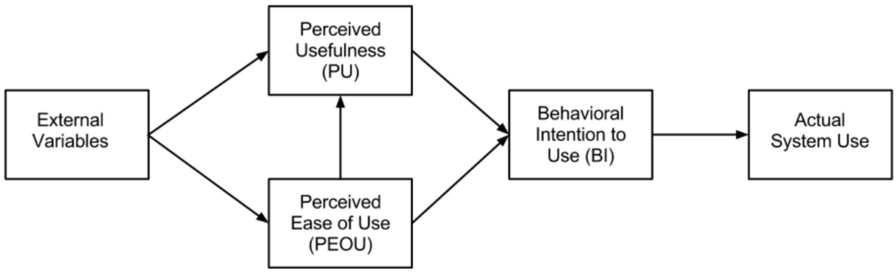


Figure 3.3: Technology Acceptance Model

It is also important to note that the TAM is normally a quantitative research technique, and therefore requires a larger amount of respondents to be used for evaluation. Even though the TAM was therefore not utilized completely, it was still used as a basis for evaluation of the application and concept. The questions presented in the model was used as a basis to know what to look for and what to ask the subjects during the interviews, and therefore played an important role in the evaluation process. The results from the questionnaire was used as an additional supplement to support the data collected in the interviews. The questions are presented in table 3.2 and 3.3. The questionnaire presented to the subjects is presented in Appendix A (in Norwegian). Each question is answered by ticking one option on a scale from one to seven, with one being unlikely and seven being likely.

No.	Question
1	Using the system in my job would enable me to accomplish tasks more quickly.
2	Using the system would improve my job performance.
3	Using the system in my job would increase my productivity.
4	Using the system would enhance my effectiveness on the job.
5	Using the system would make it easier to do my job.
6	I would find the system useful in my job.

Table 3.2: Scale items for Perceived Usefulness

3.5.3 Literature Review

As described in section 3.3.1 about the research process, a thorough background search needed to be conducted early in the project. This search for information

No.	Question
7	Learning to operate the system would be easy for me.
8	I would find it easy to get the system to do what I want it to do.
9	My interaction with the system would be clear and understandable.
10	I would find the system to be flexible to interact with.
11	It would be easy for me to become skillful at using the system.
12	I would find the system easy to use.

Table 3.3: Scale items for Perceived Ease of Use

was an important source of data for the research, and in this section this search will be presented.

Literature Search

The goal of this literature search was to search for products and research projects that utilize an Indoor Positioning System (IPS) in some way, to build a solid background for the research project. The desired outcome of the literature search was therefore literature that describe the construction, use, or utilization of an IPS, which could be used in a literature review. To structure the literature search, certain questions was created. These refer to the motivation and goal for conducting a literature search, and is focused on finding relevant literature and information that describes the use of an IPS in any way relevant to this research. The questions were:

Q1 What is state of the art within IPSs?

Q2 What solutions exists for detecting and visualizing crowd movements within a building?

These were the two main questions that guided the literature search. Several additional questions were also generated to evaluate how new knowledge would affect this project. If existing solutions for visualization of crowd movements within a building did exist, the following questions needed to be answered:

Q3 How is this solution relevant to this research project?

Q4 On what basis were these projects conducted? What were main drivers and motivation for carrying out the projects?

After the literature search were finished, regardless of if relevant solutions were found or not, a single question needed to be answered:

Q5 How do the results of the literature search affect this project?

These questions guided the search for data, and its analysis, to determine why and how it was relevant to this research project. To structure the search for data, relevant search terms were identified. The search itself were conducted through several iterations, where small changes to the search string an search terms were made in each iteration. Initially, the search terms were focused on finding relevant literature related to detecting humans located indoor. To maximize the search results, relevant synonyms for each term were included in the search. In table 3.4 an example of the initial search terms and synonyms are presented.

Term 1	**Term 2**	**Term 3**	**Term 4**
indoor	human	mobility	location
indoors	person	positioning	distribution
	individual		position
	being		placement
	population		

Table 3.4: Initial search terms

Of these terms, both Term 1 and Term 2 were required to be present in a document for it to be deemed relevant. Additionally, either Term 2 or Term 3, or both, must also be present. Several variations of the search string, including different search terms, formulations, and restrictions on publishing date were tested and discarded during the first iteration of the literature search. The search string that proved to yield the best results in the first iteration is presented in listing 3.1.

```
((indoor OR indoors) AND
(human OR person OR individual OR being OR population)) AND
((mobility OR positioning) OR
(distribution OR placement OR position OR location))
```

Listing 3.1: Initial search string

In search for literature related to Q2, the same approach was used. Table 3.5 contains examples of the terms used in this search. The goal of this search was to find papers where indoor positioning systems were tested and used in practice, to see if relevant solutions did exist.

Due to a lack of relevant search results, and in an effort to not create a too extensive search string, many combinations of these search terms were tested and used. Asking the search engine to find similar documents to relevant articles also proved to yield good results.

As described above, several iterations of search were conducted during the first part of the project. Initially, the goal of the search was to acquire a basic knowledge about IPSs and relevant research areas and technologies. As the researcher had little knowledge in the field of IPSs prior to this project, the initial searches aimed to discover literature that could provide a broad and basic understanding. This knowledge could then be used in further searching, to improve the results. After the initial structured search described above, many more specific searches were therefore conducted, based on the results from the initial search. These search

Term 1	Term 2	Term 3	Term 4	Term 5
“indoor positioning system”	use	“case study”	“room utilization”	RFID
	utilization			WiFi
	applications			
	“area of application”			
	employment			

Table 3.5: Search terms in second iteration

strings often aimed to find specific types of solutions, like studies where an IPS have been used and evaluated in a hospital setting. Because of this less structured approach of search, all of the search terms will not be described.

Search Engines

In the search for literature, three search engines were mainly used:

- Google Scholar[1]
- Mendeley[2]
- Web of Science[3]

Of these, both Google Scholar and Web of Science gives access to a search across several databases, and were used interchangeable. Mendeley claims to let you search one of the worlds largest crowd- sourced research catalogs [Mendeley, 2014]. This database often returned fewer results, but the results given often proved to be highly relevant.

Continuous Search

In addition to the initial search described in this section, a continuous search for information continued throughout the project. This was done in two ways. First, searches using the same strings terms described above were performed regularly to see if new documents or information had become available while the project was ongoing. Two different alerts on Google Scholar were also activated, using two different search strings. Alerts is a service offered by Google Scholar, which notifies the user via email every time new documents matching a search string becomes available. This is useful to stay updated on a specific topic. Secondly, searches

[1] `https://scholar.google.no/`
[2] `https://mendeley.com/research-papers/`
[3] `http://apps.webofknowledge.com/`

consisting of terms and strings discovered during the research were conducted continuously. New phrases and terms often came to light during the project, especially in talks with potential stakeholders, and were used in searches to see if previously unknown research and literature existed.

Analysis of the Results

The data collected through the literature review have played an important role in the research and is the data that is used in the background in Chapter 2. The literature review was conducted during the first part of the project, with the goal of generating a solid background, as well as motivation, for the project. The goal of searching for literature was therefore not to create an exhaustive literature review, but to acquire knowledge about the research field, and relevant research projects and technologies." The data collected through this search was analyzed continuously after each search and iteration, as relevant documents often proved to provide new search terms and data that could be used to find even more relevant documentation.

Throughout the search, all seemingly relevant papers were collected and sorted based on their title and abstract. After each iteration of searching, a more thorough review of the papers were executed. Irrelevant papers were discarded, while relevant and credible papers were kept and used in the research. All relevant papers and documents were assigned tags and keywords describing its content and topic, and stored in folders based on what it was used for in the research. Mendeley[1] was used to store all literature. In addition to the search engine described above, Mendeley is a specialized desktop and web application for managing and sharing research papers. This, among other things, enabled fast and easy search and sorting of the stored literature, annotation of pdf-files, and personal notes on each document, which enabled easier data analysis.

3.6 Data Analysis

To enable other researchers to evaluate the research, recreate results, or continue the work, it is important to provide information on how the data collected was gathered and analyzed. This will allow the readers to know how the researcher worked his or her way from the raw data to the conclusions, and is helpful for others to be able to validate and evaluate the research. In this section, the analysis of the primary data sources will be described. The data collected from the unstructured interviews was analyzed and used continuously throughout the entire research project. The evaluation interviews provided the data collected from relevant stakeholders, and is the main data source that was used for the final evaluation of the application and concept.

A problem discussed frequently in relation to qualitative data analysis is the issue of data overload [Oates, 2006c][Miles and Huberman, 1994]. Qualitative research can often generate large amounts of raw data, such as field notes and record-

[1] https://www.mendeley.com/

ings, and its analysis can be overwhelming to the researcher. This is an important issue to address. As the data collection in this research project is based on a series of unstructured interviews, and two in-depth semi-structured interviews, however, data overload was not a problem. Even though both types of interviews generated considerable amounts of raw data, and the data analysis was a time-consuming task, it was manageable due to the relatively low number of interviews. The continuous analysis of the unstructured interviews also made sure that not all the collected data had to be analyzed at once, making the task less demanding.

3.6.1 Unstructured Interviews

As described in section 3.5.1 about interviews, unstructured interviews has the primary goal of "discovery" rather than "checking", and this played an important role in the analysis of the data collected through these talks. It was often some uncertainty regarding the outcome of the meeting, and it was therefore desirable to record as much data as possible that could be used in the research. The goal was to create a background and motivation for the project, generate requirements for the application, and to discover potentially relevant stakeholders to contact.

Subsequent to every meeting, field notes kept by the researcher was reviewed and typed out. Important thoughts and notes written as short sentences and keywords during the meeting was extended and detailed meeting minutes was generated. Thoughts and ideas that emerged during or after the meeting was documented together with the meeting minutes in a detailed report from the meeting. Every report was kept in a digital journal, and marked with name, date, and keywords and tags, describing what the topic of the meeting was, who was present, and other important aspects of that meeting. Evernote[1], a desktop and web application designed for notetaking and archiving, was used to keep the journal. This enabled fast and easy search of the entire journal, and enabled the researcher to easily find the correct notes when needed.

3.6.2 Evaluation Interviews

The data collected through the evaluation interviews is the main data source used to evaluate the application and concept. As described in section 3.4 about the evaluation, this data was collected through two in-depth interviews, with two different groups of stakeholders. Both interviews were recorded, which enabled a detailed data analysis to be performed subsequent to the interview process.

The goal of this data collection was to obtain data relevant to the research questions, from relevant stakeholders. The analysis process therefore aimed to extract as much relevant data from the interviews as possible, that could be used to evaluate the concept and answer the research questions.

The analysis process consisted of two main activities: *Data Preparation* and *Data Analysis*, following guidelines from [Oates, 2006c] and [Miles and Huberman, 1994].

[1] `https://evernote.com/`

Data Preparation Before the actual analysis could begin, it was necessary to convert all the data into a format that was ready for analysis. In this process, the interview tapes were transcribed into the same digital journal (Evernote) described above, in two separate documents. Metadata, such as location, who was present, and other information necessary to describe the setting of the interview was documented at the top of the document, before the actual interview was documented. Each tape was played in succession several times, with more detailed information being recorded each time. Each piece of data was written down with where in the interview it occurred (minutes and seconds), who said it (if applicable), and the "topic" of the information. An example of a single line can be:

12:55 - Man 1: *Future potential:* "I believe this concept have potential."

Thoughts and comments by the researcher were documented together with the quotes and notes. Conversations about a given topic, or special parts of the interview, like the demonstration of the application, was given separate sections in the transcription. Start and end time on that specific part was then noted, and quotes, comments, thoughts, etc. was written in the form described above within the section. Notes taken on paper by the researcher during the interviews was combined with the transcriptions during the preparation.

Preparing the data in this way allowed all the data to be in the same format, allowing easier analysis. Using a digital journal also enabled search within a transcription. The recordings was examined several times, with new information being noted each time, until the researcher felt satisfied that all the relevant data had been extracted from the tapes.

Data analysis The analysis was an iterative process that aimed to identify and extract all the data that was deemed relevant to the research from the evaluation interviews. The first step was to go through the transcriptions of both interviews, and mark segments, or *units* of data, as either relevant or irrelevant to the research. Each unit could be a word, sentence, paragraph, or even a small part of the interview. Segments marked as irrelevant were mostly small talk from the interview that did not provide any useful information, and was ignored through the rest of analysis. Both transcriptions was in this phase printed out to enable easy note taking and scribbling of thoughts and comments.

Once all the relevant segments were marked, each transcription was analyzed in turn, and notes on what made each unit relevant was taken in the margin. This was a coding process that aimed to identify *why* and *how* a specific part of the data was relevant to the research. A unit was deemed as relevant if it was related to research in any way, and a note on its relation to the research, i.e. its category of information, could be for example "Future potential", or "Area of application". Using an inductive approach, the aim was to identify categories of information that could be observed in the data, or that occurred to the researcher during the analysis. Using this approach, an effort was made to keep an open mind and let the data speak for itself, instead of using existing theories generated before the analysis. Some categories were explicit and easy to identify, like privacy concerns regarding the collection and use of positioning data, while other needed to be changed and refined several times during the analysis. A complete list of all categories were kept and updated continuously.

Once each interview had been satisfactory analyzed, and each unit of data had been marked with a category or topic, a search for themes and inter-connections between the interviews was executed. The identification of patterns and similarities within the data is a common activity in qualitative data analysis [Miles and Huberman, 1994]. Both transcripts were thus analyzed interchangeably, and a new document containing categories and patterns identified in the data was created. Excerpts of data was copied and pasted into the new document under appropriate categories. This allowed to gain an holistic view on the data, as it made it easier to identify patterns and categories that was present in both interviews, as well as segments that was unique for only one of them. After the initial analysis was finished, this document contained excerpts and summaries of all the segments of data that was deemed relevant from both the interviews, and thus the raw results of the data analysis. An examination and review of this document was then performed, to refine it and allow for documentation of the results. The results of the data analysis will be presented in Chapter 6, before a discussion of these results in Chapter 7.

