Influence of Information System on Emergency Department Shift Leaders' Mobility

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Emergency departments are hospital units for patients, who need emergency and acute care. Due to the state of patients, shift leader nurses and physicians need to do important decisions concerning patients' treatment and care, quickly and efficiently. To be able to do that, they have to get needed information easily and efficiently. That is called knowledge-based leadership. When knowledge-based leadership is successful, the organisations' information and knowledge are processed in a way, that they may be exploited in a best possible way.

Unfortunately, nowadays the situation is not ideal in emergency departments, even though a lot of money has been invested in new information systems. Staff dissatisfaction with existing information systems have been reported and can be seen on staff satisfaction. On the other hand, there is not much research on how the information systems impact on shift leader nurses' and physicians' work.

A quasi-experimental study was done in the years 2015 – 2016 in emergency departments in three central hospitals in Finland exploring the movement patterns of the shift leader professionals before and after implementation of a new information system in on unit, called intervention unit. Data was collected with Bluetooth beacons installed in different hospital rooms and corridors and with smartphones carried by shift leader nurses and physicians. Improving the knowledge management of leaders with new information systems, it is expected, that it decreases the effort needed to seek information to support decision-making. However, the result was not so unambiguous. The movement patterns changed, but they changed also in control units.

A new information system can influence on hospital leader shift personnel mobility. Unfortunately, the lack of data made it impossible to count and compare actual walked distances. There should be more data – that is – from every day, every shift and every shift leader professional around the clock. Only that way, the comparison would be reliable. The mobility data from hospitals was already collected, when this thesis was written, so collecting the data was not part of this thesis.

Keywords: information system evaluation, indoor positioning, Bluetooth beacon

TURUN YLIOPISTO
Tulevaisuuden teknologioiden laitos
MARJO KULLANMÄKI: Tietojärjestelmän Vaikutus Sairaalan Päivystyspoliklinikan Vuorovastaavien Liikkuvuuteen
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Sairaalan päivystyspoliklinikka on potilaille, jotka tarvitsevat hätä- tai akuuttia apua. Potilaiden tilasta johtuen vuorovastaavat sairaanhoitajat ja lääkärit joutuvat tekemään potilaiden hoitoa ja huolenpitoa koskevia tärkeitä päätöksiä nopeasti ja tehokkaasti. Jotta tämä onnistuisi, heidän tulee saada tarvitsemansa tiedot helposti ja tehokkaasti. Tätä kutsutaan tietoperusteiseksi johtamiseksi. Kun tietoperusteinen johtaminen on menestyksekästä, organisaation tietoa pystytään hyväksikäyttämään parhaalla mahdollisella tavalla.

Valitettavasti tällä hetkellä tilanne päivystyspoliklinikka ei ole näin ihanteellinen, vaikka paljon rahaa on investoitu uusien tietojärjestelmien hankintaan. Henkilökunnan tyytymättömyys on raportoitu ja se näkyy henkilöstön tyytyväisyydessä. Toisaalta ei ole tehty monta tutkimusta siitä, miten tietojärjestelmät vaikuttavat vuorovastaavien sairaanhoitajien ja lääkäreiden työhön.

Kvasikokeellinen tutkimus tehtiin vuosina 2015 – 2016 päivystyspoliklinikalla kolmessa suomalaisessa keskussairaalassa tutkimalla vuorovastaavien ammattilaisten liikkuvuutta ennen ja jälkeen yhdessä yksikössä käyttöönotetun tietojärjestelmän asennusta. Data kerättiin eri sairaaloiden huoneisiin ja käytäville asennettujen Bluetooth-majakoiden ja vuorovastaavien sairaanhoitajien ja lääkäreiden mukanaan kantamien älypuhelinten avulla. Oletuksena on, että uusi tietojärjestelmä vähentää ponnisteluja etsiä tietopohjaiseen johtamiseen tarvittavaa tietoa ja näin ollen helpottaa tärkeiden päätösten tekemistä. Tulos ei ollut kuitenkaan yksiselitteinen. Liikkumisen mallit muuttuivat, mutta ne muuttuivat myös kontrolli-yksiköissä.