3.6.3 Technology Acceptance Model Questionnaire

As described in section 3.5 about the data collection, the Technology Acceptance Model (TAM) was mainly used as a basis for the evaluation of the application and concept. As a total of only seven people was interviewed, too few responses was collected to properly be able to analyze the results of the TAM questionnaire. Given a larger amount of responses, a full statistical analysis would have been performed. This would allow the researcher to evaluate the validity of the answers provided, and thus rely more heavily on the responses. In its current state, the results from the questionnaire should only be seen as an indication on perceived usefulness, and only in combination with the data collected through the evaluation interviews.

For the data analysis of the questionnaire, the answers from all seven responses was counted, and assembled in a frequency table with overview of the distribution of the answers. The frequency of responses for each question was counted, and the percentages for each score calculated. The resulting frequency table shows the responses from all the respondents on items measuring perceived usefulness. The mean score for each question was also calculated. The results from the analysis is presented in Chapter 6.

Chapter 4

The Application

In this chapter, the prototype application developed as part of this thesis will be presented. This will include both technical and non-technical parts of the application, and important decisions that have been made during the development. First, a description of the application will be given, providing an overview of the goal, and important aspects of the application. Then all the core functionality of the application will be described, before its technical design is presented. Lastly, know limitations and future work on the application will be discussed. As a supplement to this chapter, a preview of the application is given in appendix B.

4.1 Description

In this section, an description of the application will be given. This will include a summary of the goals for the application, a description of its functionality and the underlying dataset, and important design decisions that have been made during the development.

4.1.1 Goal

The goal of this research project, as described in section 3.1, was to investigate how collected positioning data can be used to aid facility managers. To achieve this goal, a prototype application that utilizes collected positioning data had to be developed, in order to demonstrate potential usage areas for the positioning data. Based on the goal of the research project, and results of the research process leading up to the development of the application, described in section 3.3, the goal for the application was defined as follows:

> **Goal** Use indoor positioning data to generate a heat map on the map of Gløshaugen campus, to visualize the distribution of crowds.

As described in section 3.3.2 about the design and development of the application, the core functionality of the application was described in general terms once an adequate knowledge of available technology and tools was obtained. The application was to parse the available indoor positioning data, and use it to generate a heat map on top of the map of Gløshaugen campus. The map of Gløshaugen, containing floor plans of every building on Gløshaugen, was provided by the MazeMap application, described in section 2.2. Using this map, the application developed should be able to visualize the distribution of crowds inside the buildings at Gløshaugen, and thus provide knowledge about their use.

4.1.2 Description of the Application

The application developed is a web application that enables its users to generate a heat map of crowd movement on Gløshaugen campus. The users selects a building group, and generates a heat map consisting of data connected to the selected buildings and floor. It also lets its users navigate between the floors of the selected buildings, and updates the heat map according to the new selected floor. Two main features for the generation of the heat map exists: snapshot, and visualization over time. Snapshot is a feature that fetches data from a selected period of time (time frame), and generates a static heat map with that data. Visualization over time moves the time frame forward one minute at the time, continuously updating the heat map with new data. This enables the user to see how the distribution of the crowds evolves over time. A detailed overview of the entire application will be given in section 4.2.

In figure 4.1, an example of the heat map is depicted, using data connected to the first floor of Hovedbygningen at NTNU. In this figure, the snapshot feature is used to generate a static heat map using data from a 15 minutes time frame.

4.1.3 Dataset

The location data used by the application is gathered by the Cisco MSE, described in section 2.3, and stored at a dedicated server at NTNU. This server continuously gathered all the location data generated at Gløshaugen from 2. September 2014 to 2. November 2014, and provides the positioning data used by the application. The positioning data consists of a large amount of individual location updates from the devices located within the range of the wireless network at Gløshaugen. As described in section 2.2.2 about the Cisco MSE, every WiFi enabled device actively searches for available Access Points (APs) by continuously transmitting probe requests. The Cisco MSE stores each probe request, and every time it is able to triangulate the position of a device, a new location update is stored on the location data server. Each location update consists of the following fields:

hierarchy A string describing the area, building, and floor a device is located on. An example of this string can be: "Gløshaugen - Realfagbygget - 2. etasje"

timestamp A Unix time stamp determining exactly when the location update was captured.

Figure 4.1: Example of the heat map

longitude A coordinate that specifies the east-west position of the location update on the Earth's surface.

latitude A coordinate that specifies the north-south position of the location update on the Earth's surface.

salt_timestamp A time stamp determining when the current salt (used in the hashing, i.e. anonymization of the devices) was generated.

id A unique ID for each device. This ID is changed every 24 hours.

accuracy The accuracy of the location update.

As a client typically sends new probe requests with a short interval, a large amount of location updates was stored every day while the location server gathered data. During the busy hours at Gløshaugen, two hours of location data usually correspond to more than 500 000 individual location updates, providing a large dataset that can be used for visualization. The data used in figure 4.1 is gathered over the course of 15 minutes (from 1:00 pm to 1:15 pm 22.10.2014), and consists of 1032 individual location updates. This means that the Cisco MSE was able to determine the location of 1032 devices on the first floor of Hovedbygningen during those 15 minutes.

4.1.4 Design decisions

In this section, important aspects of the design of the application will be described.

Single-page Application Design

The application is a Single-page application (SPA), meaning that all the functionality of the application is available on a single web page. As the map of campus is the main feature of the application, it is important that it always is available to the user. The SPA design allows the map of campus to constantly utilize 75% of the browser width, while the content of the sidebar, utilizing the remaining 25% width, can be changed dynamically upon user interaction. Instead of navigating between different pages on the same domain to view different parts of the application, all of the functionality is available on a single page. When the heat map is generated, it is added as a layer on the already existing Leaflet map. This allows the user to manipulate the map and heat map without leaving the page, and thus visualizing the results of manipulation, such as changing the heat map, instantly. As all the necessary code is fetched upon first page load, little loading is required to change the content of the sidebar or the layers, increasing the performance of the application.

Grouping of Buildings

Gløshaugen consists of 44 different buildings, and many of them, such as Kjemiblokkene and the Elektro buildings are small and connected to each other. To generate a heat map for only one of these buildings in isolation was deemed to be less useful, as they in practice is seen as a single building. To increase the usability of the application, it was decided that the smaller buildings, and buildings that naturally belong together were put in groups. The 12 resulting building groups is illustrated in figure 4.2.

Use of Static Data Files

As described in the section 4.1.3 about the dataset, a dedicated server is used to store the positioning data used by the application. To access this data, a specialized program called *getpos*, is needed. This program is described in detail in section 4.3.3.

The initial plan was to implement getpos into the application, by developing a REST Application Programming Interface (API). This would allow the users of the application to enter the time frame they wanted to visualize on into the application, and the application would ask getpos to provide the data. This data would then be used to generate the heat map. It was discovered, however, that getpos was too slow to provide the application with data in real time. A typical query for the application would be to ask for ten minutes of location data on a given day, which would take getpos approximately eleven minutes to return, which is not acceptable to a web application. To avoid this delay, it was decided that the application would use static location data files, fetched from getpos manually in

Figure 4.2: Grouping of the buildings on campus

advance, instead of implementing getpos as an part of the application. The static data file used in the prototype contains data from two hours from 13:00 to 15:00 22.10.2014, which means that the users have to ask for data within these two hours for the heat map to be generated. Apart from this, the use of static data files does not affect the users in any way. What limitations this might cause the users is discussed in section 4.4.

Time Period

The heat map is generated using data from a given time period. By default, this period is set to ten minutes. This means that the application fetches all the location updates from the given start time and ten minutes ahead in time, and use the result in generating the heat map. The user can set this time period to anything from one to thirty minutes. As described in section 4.1.3 about the dataset, a large amount of location updates was stored every second at busy hours at Gløshaugen, which means that the amount of data can quickly become a performance issue for the application. The limit of thirty minutes have therefore been set to limit the amount of data used to generate the heat map, and thus keep the performance of the application at an acceptable level.

4.2 Overview of Functionality

In this section, an overview of the functionality of the application will be given. First, the user interface of the application will be described, before the two main ways of generating the heat map will be presented.

4.2.1 User Interface

The user interface consists of two main parts: the map and heat map, and the sidebar. These are described below. Upon page load, the user is faced with the screen shown in figure 4.3. This page shows the map of campus on the right, and a list of the different building groups on campus in the sidebar on the left. On this page, the user is able to select the building group that he or she wants to create a heat map for, or draw a heat map for entire Gløshaugen at once. It is also possible to search for a specific building. In this section, the two main parts of the UI will be described.

Figure 4.3: The main page of the application

Figure 4.4: Application when the IT building group have been selected

Sidebar

The sidebar is the users main way to interact with the application. It constantly utilizes 25% of the screen width, and is always available to the user. Upon page load, the sidebar is populated with a search field, a list of the building groups, and a button for drawing a heat map for all buildings at Gløshaugen. This view of the sidebar is illustrated on the left side in figure 4.3. The button generates a heat map using the entire data file (described with the use of static data files in section 4.1.4), without filtering on floor or building group. In figure 4.5, this functionality have been used, and the heat map have been generated for all buildings at Gløshaugen, with a data file containing 41822 location updates.

The search bar enables the user to search for a specific building or building group. Once a group is selected, the content of the sidebar changes and the map is automatically panned to this building group with a fitting zoom level. The new content of the sidebar lets the user manipulate the heat map, as well as displaying information to the user. This view is illustrated in figure 4.4. The information shown includes data about the currently chosen building group, floor, time period, and the data that is used to generate the heat map. This information automatically updates itself when different parameters is changed. An example of this information is shown in figure 4.6.

Below the information section, a set of options for the heat map can be controlled, that is used to manipulate the heat map. First is the time options that determine the time and date that that should be used when fetching the positioning data for the heat map, and the time period. The date and start time is the day and hour selected for the visualization, and the time period decides how many minutes of positioning data should be used. Below the time options is the drop down menu

Figure 4.5: Heat map for all of Gløshaugen

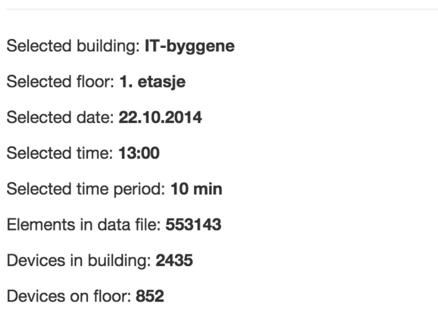


Figure 4.6: Example of the information displayed in the sidebar

for selecting floors. Changing the selected value of this menu will update the floor plans used for all buildings, and the heat map (if it has been generated). These options are depicted in figure 4.7.

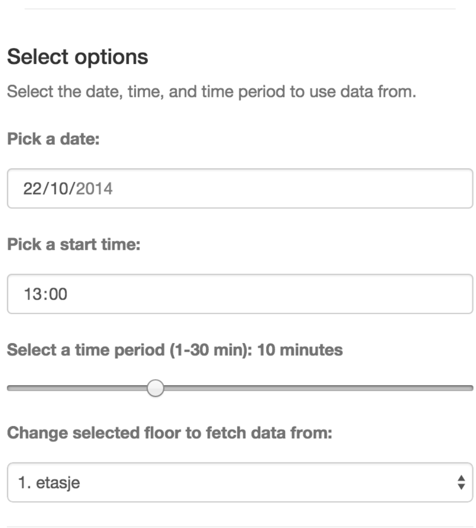


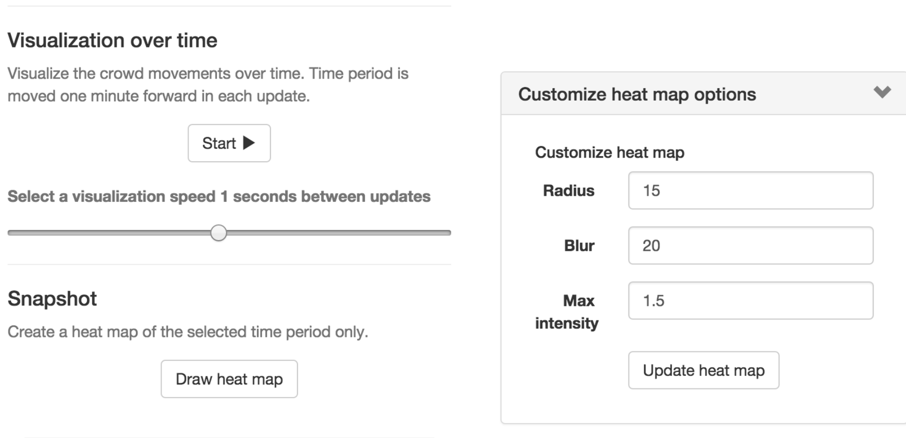
Figure 4.7: Example of the time options in the sidebar

Further down is the two different possibilities for generating the heat map, accounting for the main features of the application. Both of these features fetches data from the selected time period and floor, and adds the heat map as layer on the map. At the bottom of the sidebar is the “Customize heat map options”-panel. This is a collapsible panel that is collapsed by default, that allows the user to change the heat map appearance by changing how it aggregates the data it is provided with. The options for generating the heat map, and the customization panel, will be described in section 4.2.2, and is depicted figure 4.8. If the user wants to change the selected building group, the “Back to list”-button will reset the map, removing the heat map and zooming out. The user will then be able to select another building group.

Map and Heat Map

The map of campus is located on the right hand side of the UI, and is constantly utilizing 75% of the browser width. As described above, the the entire map of Gløshaugen is provided by the MazeMap application. This map can be controlled as a regular digital map, using drag motions to move the view, and scrolling to zoom in and out. In the bottom left corner, the cursors exact position on the map is presented on the form of latitude, longitude coordinates.

As described in the section about the sidebar above, the users main way to control the application is through the sidebar. It is through the sidebar that the floor plans presented to the user is changed, and where the heat map is generated.



(a) Options for generating the heat map **(b)** Customization options for the heat map

Figure 4.8: Options for generating and customizing the heat map

Once the heat map is created, it is added as a layer on top of the map of the selected building group. The user is then able to move the view, and zoom in and out to change the level of detail displayed. As will be explained in section 4.3.3, the heat map library automatically aggregates the data based on the zoom level on the map, merging and resizing the data points based on the options provided. Figure 4.9 shows a heat map from the IT buildings on two different zoom levels. In this visualization, the heat map is generated using 1005 data points located at the first floor of IT- bygget, IT-bygget Sydfløy, and Gamle fysikk.

4.2.2 Features

In addition to the functionality described as part of the User Interface (UI), three main features of the application will be described. The first two, *snapshot* and *visualization over time* both deals with the generation of the heat map. The third, *customization*, deals with changing the appearance of the heat map, once it has been generated. All three features are controlled from the sidebar, and are depicted in figure 4.8.

Snapshot

The snapshot feature generates a heat map using data from a fixed period of time. An example of this is shown in figure 4.9, where the heat map has been generated using position data from a time period of 10 minutes. Once a snapshot of the heat map has been generated, the user can change the view of the map by dragging and zooming in and out. The heat map will then adapt to the new view, like illustrated in figure 4.9, always using the same data.

If any of the controls in the sidebar, described above, are changed, like changing

(a) Heat map zoomed out   **(b)** Heat map zoomed further in

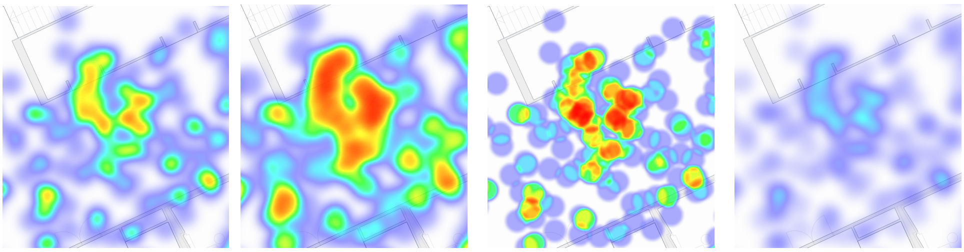
Figure 4.9: Heat map at two different zoom levels

the time period or floor, a new snapshot will be generated with new positioning data.

Visualization over Time

The visualization over time feature aims to visualize how the distribution of the crowds changes over time. With this feature, the application uses a "gliding" time period, moving the time period one minute forward in time in rapid succession, once the start button is clicked. This changes the dataset used for the visualization, as the selected start time will increase with short intervals. A new snapshot, as described above, will be generated and displayed on each update. Once the start-button is clicked, the time period therefore moves forward one minute in time, rapidly updating the heat map, until the button is clicked again to stop the visualization. The time period will remain the same throughout the visualization, but the selected start time will be increased with one minute on each update. A new snapshot will be created on every update, visualizing how the distribution of the crowd changes, and thus how the heat map evolves, over time.

By playing snapshots of the heat map in rapid succession, the application aims to visualize how the crowd inside the building moves over time. The user can still control the map during the visualization, by zooming, dragging, and changing floors. It is also possible to change how fast the heat map is updated, between 0.1 seconds, and 2 seconds. Choosing a high visualization speed, like 0.5 seconds, will let the user play through a large time period quickly, and for example visualize how



(a) Default options **(b)** Radius = 20 **(c)** Blur = 5 **(d)** Max = 3

Figure 4.10: Effect on change in heat map options

the crowd moves inside a building throughout an entire day. Another possibility is to see where people tend to move after a lecture or gathering. By centering the map over a lecturing hall and using the visualization over time feature, the user can visualize where the amount of people tend to increase or decrease during and after a lecture or gathering.

Customization

The customization feature lets the users of the application customize the appearance of the heat map by changing its options. These options decide how the heat map is generated, and makes it possible to adapt the heat map to different kinds of data. The possibility to change the value of these options is provided by the heat map plugin, which will be described in section 4.3.3. The options included in the application are *radius*, *blur*, and *max*. Each location point in the heat map is drawn as a circle with blurred edges. *Radius* changes the size of the circle, while *blur* decides how sharp its edges should be. *Max* is described as point intensity, and decides how intense the color of the heat map should be when points are clustered together, relative to how many points are in the given cluster. The default values are 15 for radius, 20 for blur, and 1.5 for max respectively. Figure 4.10 depicts the same area and dataset with different heat map options, where one option have been changed in each figure.

4.3 Technical Design

This section will describe the technical design of the application, to explain what happens "behind the scenes". This will include a short description of the programming language used and the architecture of the application, an overview of the libraries and tools used in the development. The application have been tested using Google Chrome browser.

4.3.1 Programming Language

The application is a web application, written in JavaScript and HyperText Markup Language (HTML). HTML it the standard markup language used to create web pages. It consists of HTML *tags*, that form the building blocks of all web pages. JavaScript is the language of the browser, and is one of the most popular programming languages for web development [Crockford, 2008]. HTML has the ability to embed scripts, written in languages such as JavaScript, that can affect the behavior of a web application. The application developed by the researcher in this project is written purely in JavaScript and HTML.

4.3.2 Application Architecture

The application is structured in a Mode-View-Controller (MVC) pattern. The MVC pattern breaks system functionality into three components: a *model*, containing the data of the application, a *view*, displaying portions of the application and interacts with the user, and the *controller*, which mediates between the model and view [Bass et al., 2012]. The view is a single file (`index.html`) containing the UI of the application, and the controller (`leaflet_controller.js`) is both model and controller. Using AngularJS' two way data binding, changes in the model is instantly reflected in the view and vice versa. Additionally, the controller uses a service (`leaflet_service.js`) to fetch and manipulate the location data. This service handles everything related to fetching and manipulation of the location data to separate the logic of the application. Additionally, the service is responsible to fetch the list of all the building groups on campus upon request from the controller.

4.3.3 Libraries and Tools

Several different tools and libraries were used during the development of the application. Some of these have been essential both to the development of the application, and to the final product, and this section aims to describe these.

Leaflet

Leaflet[1] is an open-source JavaScript library for interactive maps, and is the framework that is used by MazeMap to display maps. As MazeMap is the underlying application powering the maps of the heat map application, Leaflet is an essential part of the application. Leaflet is designed with simplicity, performance and usability in mind, and works across all major desktop and mobile platforms. In addition to creating highly customizable maps, Leaflet comes with a wide range of plugins that enables developers to extend its functionality even further.

[1] `http://www.leafletjs.com`

Leaflet.heat

Leaflet.heat[1] is a Leaflet plugin that enables developers to create a heat map, and add it as a layer to a Leaflet map. This plugin handles everything related to the generation of the heat map. The layer is initialized by providing the plugin with an array consisting of all the locations that should be used to create the heat map. Each location consists of geographic latitude and longitude. The plugin then adds each location point to the layer, clustering points that is close to each other together. When the zoom function on the map is used, the plugin automatically updates the heat map layer to adapt to the new zoom level.

AngularJS

AngularJS[2] is and open-source web application JavaScript framework that extends the standard HTML vocabulary. AngularJS is a MVC framework that synchronizes data between the UI (view) and JavaScript objects (model) through 2-way data binding. By providing *directives* that add functionality to the markup, AngularJS allows developers to create powerful, well structured client-side applications. Using a framework in development can help structure the code so it is modular, readable, and secure, with high performance. AngularJS was used as the underlying framework in the development of the application, and therefore provided services that eased the development of the application.

Bootstrap

Bootstrap[3] is a powerful front-end framework that aims to enable faster, easier, and more consistent web development, with a focus on the UI. It provides developers with HTML and Cascading Style Sheets (CSS)-based design templates as well as optional JavaScript extensions, that makes it easier to develop responsive and consistent web applications. Bootstrap was used as basis for the UI in the application.

MazeMap API

In addition to providing the application with map and floor plans of Gløshaugen campus, MazeMap has an API that have been used as a tool. This API, among other functionality, provides lists of all buildings, rooms, and floors on Gløshaugen, along with a lot of information about each entity. These lists are provided as JavaScript Object Notation (JSON) files by the API, and was used in the application to enable listing and selection of buildings, changing of floors, and search.

[1] `https://github.com/Leaflet/Leaflet.heat`
[2] `http://www.angularjs.org`
[3] `http://www.getbootstrap.com`

getpos & Location Data Server

As described in section 4.1.3, the location data used by the application is stored at a dedicated server at NTNU. To fetch data from this server, a specialized application called *getpos* is needed. getpos is a small application enables its users execute queries to the location server, requesting location data from a given time period. Upon receiving a request from getpos, the server returns a JSON file containing all the location data that is gathered on Gløshaugen campus within the given time frame.

getpos is needed for two reasons. First, as described in section 2.2.3 about the gathering of location data, the data gathered on this server is potentially sensitive, as it enables the possibility of tracking specific devices. Two-way certificate checking is used to ensure that only certified applications can fetch the data. getpos holds a valid certificate, and is therefore able to fetch data from the server. Secondly, all the coordinates that is stored on the server is stored in its own local system of coordinates, and conversion between these coordinates and GPS coordinates happens at the client side. getpos handles this conversion.

getpos and the location data server have been essential tools for the development of the application, as they provide the data that is used by the application.

4.4 Limitations and Future Work with the Application

There are some limitations regarding the application that needs to be discussed, mainly concerned with the underlying positioning data, and how it is retrieved and used. In this section, these shortcomings will be discussed, before the future work remaining on the application as a result of these limitations will be presented.

4.4.1 Dataset Limitations

The issues with the dataset can be parted into two groups: how it is retrieved, and its quality. The first issue is concerned with getpos and the location data server, described in section 4.3.3. As was described in section 4.1.4 about design decisions for the application, it was discovered that getpos was too slow to implement as a part of the application. A limitation with the dataset used by the application is therefore that the retrieval of the data is time-consuming, making it difficult to implement getpos and the location data server into an application. As the development of a better solution for storing and retrieving location data was outside the scope of this project, static data files, retrieved manually by the developer, had to be used instead. How this limits the application will be discussed below, in section 4.4.2.

Second is the quality of the data. In its current state, the accuracy of each location update in the dataset varies. As mentioned in section 4.1.3 about the dataset, one of the properties attached to each location update is an accuracy field. The value of this property determines how accurate the Cisco MSE estimates the triangulated location of the given device to be. Many factors can decrease the accuracy of the triangulation, with the topology, i.e. the location, of the network Access Points (APs) in the environment being the most important. If there are too few APs at a location, the accuracy of the determined location will decrease, as fewer APs can be used for the triangulation. Additionally, anything that obscures the view between the sender and receiver can influence the propagation of electromagnetic waves, and thus degrade the accuracy of the positioning. Independent of what the reason for low accuracy might be, varying accuracy of the location updates limitation with the dataset, as it makes it difficult to assure the quality of the data used in the visualization.

It is also important to note that it is impossible to determine what kind of device each location update comes from, and who owns the device. As everything that is able to connect to the WiFi network is recorded into the dataset, it is possible that one person will be recorded several times. It is for example not uncommon for a student at NTNU to have both a cell phone and a laptop connected to the WiFi network at the same time during a lecture, which implies that the student is counted twice in the dataset.

4.4.2 Limitations with the Application

The use of static data files, instead of dynamically retrieving location data from a server upon request from the user, is the main limitation with the application. As described in section 4.1.4 about design decisions for the application, a static dataset is used for the visualization. This dataset is a subset of the location data stored at the location data server, that contains positioning data from two hours from 13:00 to 15:00 22.10.2014. This implies that the user of the application has to choose a date and hour within the time period in the datafile used, for the visualization to work. If a date or hour outside the range of the datafile is selected, the application does not generate a heat map, as it does not receive any data. These issues is a limitation with the application, as it drastically limits the total time period the user can select from for the visualization.

The reason that the file described above was used instead of a larger file, that would be able to hold a larger time period, is because of limitations in the browser. Tests performed by the researcher showed that if the size of the datafile exceeded 150 to 200 megabytes, the browser was likely to slow down drastically or crash. The datafile currently in use have a size of 122 megabytes.

Even though the use of a static datafile limits the practical use of the prototype, it is important to notice that the functionality of the application is not affected. The only difference for the user between a static and dynamic data source is the total amount of time it is possible to choose from when generating the heat map. Given a larger datafile, or a better solution for retrieving data, the application would be able visualize over a larger time-period.

Performance can also become an issue with the current version of the application. Even though the datafile currently in use is quite small, it is possible that the performance of the application could increase with the use of a dynamic data source. With the current version, the browser needs to process and hold the entire static data source in memory while the application is running, which might affect performance. With a better data source, the allover performance of the application is likely to increase, even though the retrieval of data might increase due to the need of communication with a remote server.

4.4.3 Future Work with the Application

Based on the limitations discussed above, two main areas of future work remains with the application. The areas discussed in this section are mainly concerned with issues that should be solved for the application to work optimally. Potential new features, or how the application can be tailored to fit the needs of a specific stakeholder will not be discussed, as these are both areas that would require more research.

First is the development and implementation of a better solution for storing and retrieving the location data. A server containing data prepared for the application would allow the application to request location data from any time period that is stored on the server, and receive the results quickly. This would allow its users to visualize crowd movements over a much larger period of time, which is deemed to increase the usefulness of the application.

Second is a solution for quality assurance of the location data. In the application, filtering on accuracy is a feature that can be implemented, to filter out devices that is reported to have an inaccurate position. This would enable the application to only use location updates with a certain degree of accuracy in the visualization. Better quality assurance on the collection of the data is outside the scope of this project, but is also something that is deemed to increase the quality of the used dataset.

Chapter 5

Problem Elaboration

An important part of this research project have been to identify potential stakeholders, and scenarios where these stakeholders might be able to benefit from the use of indoor positioning data. Four main groups of potential stakeholders have been identified, each containing several specific stakeholders and scenarios describing how they are deemed to be able to utilize the positioning data. This chapter aims to provide a detailed problem elaboration, through the identification of potential stakeholders and ways they might be able to benefit from the positioning data. First, an overview of important meetings held during the project will be given, to describe the background for the identification of stakeholders. Then the four groups of stakeholders will be described, before the stakeholder groups selected for evaluation is presented.

5.1 Meetings

The goal of meetings stakeholders relevant to the concept have changed along with the status of project. In the early phases, before the development of the application could begin, meetings were mainly used to help identify problem areas and motivation for the project. These meetings, in combination with the literature review, played an important role in building a foundation for the project. Once the application was ready for demonstration, meetings were used to get feedback on the application and concept, as well as identifying possible users for the application. The goal of these meetings was to create a foundation that could be used to identify and contact users that could be used to evaluate the concept according to the research questions. In this section, the most important meetings held throughout the project will be described.

5.1.1 Foundation

Early talks with Jan Sverre Rønning from the Student and Academic Division at NTNU showed that there was a keen interest at NTNU for a solution utilizing indoor positioning data. Jan Sverre Rønning, among other things, is responsible for the coordination of use of shared classrooms, and for coordinating timetables for lecturing and examinations. He has an interest in the use of common areas and lecturing halls, and have been in contact with both Trådløse Trondheim and researchers at NTNU before regarding the use of indoor positioning data. It was at this meeting that the idea of using a heat map to visualize the movement of crowds first came up.

A similar meeting was held with Trådløse Trondheim, in trying to identify more concrete problem areas for the project, and to understand the technical possibilities and limitations of the data. In addition to providing important background information on the problem areas, these early meetings played an important role in creating motivation for the project. Even though similar projects from NTNU had shown that there was an interest of utilizing indoor positioning data, talking with potential stakeholders was important to ensure the interest in the topic.

5.1.2 Application Feedback

Once a prototype of the application was ready, demonstrations was held for potential stakeholders. These meetings provided feedback on the application, that could be used for further development, as well as allowing the researcher to pitch the concept to relevant parties. In demonstrating the application to stakeholders, it was possible for them to see if this was something they had interest in, and thus help the researcher to identify potential users that could possibly be used for evaluation.

At the first meeting, Dirk Ahlers and Åsmund Tokheim, as well as John Krogstie, the supervisor for the project, was present. Dirk Ahlers is a research scientist at the Department of Computer and Information Science at NTNU with an interest in the use of positioning data, and Åsmund Tokheim is a systems developer at MazeMap. At a second meeting, Jan Sverre Rønning, Åsmund Tokheim, Thomas Jelle, and John Krogstie was present. Thomas Jelle is CEO at MazeMap and Wireless Trondheim. As all of these either works with, or has a specific interest in the topic of indoor positioning data, and thus were regarded as stakeholders for the project. They were able to provide important feedback on the functionality of the application, and information on stakeholders that could potentially be used for evaluation.

5.1.3 Usage Scenarios

In a separate meeting with Morten Hatling from SINTEF and John Krogstie, a discussion of possible usage scenarios for the application was conducted. Morten Hatling is a senior scientist at SINTEF, and, among other things, project leader of "K2 - Workplace of the Future". The K2 project is described in section 2.3.4, along with the PAW project where Morten was one of the customer representatives. PAW is similar to this project in that it visualizes indoor positioning data, and Morten was therefore a stakeholder.

The goal of this meeting was to get a more concrete understanding of possible usage scenarios for the application, that at a later point could be used for evaluation. As Morten Hatling has extensive experience in the field of indoor positioning data, he was able to shed light on both possible users, and how they could be able to benefit from the application. This meeting laid the groundworks for the identification of possible users for the application and concrete suggestions for usage scenarios. These will be described in section 5.2. Many of the initial thoughts and ideas for the application, regarding how it could be used who could benefit from it, was confirmed in this meeting, and enabled the project to move forward. Morten Hatling also were able to provide contact information to several potential users that were used for evaluation at a later point, which proved invaluable to the evaluation process.

5.2 Stakeholders

Based on the data collected through the meetings described in section 5.1 above, four main groups of potential stakeholders were identified. Each group consists of specific types stakeholders that is deemed to be able to benefit from the utilization of indoor positioning data, and was grouped together based on their field of work. The usage scenarios described along with each group in this section is based on theories on how each group is deemed to be able to benefit from the utilization of the data. These theories was used as a basis for selecting potential stakeholders that could be used for the evaluation of the application.

A common feature for all four groups is that they are connected to the field of facility management. A definition of facility management is that it is "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology" [Cotts et al., 2009]. Kincaid [1994] claims that facility management emerged from the combination of three different activities, namely property management, property operations and maintenance, and office administration. Activities such as the coordination and administration of space, infrastructure, people, and construction are all part of the field of facility management. The four main groups of potential stakeholders are all involved with these activities, which is the main reason why they were deemed to possibly be able to benefit from the utilization of indoor positioning data.

5.2.1 Organizational Leadership

This group can be parted into two subgroups, depending on the goal of using the positioning data. Common for both subgroups is that the potential users of the positioning data, and thus the application, is working in the management of an organization.

Administration and Coordination of Space

This subgroup consists of potential stakeholders that is concerned with the administration and coordination of space. As described in section 2.4.2 about space utilization, management of spatial resources is a difficult and time-consuming task. This subgroup of potential stakeholders is deemed to be able to utilize the positioning data to optimize the administration and coordination of spatial resources, by gaining knowledge about how their environment is used. Monitoring how their buildings is used in practice can help management in an organization to better manage the spatial resources that is available. An example of a stakeholder within this group, that was discussed during the meetings described in section 5.1, is universities and other educational institutions. Such organizations often have large areas with hundreds or thousands of rooms to manage, which can be a difficult and time-consuming task. Live and historic data on crowd movements and building occupancy is expected to be a valuable resource for such a stakeholder.

Operational Management

Common for all leadership in organizations is the goal of creating the best possible work environment, both socially and professionally. This group consists of stakeholders that is concerned with analysis and improvement of workplace processes. The positioning data can be used to monitor the work environment, and identify trends and patterns, which can be utilized by this group of stakeholders to gain knowledge about their employees use of the environment. Identification of which groups in the workplace usually meet physically during the day, and which common areas is the most popular among the employees, are examples of areas where the positioning data can help the leadership gain knowledge. Such information is deemed to be usable to improve the work environment based on data from the movements of the employees.

Potential usage scenarios also encompasses visualizing effects on change in the work environment, to see how large changes, such as transition from closed offices to open plan, or smaller changes such as a new coffee machine in the common area, affects the movements of the employees. All this information could again be coupled with data from other parts of the organization, such as production or revenue, to see how changes affects the organization in general. Observations and knowledge of the movement of the crowds can then be supported by experience data from other areas of the organization to help future decision making. The meeting with Morten Hatling supported the assumptions that this was something that could be relevant for organizational management.

5.2.2 Construction, Architecture, and Real Estate

This group consists of companies that need or benefit from acquiring as much information about the use of the buildings they manage as possible. Construction and architecture companies should be able to utilize data on how the buildings they have constructed is used in practice in many different ways. They both have models and theories on how different techniques and methods they use in the drawing or construction of a building affect its use, but it might be difficult to evaluate how this works in practice. Real historic and live data on the utilization and occupancy of the building can be used to evaluate models and theories to improve the outcome of future projects.

When ordering the construction of a new building complex, an organization will often have clear thoughts and desires on how the new building will be used, with regard to e.g. interdisciplinary cooperation. They want the building to work *for* them, and for it to be tailored for their specific needs. Data on how existing buildings with similar requirements and needs have been used can aid in the construction of the new complex. This type of data can therefore be a valuable source of knowledge that can be used to improve future projects, and to document the success rate of previous projects.

Regarding real estate, data and documentation on how a building have been used in the past can help in acquiring a suitable complex for an organization. Similar as the example mentioned above, an organization that is looking for a new building might have specific needs that must be satisfied in a new building. Data on the use of a given complex can help real estate companies find suitable buildings, and enable them to document how and why this building will be suitable for the organization.

5.2.3 Public Buildings

This group consists of stakeholders managing public buildings, such as shopping centers, museums, large hotels and casinos, and airports. These are all commercial buildings, where the management often strive to acquire as much information about the movement of their visitors as possible, in order to analyze it, and in some cases control it. This is especially true with shopping centers, where the management benefit from controlling the movement of the visitors as much as possible in order to increase the amount of money spent by the visitors. Analysis of the movement of the visitors, and general occupancy in different parts of the building or building complex, can help the management of public buildings better tailor their services to fit the customers. Shopping center and airport management can among other things use it to identify shopping patterns and create informed pricing plans for tenants, while museums and hotels can use it to identify and remove bottlenecks. Movement patterns have previously been identified by methods like following visitors around the complex or from cash register data, but with a system that register the movement of a large amount of the visitors, this can be done automatically.

Similar as with organizational leadership described above, public building owners can use positioning data to observe and analyze the effects of change in the environment. Changes in crowd movement as a result of a new café or restaurant, or changing location of a specific store, can be analyzed together with the revenue of the center to determine the optimal way of organizing the points of interest. The same applies to museums and similar buildings that want to avoid creating bottlenecks, and direct people in a optimal route through the building.

5.2.4 HVAC, Cleaning, and Maintenance

The last group consist of stakeholders concerned with heating and ventilation, maintenance, and cleaning. For maintenance and cleaning, the use of positioning data could be useful to "dynamically" adapt services based on the use of the building. Stakeholders within this group could use the positioning data to monitor crowd movement, and use this to direct the cleaning personnel to the most crowded areas, where it is most likely to be dirty. Regarding maintenance, monitoring the occupancy of a building over time could help predicting where it is most likely that the building will need maintenance next, or create automatic alerts based on its use. HVAC systems could use live location data to automatically adapt the ventilation based on the number of people in different parts of the building.

5.3 Selection

Based on feedback from the meetings held during the third iteration of the application development, and in consultation with the supervisor, two main groups of potential stakeholders were selected for evaluation. As described in section 3.4 about the evaluation, it was desirable to evaluate the application with a limited number of relevant stakeholders, as opposed to a larger number of less relevant sources. The two groups of stakeholders that was deemed to best be able to benefit from the application and indoor positioning data was therefore selected. These were *Organizational Leadership* and *Construction, Architecture, and Real Estate*.

Within the first group, it was decided to focus on stakeholders concerned with the administration and coordination of space, and more specifically, universities. Meetings with Jan Sverre Rønning from Student Academic Division at NTNU had already provided strong indications that management at NTNU was interested in the utilization of the positioning data, and it was therefore decided to reach out to the Property Management Division at NTNU for evaluation. Within the second group, it was decided to focus on construction and architecture companies. Morten Hatling recommended contacting Statsbygg, which he expected to be interested in the concept. He was also able to provide contact information to a representative from Statsbygg Trondheim office. Both stakeholder groups was contacted, and wanted to participate in the evaluation. A more detailed description of each stakeholder group will be given in section 6.1, before the results of the evaluation.

Chapter 6

Evaluation

In this chapter the results from the data analysis of the evaluation interviews will be presented. As described in section 3.6, the data collected through the unstructured interviews and literature review was analyzed and used continuously throughout the project. The main data source for the evaluation of the application and concept was the evaluation interviews, and the aim of this chapter is to present the data resulting from these interviews. It will focus on presenting the data extracted from the analysis process, to give an overview of the data that was collected. What the results of this evaluation means will be presented as a discussion is chapter 7. First, a short description of the two stakeholder groups interviewed will be given. Then, and overview of all the categories that was identified within the data will be described, before the results from the Technology Acceptance Model (TAM) questionnaire is presented.

6.1 Demographics

Two groups of stakeholders was interviewed in the evaluation interviews. Both interviews was conducted on the same day, with one hour between them. In this section, both stakeholder groups interviewed will be shortly described.

The first interview was with the Property Management Division at NTNU. The Property Management Division is responsible for the management, maintenance and development of NTNUs properties, including campus development. They are also responsible for coordinating work related to NTNUs environmental goals. From this division, three representatives were present: two female and one male.

The second interview was with Statsbygg. Statsbygg is the Norwegian government's key advisor in construction and property affairs, building commissioner, property manager and property developer. They provide appropriate, functional premises to public sector enterprises, as well as realizing prevailing sociopolitical objectives in relation to architecture, governmental planning interests, preservation of heritage sites and the environment. From Statsbygg, four representatives was present: one female and three male.

6.2 Categories

As described in the data analysis description in section 3.6.2, the aim of qualitative data analysis is to abstract patterns and information that is relevant to the research being conducted. In this section, the categories and patterns identified through the qualitative data analysis will be presented, in an effort to describe the data collected. All the data collected through the interviews was placed within one of four main categories identified, depending on the nature of that data. The four main categories are: *Data Utilization & Areas of Application*, *Privacy*, *Opinions and Ideas*, and *Demand for Functionality.* These are all very general and broad categories, used to describe the general topic of a part of the data.

6.2.1 Data Utilization & Areas of Application

The first main category from the interviews is *Data Utilization & Areas of Application.* According to the problem definition, the goal of this project is to investigate how collected positioning data can be used to aid facility managers. This was described to the interview subjects before the interviews was conducted, and the topic of how this data can be utilized, and potential areas of application for this type of location data was therefore a recurring topic.

Two main themes can be extracted from the interviews in discussion of how the positioning data is able to aid facility managers. In the following sections, both main themes will be described. First is the topic of how one utilize the application and its data: to gain *overview of area utilization and usage*, or to gain *overview of movement.* This is the two main ways of utilizing the positioning data, both providing a different overview of crowd distribution and movements within a building.

Second is the topic of what the *goal* of utilizing the positioning data is. *Fire and evacuation*, *Knowledge building*, and *Property management* are the three main topics describing specific areas of application, utilizing the application and data to gain knowledge about how a building is used.

Below, both main themes will be described, along with concrete examples from the data collected from the interviews. The following sections within this main category is divided into the two main themes describe above, both containing smaller and more specific topics as subsections. First, an overview of the topics of discussion is given, before the themes are described. Not all topics will be given a separate section, as they often are a part of a larger theme.

Overview

Throughout the interviews, several smaller subcategories and concrete areas of application was identified. In table 6.1, an overview of each of the topics that either occurred repeatedly, or that was discussed in depth, is presented along with the number of times they occurred separately in each interview. A topic was considered to occur separately if it was brought up by one of the interviewees when that topic was not already in discussion. These are not necessarily areas of application, but rather topics of discussion found in the interviews.

Looking at the table, one can identify both diversities and similarities in interest from the two actors interviewed. While NTNU Property Management Division appears to have most interest in how the use of the positioning data can aid them with regard to fire and evacuation situations, Statsbygg have a larger focus on improving the efficiency of building usage and knowledge building. At the same time, half of the topics was discussed at least once in each interview. Many of the topics was also often discussed interchangeably, and is therefore sometimes connected. Identification of movement patterns that can be used in fire protection is one example of this.

Topic	**NTNU**	**Statsbygg**
Fire and evacuation	4	0
Improving efficiency of building usage	0	4
Indoor traffic arteries	2	0
Knowledge Building	0	2
Movement patterns	4	1
Observe change in building use over time	0	1
Observe effect of change in environment	0	2
Overview of building use	2	2
Planning	1	2
Property management	1	4
Replace manual counting	1	2
Use of entrances and exits	3	1

Table 6.1: Overview of the possible areas of application identified in the data collected from the interviews

Utilization of Data

Within the main category of data utilization and areas of application, the first main topic of discussion is how one can utilize the positioning data and the application. Two main themes can be extracted from the interviews within this topic, which both discusses how the positioning data is used: to gain *overview of area utilization and usage*, or to gain *overview of movement*.

Within the theme of *overview of area utilization and usage*, the positioning data is used to identify how a specific area, such as a given room or lecture hall, is used. This can for example be used to identify room utilization (how many people are in a room compared to its capacity), or at what times a room usually is in use. Within the theme of *overview of movement*, the positioning data is used to see how people move inside a building, such as identifying movement patterns and indoor traffic arteries.

Overview of Area Utilization and Usage Using the positioning data as a replacement for manually counting the number of people in a room at a given time was mentioned several times as something that would be useful. Projects where manual counting of people was used to identify occupancy was mentioned both in the evaluation interviews, as well as in previous data collection. PAW, described in section 2.3.4 is one example of this. Additionally, the ability to gather and analyze data from a given area over time is seen as a unique opportunity to identify how a given area is used in practice. Knowledge about how spatial resources is used is considered valuable information, and something that is currently in demand.

Overview of Movement This way of utilizing the positioning data is focused on analyzing how people move indoors. Many different areas of application was identified within this category, all building on the identification of movement patterns. By visualizing not just where, but *how* people move inside a building, one is able to gain valuable knowledge about the people occupying the building, as well as the building itself. This knowledge can be used for many different purposes, with fire and evacuation, and identification of popular entrances and exits being discussed repeatedly. Specific usage scenarios for the identification of movement is primarily focused around safety, which will be described further below.

Areas of Application

Many more or less concrete possible areas of application was identified in the data analysis. Below, the three most distinguishable categories within areas of application will be presented, all describing a specific goal of using the positioning data, before a short summary of concrete ways of utilizing the concept is presented in table 6.2.

Fire and Evacuation Fire and evacuation situations, and fire protection, is an possible area of application where the use of indoor positioning data was identified to be able to aid facility managers. NTNU Property Management Division repeatedly discussed this as an area where the positioning data, and a visualization of that data, could be useful. The identification of movement patterns in an escape situation, like a fire drill, can enable the leadership to identify how fast people escape the building, if there are bottlenecks, which exits they use, and generally where people go. A general overview of the number of people in the building can also give a concrete indication on exactly how many people that needs to be evacuated in case of an emergency. Especially the identification of popular entrances and exits was deemed a desirable area of application within this category.

Knowledge Building Knowledge building is a broad category, focusing on creating knowledge about the usage of buildings, that can be used in many different scenarios. Statsbygg especially saw an opportunity to use it to improve the efficiency of building use. Having an overview of the spatial distribution of people in a building enables one to see where people are located, and, more importantly, where they are *not*. Identifying areas that have very little or no usage can help facility managers to determine excess areas that can be repurposed, and thus be used more efficiently and intensively.

Similarly, mapping of popular areas and general building use can be used to estimate and/or observe the effects of change in the building. Knowledge about the regular use of a popular part of a building on a university can help estimate how many people will have to find new places to work if a wing is closed for reconstruction, and if the rest of the building is able to handle the extra pressure. Upon performing the reconstruction it is possible to observe the effects it has on the people using the building, as well as the rest of the area. The same observations can be made with smaller changes, such as adding a new meeting room, or a new kiosk. Observing how the use of a building changes over time is also mentioned as a possible area of application.

All of this information can be used to create knowledge that can be used for other purposes, as well as directly through such activities as estimation and observation. By storing information on how a building is used over time, analysis is deemed to be able to aid facility managers making decisions. Three concrete examples is mentioned in the interviews. First, data on the use of a building can help actors such as Statsbygg to decide what they build more of, and what they build less of. Areas that prove to have a low usage rate might be changed when constructing a new building, or reconstructing an old one. Second, coupled and analyzed together with data on the production happening within the building, the positioning data could contribute to create valuable knowledge about the production and output of a building. Third, it could be used for planning of timetables and events, such as timetables on universities, or agendas on courses and seminars. In all of these examples, the use of the positioning data was discussed in a context where it was part of a "bigger picture", and thus helped contribute to existing and ongoing processes.

Property Management The last category considers general property management, and includes cleaning, maintenance, and Heating, ventilating, and air conditioning (HVAC) systems. Regarding cleaning and maintenance, the system was deemed to be able to help administration see exactly which areas of a building that was most used, which could be used to create cleaning and maintenance plans. These scenarios considers areas of application regarding gaining overview of building use, identification of popular entrances and exits, and indoor traffic arteries, that can be used for planning.

Regarding HVAC systems, the positioning data could be used to regulate the system depending on the occupation in the building, and thus saving energy by running the system to a minimum in areas with low occupancy. Including the system as a module in a larger facility management system was also deemed very desirable, as data on occupancy is an important part of property management.

Summary Many different ways of utilizing the application and its data was identified, with Fire and Evacuation, Knowledge Building, and Property Management being the three most distinguished categories. These categories describe a goal the stakeholder groups had for using the application, and is therefore necessarily directly areas of application. Each of these goal therefore utilize the concept in one way or another, utilizing one or more concrete areas of application possible with the positioning data. In table 6.2, a summary of the concrete possible areas of application identified in the data collected form the interviews is presented, in an effort to summarize the the ways the application and its data could be able to aid facility managers.

Area of Application	Description
Cleaning, maintenance and HVAC systems (property management)	Use data from the system in planning planning and performing cleaning and maintenance, and in operating a HVAC system.
Estimate effects of change	Use knowledge about the usage of an area to estimate the effects a change on it will have on the people using it and on the rest of the building(s), regarding both occupancy and movement.
Fire protection and evacuation	Use knowledge about the use of a building in fire protection, and data from an evacuation situation to improve safety.
Identify movement patterns	Identify patterns and gain general knowledge about how people move indoors, such as indoor traffic arteries.
Identify popular entrances and exits	Identify which entrances and exits people most commonly use.
Improving efficiency of building usage	Identify areas where an area can be used differently to improve its intensity and efficiency.
Knowledge building	Use the positioning data to create useful knowledge that can be used in long and short term decision making and planning.
Observe change in building use over time	Observe how the building usage changes over time.
Observe effects of change	Observe how changes in an area affects the people using it and on the rest of the building(s), regarding both occupancy and movement.
Overview of building use	Gain general knowledge about how a specific area or building is used in practice
Planning	Use the application and the positioning data for planning.
Replace manual counting	Automatic registration of number of people in a room can eliminate the need to manually count.

Table 6.2: Summary of possible areas of application for the positioning data or application

6.2.2 Privacy

Privacy issues and surveillance is a recurring topic in the interviews, and questions if the collection and use of the positioning data is legal occur in both interviews. As described in section 2.2.3 about data collection and privacy, the positioning data collected at NTNU is anonymized, and it is therefore not possible to follow a selected person for more than 24 hours. Additionally, it is impossible to know who it is that you are following from the application, and the module performing the anonymization is approved by The Data Protection Authority of Norway. Upon being explained this, the interviewees seems reassured that the use of the data is legal. Questions regarding the use of this kind of data is ethical or not was not asked directly, but a certain concern can be detected. The topic of privacy and privacy protection is therefore an important issue in both interviews, and something that the stakeholders care about.

6.2.3 Opinions and Ideas

Several more or less concrete opinions and ideas regarding the application and concept was expressed during the interviews. The information in this section deal with the future potential of the concept, often with special regard to how it can and/or must be changed for the stakeholders to be able to utilize it.

Need of Data File

The prototype application developed for the evaluation focuses on the visualization of indoor positioning data, to provide an example of how this data can be used. While the application performed its job at a satisfactory level, the need for the stakeholders to be able to extract the data used in the application is a recurring topic. While the visualization itself might be able to provide new knowledge about the usage of buildings, both stakeholder groups express the need for them to also be able to extract the underlying data, at a format that can be imported to other applications. This would allow them to perform better and automatic analysis on it, opening up for a wider range of usage areas. Rather than using the prototype application itself to analyze the positioning data, it was expressed a desire to use existing tools to automatically analyze the positioning data, and then use the application to visualize the discoveries made through this analysis process.

Better Data and Quality Assurance

As described in section 4.4 about the underlying data used by the application, several known limitations and weaknesses exists within the positioning data. While both stakeholder groups understood and accepted the effects of these drawbacks, a recurring topic was the need to assure the quality of the positioning data to determine exactly what its drawbacks were, and how it affected the data. Assessing the quality of the positioning data was deemed to allow the stakeholders to use the data despite low quality in some areas, as this would determine on what areas it is adequate, and in what areas it needs improvement. Testing the positioning data by manually counting the number of people in a room at given times, and then compare this to the numbers reported in the data to see how it differed, could help them assess the quality of the data. In summary, the stakeholders expressed the need to assure the quality of the positioning data, to "see what it's good for", before it could be used in production.

For the stakeholders to be able to properly utilize the positioning data, it was also deemed that it would need to be stored over a large period of time. Seeing snapshots of moments or short animations can be useful, but for them to be able to create knowledge by using the positioning data they would need to be able analyze the data over a large time period.

Future Potential

Given the functionality and adaption mentioned above, in addition to tailoring of the application to fit specific needs and usage areas, both stakeholder groups expressed that they saw a large future potential for the use of indoor positioning data. This way of utilizing the positioning data was met with excitement, and it was expressed that the positioning data would possibly be able to aid both the two stakeholder groups interviewed directly, in addition to many other potential actors.

6.2.4 Demand for Functionality

Two specific demands for functionality were identified in the interviews, that does not already exist in the positioning data or application. Both of these were mentioned several times throughout the interviews, and is deemed to increase the usefulness of the positioning data.

Data Connected to a Given Room For the users to be able to properly identify the usage of a given room, each element in the positioning data set would need to be connected to the room it is located on. As described in section 4.1.3 about the positioning data, each location update is currently placed on the map of a building using longitude latitude positions. It is therefore difficult to provide statistics for a given room only, as a data element only "belongs" to a building and floor. Based on this desire, the positioning data would need to be extended so that each element is connected to a room, the same way it is connected to a floor or building in the current data set. This would allow an application utilizing the positioning data provide its users the ability to search for a specific room, and use only location updates from that room in visualization and analysis.

Use of Entrances and Exits In the current data set, it is very difficult to properly identify which entrances and exits of a building or area people use. The ability to identify the most popular entrances and exits used was deemed to be a very useful feature in several different scenarios, including fire and evacuation especially.

6.3 Technology Acceptance Model Questionnaire

In this section, the results from the Technology Acceptance Model (TAM) questionnaire will be presented. As described in section 3.5.2 about TAM, the model was used as a basis to know what to look for in the interviews, and therefore not utilized completely. The focus of the data collection was to assess the perceived usefulness of the application and concept, and not necessarily the potential users behavioral intention to use the system. As the interviewees were unable to test the application themselves, and that the focus of the data collection was only to assess the perceived usefulness of the application, the six last questions regarding perceived ease of use was made optional. The result of this was that only a few responses on the usability of the application was recorded, and was therefore omitted from the data analysis.

A total of seven form were filled out, all answering on the six first questions regarding perceived usefulness of the system. These questions is presented again in table 6.3. Each question is answered by ticking one option on a scale from one to seven, with one being unlikely and seven being likely.

No.	Question
1	Using the system in my job would enable me to accomplish tasks more quickly.
2	Using the system would improve my job performance.
3	Using the system in my job would increase my productivity.
4	Using the system would enhance my effectiveness on the job.
5	Using the system would make it easier to do my job.
6	I would find the system useful in my job.

Table 6.3: Scale items for Perceived Usefulness

In table 6.4, the frequency table from the TAM questionnaire measuring perceived usefulness is presented, with the responses from both stakeholder groups is gathered in one table. The first thing to notice is that the respondents did not use the entire scale. Apart from question 1 and 2, all responses range from score 4 to 7. Question 2 and 3 have the lowest scores, with a mean of 4.4 and 4.9, respectively. The remaining four questions all have a mean above 5, with question 6 having a mean of 6.6.

	1		2		3		4		5		6		7	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
pu1	0	0	0	0	1	14.2	0	0	1	14.2	5	71.4	0	0
pu2	1	14.2	0	0	1	14.2	0	0	2	28.6	3	42.9	0	0
pu3	0	0	0	0	0	0	2	28.6	4	57.1	1	14.2	0	0
pu4	0	0	0	0	0	0	2	28.6	2	28.6	3	42.9	0	0
pu5	0	0	0	0	0	0	0	0	3	42.9	2	28.6	2	28.6
pu6	0	0	0	0	0	0	0	0	0	0	3	42.9	4	57.1

Table 6.4: Frequency table showing responses from Statsbygg and NTNU Property Management Division on items measuring perceived usefulness.

Chapter 7

Discussion

This research has investigated the use of indoor positioning data. Two research questions has guided the research, focusing on investigating how indoor positioning data can be utilized to aid building managers, and who that can benefit from the use of such data. The use of a qualitative research approach allowed the research to explore the feelings, opinions, and experiences that actual facility managers had regarding the utilization of indoor positioning data. This has allowed the research to provide data that can be used to answer both research questions, and thus achieve the goal of the research. In this chapter, the research and its results will be discussed, using the data collected and analyzed throughout the project.

7.1 Beneficiaries of Utilization of Indoor Positioning Data

The first research question addresses the issue of *who can benefit from the use of indoor positioning data*. The term "facility manager" is a vague term, and the desired results of this research question was therefore twofold: (1) to identify stakeholders that could be used for data collection and evaluation of the application, and (2) to provide data that can be used in future research, by identifying general groups of stakeholders that hold an interest in the topic of indoor positioning data. To provide useful data that can be used in future research projects, it was not desirable to name list of specific stakeholders, such as particular companies, that could be used for data collection, but rather identifying *groups* of stakeholders that is deemed to be able to utilize the data.

A large number of potential stakeholders was identified through the literature review and unstructured interviews executed in the first part of the project. As described in chapter 2, the data have already been utilized at a large number of locations, with hospitals, universities, and public buildings like shopping malls and museums leading the way. During the evaluation interviews, both actors stated that the utilization of the data held a large potential, and that they deemed it to be something that a lot of different organizations and companies would be interested in. Several companies with similar responsibilities as Statsbygg was mentioned, in addition to other departments within NTNU. Additionally, both actors stated their own interest, confirming that the utilization of such data was something they imagined they would be able to benefit from.

In chapter 5, four main groups of potential stakeholders is presented, all revolving around the topic of facility and property management. As will be described further in the discussion of the second research question, many of the ways a facility manager can benefit from the utilization of indoor positioning data revolves around gaining knowledge about how their buildings and environments are used. facility managers that would find such knowledge valuable should therefore be able to benefit from the utilization of indoor positioning data. The four groups of potential beneficiaries described in chapter 5 was initially based on theories drawn from the data collected from the literature and unstructured interviews and meetings held during the first part of the project. Combining this data with the data collected from the evaluation interviews allowed these groups to refined and adapted, providing an overview of types of organizations and companies that might be able to benefit from the utilization of indoor positioning data.

7.2 Utilization of Indoor Positioning Data to Aid Facility Managers

The second research question seeks to investigate *how indoor positioning data can be utilized in order to aid facility managers.* Looking at the data collected through this research project as a whole, it is clear that the facility managers are interested in the use of indoor positioning data.

The results from the evaluation interviews shows that both stakeholder groups were able to imagine usage scenarios for the utilization of the data, as well as concrete areas of application. In order to answer the question of how indoor positioning data can be utilized to aid facility managers, one have elaborate on what areas a given facility manager needs *aid*. Looking at table 6.1, one can identify both similarities and diversities in the interests of the two stakeholder groups interviewed. While NTNU Property Management Division appears to have most interest in how the use of the data can aid them with regard to fire and evacuation situations, Statsbygg have a larger focus on using it to improve the efficiency of building usage and for knowledge building. These areas of interest determines the area where the facility manager would like the data to aid them, and thus the *goal* of using the data. How the utilization of indoor positioning data is able to aid a facility manager can therefore seem to depend largely on the facility manager, and in what areas they would like to improve.

While the goals of using the data for these two actors therefore is quite different, it is important to notice that many of the same concrete areas of application was mentioned in both interviews. For NTNU Property Management Division, the identification of movement patterns to use in fire protection, emergency situations, and evacuation seems to be the most interesting way of utilizing the data. Statsbygg also shows an interest in the identification of movement patterns, but want to use it to create new knowledge about how the building is used, which can be stored and used in decision making regarding construction and reconstruction of buildings. While the *goal* of utilizing the data therefore proves to change depending on the facility manager, many of the same areas of application for the data is mentioned.

Looking at the data collected in the background study, presented in chapter 2, one can see the same pattern. A wide range of areas and scenarios where Indoor Positioning Systems have been put to use was identified, with many different purposes and goals. The main focus in the research literature seems to be on utilizing the systems in a hospital and emergency care environment. Many different systems can be identified, being used to track both human and equipment directly, as well as utilizing the data to monitor and improve human processes. One paper specifically stated that one of the most promising areas of potential for IPSs is its ability to unobtrusively gather large amounts of data from its environment, which can make it easier to observe and evaluate existing and ongoing processes. Other research reports claim that systems have successfully been implemented in hospitals, and that it helps improve the care it provides to its patients. Commercial systems is also being implemented at an increasing number of locations, providing services to visitors, as well as information and services to managers. Identification of shopping patterns and context aware advertising is among the potential usage areas being mentioned.

In this thesis, many different areas of application have been identified, outlining possible ways the utilization of indoor positioning data can able to aid facility managers. Even though the *goal* of utilizing the data vary depending on the organization using it, a common underlying theme is that it can be used to create knowledge, that again can be used for a wide range of different purposes. Fire preparation and evacuation, improving efficiency of building usage, and property management were recurring topics where the facility managers interviewed deemed the data to be able to aid them. In the literature, human process improvement, tracking of people and equipment, and contextual aware mobile applications is mentioned repeatedly as areas where the data can be utilized. Even though it therefore is difficult to provide a clear answer to how the data can be utilized to aid facility managers, this research leaves no doubt that it should be able to aid them if used correctly.

7.3 Implications

This research have investigated how collected indoor positioning data can be used to aid building managers, as well as who might benefit from the utilization of such data. In this section, the implications these results have for the research field and future projects will be discussed.

7.3.1 Perceived Usefulness

The problem definition for this project states that the evaluation of the prototype application should determine if this way of utilizing positioning data is able to aid facility managers, and thus if the concept of visualizing crowd movement has potential for relevant stakeholders. This research leaves no doubt that there is an interest in the utilization of indoor positioning data, and that visualization of crowd movement is something that facility managers find interesting. Looking at the results from the evaluation interviews, including the results from the TAM questionnaire, the perceived usefulness the stakeholders have for the data is high.

During the evaluation interviews, most of the focus was put on the underlying data, and how it could aid the interviewees, and not just the application itself. The application generates a heat map from the data, and uses this to visualize crowd movements and building occupancy. Even though this was seen as useful and functionality that could aid the facility managers, the need for a file containing the underlying data was recognized and discussed in both interviews. Even though the application itself to some extent would be able to aid the facility managers directly, by providing a visualization of crowd movements within a building, the high usefulness expressed by the interviewees was mostly based on the future potential of the data. To harvest this future potential, a specialized application focusing on the needs of a specific facility manager would have to be developed. While the application in its current early state therefore would have to be further developed to be able to properly aid a facility manager, it still performed its job of visualizing crowd movements and sparking a discussion about the usefulness of the data very well, and as intended. By evaluating the application, the researcher was able to determine that the stakeholder groups interviewed had a high perceived usefulness of the positioning data and the way the application is utilizing it. This is also supported by the results from the Technology Acceptance Model (TAM) questionnaire, where the mean score of question 6 ("I would find the system useful in my job") was 6.6 out of 7 possible.

7.3.2 Potential Stakeholders

Some of the potential utilization of indoor positioning data has, depends on the number of actors interested in it. In addition to being something the two stakeholder groups interviewed had a clear interest in, this research indicates that a long list of potential stakeholders would be able to benefit from the utilization of the data. This only increases the potential of the data, as it is something that might be able to aid more than a few specific stakeholders.

The results contributes by providing a list of areas and organizations where the data might be able to aid, that can be used in future research projects. Upon demonstrating the application in the evaluation interviews, a certain "wow factor" could be detected, as both actors was unaware, and clearly surprised, by the possibilities held by the positioning data. This can indicate that the data still holds unknown potential, as possible beneficiaries might be unaware of the services it can provide them. The resulting list of potential stakeholders presented in this research can therefore be used to reach out to actors that is deemed to be able to benefit from the utilization of the data, to present the concept to them. This can be used in both research projects and commercial products to tailor a solution for specific actors.

7.3.3 Future Work

The results from this research maps many possible areas of application for indoor positioning data according to the needs of relevant facility managers, and outlines potential stakeholders that is deemed to hold an interest in the utilization of such data. This not only assures the interest relevant stakeholders have in the area of indoor positioning data, but provides a starting point for future work and research. The goal of this study was to investigate how collected positioning data could be used to aid facility managers. One of the results of this goal is a broad and general list of possible areas of application that the two stakeholder groups interviewed helped generate. Even though the list needs refinement and tailoring towards specific users, it can be used as a starting point for future work.

7.4 Limitations

There are some limitations with this study, regarding the execution of the study itself, as well as the results following from the research. In this section, the limitations with this study will be discussed.

7.4.1 Limitations with Qualitative Research

Some general issues with qualitative research needs to be discussed in relation to limitations with this study. The lack of well formulated methods of data analysis is a known problem with qualitative research. Miles and Huberman [1994] recognize this as one of the biggest difficulties with qualitative data analysis, as it is difficult to determine the reliability and validity of the resulting data. Where quantitative data analysis can rely on well-established mathematical and statistical procedures, qualitative data analysis is a less straightforward task. Following from this, research results rely more on the views and skill of the researcher than with quantitative research [Oates, 2006c], and there is a distinct possibility of research bias [Miles et al., 2013].

These are areas where qualitative research receives criticism, and it is therefore an important issue to discuss in a discussion of the possible limitations of this study. To avoid the most common pitfalls, and in an effort to ensure the validity and reliability of the results, an effort was made to provide transparency into the entire research process and its results, to allow the reader to follow the process. It is still important to acknowledge that the researcher has little experience in conducting research, and that this is a possible limitation with this study.

7.4.2 Data Collection

Regarding the results, the biggest limitation is the low number of interviewees. Four main groups of potential stakeholders was identified earlier in the research, and to ensure the validity of these groups, at least one facility manager from each group should have been interviewed. Due to limited time available for data collection, however, only stakeholders from the two most promising groups was selected and contacted. Interviewing more facility managers would have provided more data, and would have increased the reliability and validity of the results. Additionally, it would allow the results to rely more heavily on the answers from the TAM questionnaire, as seven responses is too low to properly rely on the results. While it would have been unfeasible to perform in-depth interviews with very large number stakeholders, more interviews could have increased the quality of the results, both regarding the qualitative analysis and TAM questionnaire.

Where possible, one should also go back to the field to collect further data that supports or contradicts the emerging theories and explanations that emerge during analysis. Both facility managers in this research was interviewed on the same day, and it was therefore not possible to analyze one interview before the next was conducted. Given more time, a new round of data collection should therefore have been executed.

7.4.3 Results

The biggest limitation of the results is the possibility of researcher bias. Researcher bias is difficult to avoid, as it is impossible for human being to completely empty their minds of previous experiences and opinions prior to the data collection. In chapter 5, the groups of facility managers that was deemed to be able to benefit from the utilization of indoor positioning data is described, along with how each group was expected to be able to benefit from it. These groups was created prior to the interviews, and therefore possibly something the researcher was expecting, and possibly looking for during the interviews. Even though the interviews and analysis process was conducted in an inductive manner, letting the data "speak" for itself, it is possible that the researcher have affected the results, even though a considerable effort was put into having an open mind.

Another aspect of researcher bias is the effect the researcher has on the actual interviews, and thus the resulting data. In semi-structured interviews, as described in section 3.5.1, the interviewer is supposed to guide the interview by asking pre-defined questions, but at the same time let the interviewees speak their minds. The way the interviewer acts and asks questions can affect the answers given by the interviewees, and is therefore a possible limitation of the results. Additionally, Oates [2006a] recognizes this as limitation of the design science research methodology, as the presence of the researcher when presenting the artifact can affect its acceptance. It might be deemed a success with the researcher present, but once he or she is gone, this might change. These limitations are difficult to avoid and detect, and might affect the results, and it is therefore important to acknowledge their existence.

Lastly, the state of the prototype application can have affected the results. In the current version, the application is bug-free and able to demonstrate the intended functionality without issues. As described in section 4.4, however, there is still remaining work to be done on the application, especially regarding the limited amount of data available to use in the visualization. Even though the application works, a finished version might have been able to demonstrate the utilization of the data better and/or differently, and therefore produced different results from the interviews.

Chapter 8

Conclusion and Future Work

8.1 Conclusion

This research project have used a qualitative research approach to investigate how indoor positioning data can be utilized to aid facility managers. Four groups of potential stakeholders for this type of data was identified through a short literature review and several unstructured interviews with relevant stakeholders. A prototype web application was then developed, and then evaluated through two in-depth interviews with actual facility managers, to evaluate and investigate how indoor positioning data might be able to aid them in their work. The data collected through the evaluation interviews resulted in a detailed description of areas of application where indoor positioning data can be utilized to aid facility managers, as well as concerns, demands, and opinions the stakeholders had concerning the positioning data.

Two research questions has guided the research, focusing on investigating who that can benefit from the use of indoor positioning data, and how such data can be utilized in order to aid facility managers:

RQ1 Who can benefit from the use of indoor positioning data?

RQ2 How can indoor positioning data be utilized in order to aid facility managers?

The results show that there is a clear interest in the utilization of indoor positioning data among facility managers. Four main groups of potential stakeholders was identified during the research, and the relevancy of two of these groups was confirmed in the evaluation interviews. The facility managers interviewed had no problem identifying possible areas of application where indoor positioning data was deemed to be able to aid them, given it being used correctly. These results describes that facility managers within several different sectors might be able to utilize indoor positioning data, and outlines possible areas of application.

8.2 Future Work

The current version of the application developed as part of this research project is an early prototype, and therefore lacks some important functionality. A natural first step for further work would therefore be to finish the application, either following the suggestions made in section 4.4 about the limitations and future work of the application, or by creating new requirements based on the results of this research. Either way, the application should be able to use a larger time-period for the visualization, to enable its users to view historical data.

Some limitations with this research have also been identified, the biggest being the low number of interviewees used for data collection. A larger, and more thorough data collection should therefore be conducted. A future project working towards the same goal as this one would be able to continue investigating how indoor positioning data can aid facility managers, and collect data that strengthen or contradicts the theories and conclusions drawn in this project. Collecting data from a larger number of stakeholders would also allow a researcher to utilize the Technology Acceptance Model better. This model can be used to predict the users behavioral intention to use a system or technology, and help estimate if a system will be accepted by its intended users or not. Using a sufficient number of stakeholders, an appropriate version of TAM could be used to estimate the intention the stakeholders have to use the system.

Another option is to investigate further how one selected group of facility managers can benefit from the data, by investigating how specific facility managers within a given field can utilize it. The results from this research are broad, and research on more specific areas where the positioning data can be utilized can be valuable. The application used in this research project aims to demonstrate one way of utilizing the data, and it is therefore not ready for production. Further research focusing on one selected facility manager would allow the identification of requirements for an application tailored for that facility manager's needs, and enable the development of an application they could use in their daily work.

Bibliography

Amini, M., Otondo, R. F., Janz, B. D., and Pitts, M. G. (2009). Simulation Modeling and Analysis: A Collateral Application and Exposition of RFID Technology. *Production and Operations Management*, 16(5):586–598.

Andreassen, E., Blokland, B. V., and Ilebekk Johansen, S. (2013). Pattern Analyser for Workspaces (PAW) - Customer Driven Project. Technical report, Norwegian University of Science and Technology.

Andresen, S. H., Krogstie, J., and Jelle, T. (2007). Lab and Research Activities at Wireless Trondheim. In *2007 4th International Symposium on Wireless Communication Systems*, pages 385–389. IEEE.

Aruba Networks (2014). MERIDIAN MOBILE APP. Available: `http://www.arubanetworks.com/pdf/products/DS_MeridianPlatform.pdf`. [Accessed: 2014-11-07].

Bass, L., Clements, P., and Kazman, R. (2012). *Software Architecture in Practice*. SEI Series in Software Engineering. Pearson Education.

Beestar (2014). Beestar Home. Available: `http://www.beestar.eu/`. [Accessed: 2015-05-14].

Berry, J. K. (1998). Analyzing In-Store Shopping Patterns. *GeoWorld*, pages 30–32.

Beyrouthy, C., Burke, E. K., Landa-Silva, D., McCollum, B., McMullan, P., and Parkes, A. J. (2007). Towards improving the utilization of university teaching space. *Journal of the Operational Research Society*, 60(1):130–143.

Biczok, G., Diez Martinez, S., Jelle, T., and Krogstie, J. (2014). Navigating MazeMap: Indoor human mobility, spatio-logical ties and future potential. In *2014 IEEE International Conference on Pervasive Computing and Communication Workshops, PERCOM WORKSHOPS 2014*, pages 266–271.

Boston Children's Hospital (2014). My Way App — Boston Children's Hospital. Available: `http://www.childrenshospital.org/patient-resources/during-your-visit/my-way-app`. [Accessed: 2014-10-07].

Cisco Systems Inc. (2013). Real-time Traffic over WLAN Roaming. In *Real-Time Traffic over Wireless LAN Solution Reference Network Design Guide*, chapter 1, pages 1–18.

Cotts, D. G., Roper, K. O., and Payant, R. P. (2009). *The Facility Management Handbook*. AMACOM Div American Mgmt Assn.

Crockford, D. (2008). *JavaScript: The Good Parts*. O'Reilly Media, Inc.

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 13:319–340.

Ekahau (2014). The Ekahau Real-Time Location System.

Fallah, N., Apostolopoulos, I., Bekris, K., and Folmer, E. (2012). Indoor human navigation systems: A survey.

Gao, S., Krogstie, J., Thingstad, T., and Tran, H. (2015). A mobile service using anonymous location-based data: finding reading rooms. *International Journal of Information and Learning Technology*, 32(1):32–44.

Gartner (2012). Gartner Highlights Top Consumer Mobile Applications and Services. Available: `http://www.gartner.com/newsroom/id/2194115`. [Accessed: 2015-05-26].

Google (2014). Indoor Maps availability. Available: `https://support.google.com/gmm/answer/1685827?hl=en&topic=1685871&ctx=topic`. [Accessed: 2014-12-04].

Google I/O (2013). Google I/O 2013 - The Next Frontier: Indoor Maps. Available: `https://www.youtube.com/watch?v=oLOUXNEcAJkhttp://www.youtube.com/watch?v=oLOUXNEcAJk`. [Accessed: 2014-12-04].

gps.gov (2014). GPS.gov: GPS Accuracy. Available: `http://www.gps.gov/systems/gps/performance/accuracy/`. [Accessed: 2015-02-25].

Gu, Y., Lo, A., and Niemegeers, I. (2009). A survey of indoor positioning systems for wireless personal networks. *IEEE Communications Surveys and Tutorials*, 11:13–32.

Hevner, A. R., March, S. T., Park, J., and Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, 28:75–105.

Hightower, J. and Borriello, G. (2001). Location Sensing Techniques. *IEEE Computer*, 34(8):57–66.

Kincaid, D. (1994). Integrated Facility Management. *Facilities*, 12:20–23.

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., Behar, J. V., Hern, S. C., Engelmann, W. H., and Others (2001). The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants. *Journal of exposure analysis and environmental epidemiology*, 11(3):231–252.

Lee, S., Kim, M., Kang, S., Lee, K., and Jung, I. (2012). Smart scanning for mobile devices in WLANs. In *2012 IEEE International Conference on Communications (ICC)*, pages 4960–4964. IEEE.

Li, B., Salter, J., Dempster, A., and Rizos, C. (2006). Indoor positioning techniques based on wireless LAN. *... Conference on Wireless ...*, CD-ROM pro:13–16.

Li, N., Calis, G., and Becerik-Gerber, B. (2012). Measuring and monitoring occupancy with an RFID based system for demand-driven HVAC operations. *Automation in Construction*, 24:89–99.

Little, J. and O'Brien, B. (2013). A Technical Review of Cisco's Wi-Fi-Based Location Analytics. (July):1–9.

Liu, H., Darabi, H., Banerjee, P., and Liu, J. (2007). Survey of Wireless Indoor Positioning Techniques and Systems. *IEEE Transactions on Systems, Man and Cybernetics, Part C (Applications and Reviews)*, 37(6):1067–1080.

Martínez Pérez, M., Cabrero-Canosa, M., Vizoso Hermida, J., Carrajo García, L., Llamas Gómez, D., Vázquez González, G., and Martín Herranz, I. (2012). Application of RFID technology in patient tracking and medication traceability in emergency care. *Journal of medical systems*, 36(6):3983–93.

Mashable (2012). Macy's Flagship New York Store Gets Indoor GPS Navigation. Available: `http://mashable.com/2012/11/08/macys-indoor-gps/`. [Accessed: 2014-12-03].

MazeMap (2014). MazeMap.com. Available: `http://mazemap.com/what-it-is`. [Accessed: 2014-10-04].

Mendeley (2014). Network & Discover — Mendeley. Available: `http://www.mendeley.com/features/network-and-discover/`. [Accessed: 2014-09-29].

Mersland, D. J. (2013). Visualisering av Kumulativ Posisjonsdata Over Tid. Technical report, Norwegian University of Science and Technology.

Miles, M. B. and Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Miles, M. B., Huberman, A. M., and Saldaña, J. (2013). *Qualitative data analysis: A methods sourcebook*. SAGE Publications, Incorporated.

Myers, M. D. and Avison, D. (1997). Qualitative research in information systems. *Management Information Systems Quarterly*, 21:241–242.

Noureldin, A., Karamat, T. B., and Georgy, J. (2013). *Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration*. Springer Berlin Heidelberg, Berlin, Heidelberg.

Oates, B. J. (2006a). Design and Creation. In *Researching Information Systems and Computing*, pages 108–125. SAGE Publications.

Oates, B. J. (2006b). Interviews. In *Researching Information Systems and Computing*, pages 186–201. SAGE Publications.

Oates, B. J. (2006c). Qualitative Data Analysis. In *Researching Information Systems and Computing*, pages 266–279. SAGE Publications.

Peffers, K., Tuunanen, T., Gengler, C. E., Rossi, M., Hui, W., Virtanen, V., and Bragge, J. (2006). The Design Science Research Process: A Model for Producing and Presenting Information Systems Research. In *the Proceedings of Design Research in Information Systems and Technology DESRIST'06*, volume 24, pages 83–106.

Peffers, K., Tuunanen, T., Rothenberger, M. a., and Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, 24:45–77.

SINTEF (2012). K2 - Morgendagens Arbeidsplass. Available: `http://www.sintef.no/prosjekter/sintef-teknologi-og-samfunn/2012/K2---Morgendagens-Arbeidsplass/`. [Accessed: 2015-03-09].

Sohn, M. D. (2010). Occupancy-Based Energy Management in Buildings: Final Report to Sponsors. *Lawrence Berkeley National Laboratory*.

Sonitor Technologies (2015). About Sonitor RTLS Technologies. Available: `http://www.sonitor.com/about.html`. [Accessed: 2015-05-26].

Stahl, J. E., Holt, J. K., and Gagliano, N. J. (2009). Understanding performance and behavior of tightly coupled outpatient systems using RFID: initial experience. *Journal of medical systems*, 35(3):291–7.

StartupsFM (2013). 5 pressing educational problems Beestar's Location Intelligence Platform solves. Available: `http://goo.gl/XdrLMF`. [Accessed: 2015-05-14].

TechCrunch (2013). Shopkick Is Now Profitable. Available: `http://goo.gl/Aym61`. [Accessed: 2014-12-09].

Tran, H. T. and Thingstad, T. (2014). A Location-based Mobile Service utilizing Anonymous Indoor User Location Data. Technical report, Norwegian University of Science and Technology.

Turner, D. (2010). Qualitative Interview Design: A Practical Guide for Novice Investigators. *The Qualitative Report*, 15(3):754 – 760.

Vaishnavi, V. K. and Kuechler, B. (2004). Design Research in Information Systems. *MIS Quarterly*, 28:75–105.

Wicks, A. M., Visich, J. K., and Li, S. (2006). Radio frequency identification applications in hospital environments. *Hospital topics*, 84:3–8.

Yao, W., Chu, C. H., and Li, Z. (2012). The adoption and implementation of RFID technologies in healthcare: A literature review. In *Journal of Medical Systems*, volume 36, pages 3507–3525.

Appendices

Appendix A

Technology Acceptance Model Questionnaire

Below is the questionnaire presented to the subjects during the evaluation of the application. The questions is fetched from Davis [1989], and translated into Norwegian.

Technology Acceptance Model - Spørreskjema

		Usannsynlig						Sannsynlig
	Opplevd nytte	1	2	3	4	5	6	7
1	Bruk av systemet i min jobb vil gjøre meg i stand til å utføre oppgaver raskere							
2	Bruk av systemet vil forbedre min ytelse på jobben							
3	Bruk av systemet vil øke min produktivitet på jobben							
4	Bruk av systemet vil øke min effektivitet på jobben							
5	Bruk av systemet gjør det lettere for meg å utføre jobben min							
6	Jeg vil finne systemet nyttig i jobben min							

		Usannsynlig						Sannsynlig
	Opplevd brukervennlighet	1	2	3	4	5	6	7
7	Det vil være lett for meg å lære å bruke systemet							
8	Det vil være lett for meg å få systemet til å gjøre det jeg ønsker							
9	Min interaksjon med systemet vil være tydelig og forståelig							
10	Jeg vil oppleve systemet som fleksibelt å samhandle med							
11	Det vil være lett for meg å bli flink til å bruke systemet							
12	Jeg vil finne systemet enkelt å bruke							

Appendix B

Application Preview

In this appendix, a short preview of the application will be given. This preview is created to provide examples of how the application works, and is meant to supplement the overview given in chapter 4. In this preview, only the heat map will be demonstrated.

This preview is also similar to the one sent to potential stakeholders during the project, in that it provides an overview of the functionality of the heat map in the application. In the preview sent to the stakeholders, a short description of the application was also given.

The screenshots in this preview is taken from two buildings at Gløshaugen campus: Byggtekniske Laboratorier and Realfagsbygget. The screenshots are taken using the snapshot feature, explained in section 4.2.2.

B.1 Byggtekniske Laboratorier

In the example from Byggtekniske Laboratorier, the heat map is generated using data gathered over the course of 10 minutes, from 10:00 to 10:10 Wednesday 22.10.2014. A total of 2044 location updates was registered in Byggtekniske Laboratorier during this period, distributed over three floors. Figures B.1, B.2, and B.3 illustrates the heat map at three different zoom levels, on the first floor of the building. In this illustration, the heat map is generated using 809 location updates.

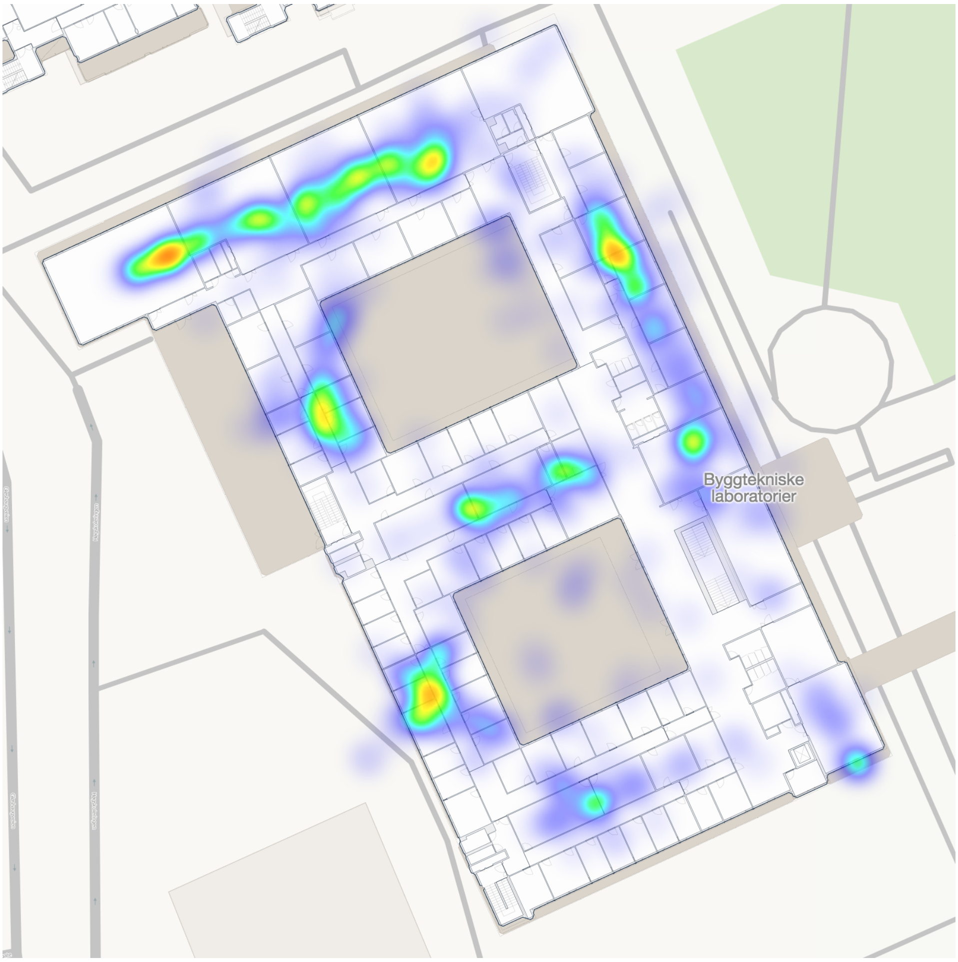


Figure B.1: Overview of the heat map on the first floor of Byggtekniske Laboratorier

Figure B.2: The heat map zoomed in on the first floor of Byggtekniske Laboratorier

Figure B.3: The heat map zoomed further in on the first floor of Byggtekniske Laboratorier

B.2 Realfagsbygget

In the example from Realfagsbygget, the heat map is generated using data gathered over the course of 10 minutes, from three different periods, Wednesday 22.10.2014. The example is taken from first lower floor of Realfagsbygget, and the map is zoomed in on the area surrounding the lecturing halls R1 and R2. Both of these lecturing halls are large, with a capacity of 478 and 269 people, respectively. Outside the lecturing halls, there is a café area, with a small café selling coffee, cookies and snacks. An overview of the area is given in figure B.4.

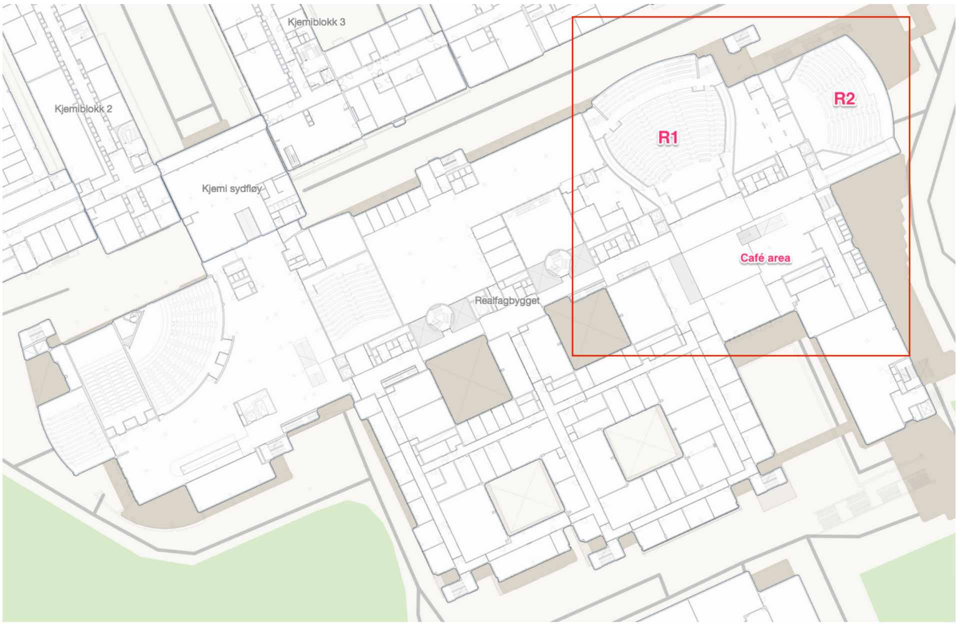


Figure B.4: Overview of the area used in the visualization in Realfagsbygget

The three periods in the visualization are:

- **Period 1 - 13:30 - 13:40:** In this period a total of 9916 location updates is registered in Realfagsbygget, with 2350 of them being in the first lower floor.
- **Period 2 - 13:45 - 13:55:** In this period a total of 9166 location updates is registered in Realfagsbygget, with 1885 of them being in the first lower floor.
- **Period 3 - 14:00 - 14:10** In this period a total of 10135 location updates is registered in Realfagsbygget, with 2128 of them being in the first lower floor.

The heat map indicates that there is an ongoing lecture in both R1 and R2 during Period 1, as a large gathering of people is present in both rooms. Comparing Period 1 and Period 2, the heat map indicates that the lecture in R1 finished around 13:40, as most of the people previously located in the room has moved. The heat map also gives indications that more people is located in the café area in Period 2 than in Period 1. Looking at Period 3, one can see a drastic increase in the amount of people located in the café area, compared to the two other periods. Lectures at NTNU usually lasts 45 minutes, from 15 minutes past an hour. This means that the visualization in Period 3 created using location data captured during a break, which can explain the increased pressure at the café area. Figure B.5, B.6, and B.7 illustrates the visualization from each period.

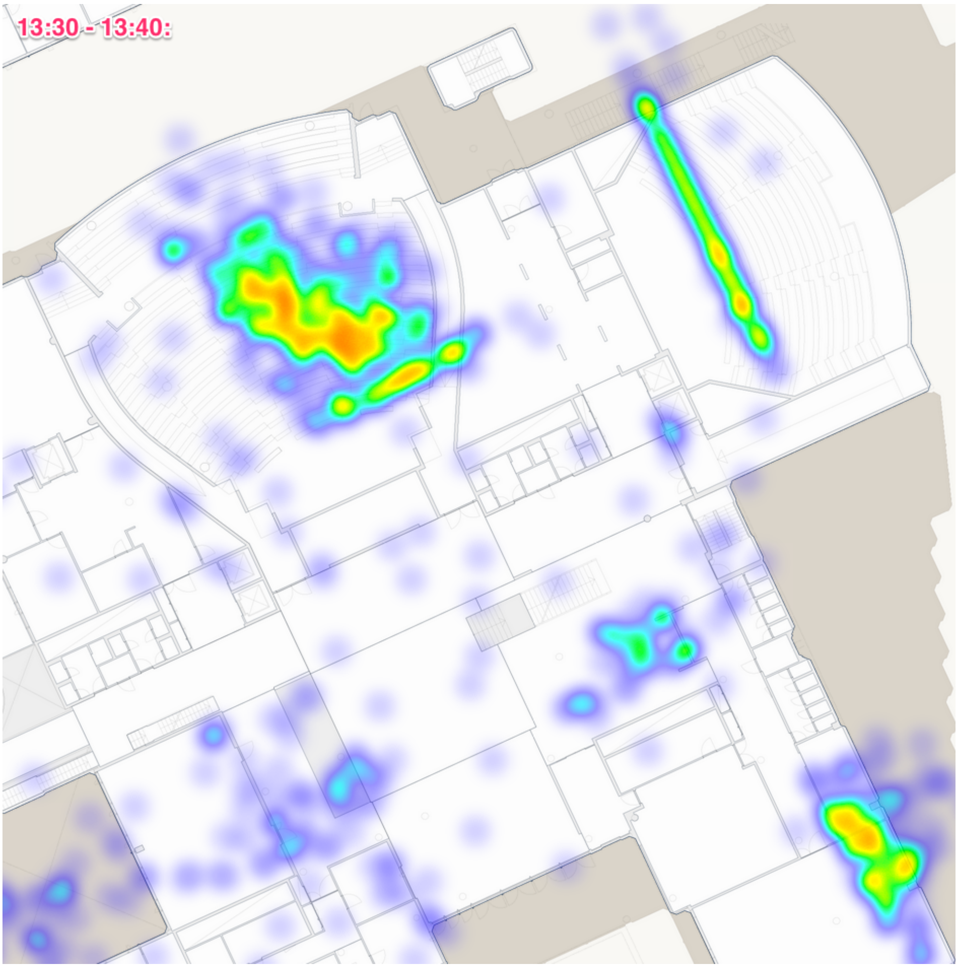


Figure B.5: Visualization from Period 1

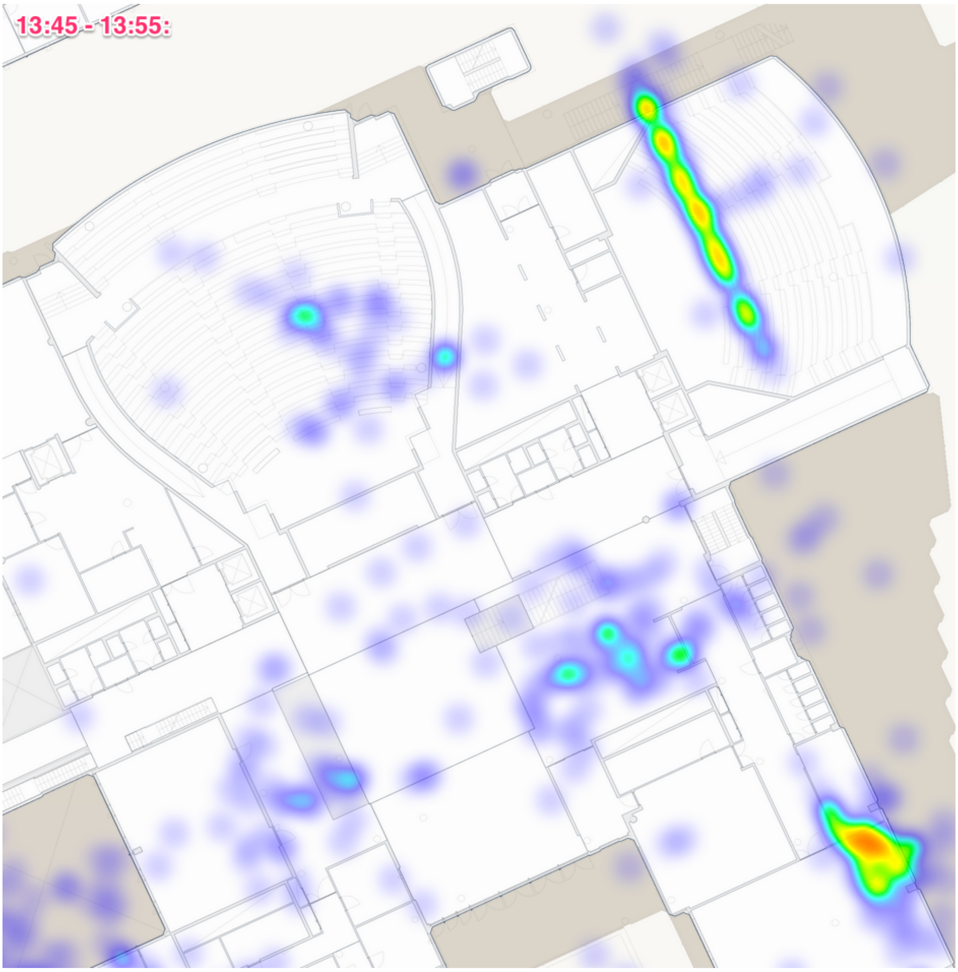


Figure B.6: Visualization from Period 2

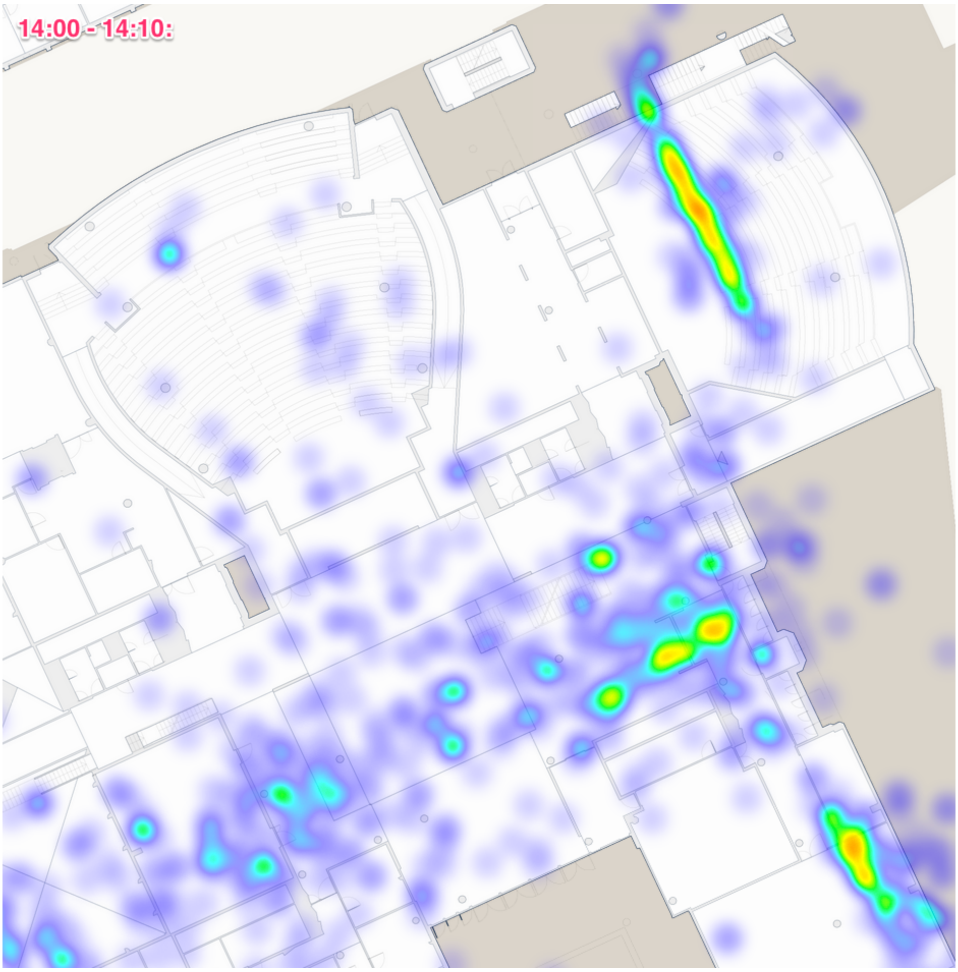


Figure B.7: Visualization from Period 3