Uusi tietojärjestelmä voi vaikuttaa sairaalan vuorovastaavien liikkuvuuteen. Valitettavasti kerättyä dataa ei ollut riittävästi, jotta olisi pystynyt laskemaan ja vertaamaan varsinaisia kuljettuja matkoja. Dataa pitäisi olla joka päivältä, joka työvuorosta, jokaiselta ammattilaiselta ympäri vuorokauden. Vain sillä tavoin liikkumisen vertailu olisi luotettavaa. Sairaaloista kerätty liikkuvuuden data oli jo kerätty tätä tutkielmaa kirjoittaessa, joten datan kerääminen ei ollut osa tätä tutkielmaa.

Avainsanat: tietojärjestelmän arviointi, sisätilapaikannus, Bluetooth majakat

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Abbreviations and Acronyms

ARM	Advanced RISC Machine
BLE	Bluetooth Low Energy
CPU	Central Processing Unit
ED	Emergency Department
GDPR	General Data Protection Regulation
GPS	Global Positioning System
ID	Identifier
IoT	Internet of Things
IR	Infrared
JSON	JavaScript Object Notation
MHz	Megahertz
PDR	Pedestrian Dead Reckoning
RSS	Received Signal Strength
URL	Uniform Resource Locator
WLAN	Wireless Local Area Network

1 Introduction

Every hospital has an emergency department (ED). It can also be called emergency ward (EW), accident & emergency department (A&E) or casualty department. An emergency department is a unit for patients, who need emergency and acute care. In practice, they don't have prior appointments, because their need for care and treatment has emerged suddenly. Patients can come to the emergency department by own means, but quite often, they come by ambulance.

The day-to-day situations in emergency departments are very hectic. Many patients have even life threatening injuries and illnesses. Due to patients' severe conditions, they need quick and efficient care and treatment. Nurses and physicians in charge must make important decisions quickly and efficiently, to be able to enable the right kind of treatment and care to the patients. Each shift has a responsible nurse and physician. To be able to do the right kind of decisions about treatment and care, the staff needs real-time information quickly and efficiently. Unfortunately, that is not happening today in emergency departments. The needed information is in many places and shift leader nurses and physicians need to walk a lot to get all the information needed. All that time may delay decision-making and eventually also patient care. Even though a lot of money has been invested in health care information systems, knowledge-based leadership of shift leaders is still not running smoothly. The staff is not satisfied with the current situation, which can be seen in staff satisfaction. In fact, the results of such researches are very modest. [1 - 5].

Even though researches have been done, there is still not much research about how information systems impact on shift leaders' work in acute care. A quasi-experimental study was done in the years 2015 – 2016 to explore the impact on an information system on the movement of shift leaders in emergency departments [6]. It was done in three central hospitals in Finland. The units were on-call polyclinics. They are very similar, when it comes to their operation, handling about 40 000 – 60 000 patients per year.

Data were collected with Bluetooth beacons and smartphones. Several Bluetooth beacons were installed in rooms and corridors of three emergency departments. Beacons sent constantly signals and the smartphones, carried by shift leader nurse and physician, received these signals. The signals were saved to a database as events.

The situation in these three hospitals were as follows: in control unit A the information system Columna Clinical Care Logistics was already in use, in intervention unit that information system was deployed and in control unit B there was no Columna Clinical Care Logistics in use and it was not deployed there. The data was collected before the new information system was deployed in intervention unit and after deploying it. Before the new information system was deployed, the data, that nurses and physicians needed to be able to treat patients quickly and efficiently, was in many places and they had to move a lot to get all the information needed. The aim of the research was to explore, if an information system implementation influenced shift leaders' movement and how indoor positioning data from emergency department best can be analysed.

Collection of the movement data from hospitals, was not part of this thesis – the Bluetooth data were already collected, when this thesis was written [6]. This thesis is a part of UTU

Connected Health program research entity, which examines the effectiveness of information systems to hospital staff's work and patient processes.

1.1 Motivation

Nowadays, knowledge-based leadership by shift leaders in hospitals' emergency departments, is not optimal. That is because important information is needed without delay to be able to do important life-saving decisions operations management. Unfortunately, that is not the case nowadays. The needed information is disassembled in many places and hospitals' professionals need to walk quite a lot to get the information. By improving shift leaders' information management, knowledge-based leadership gets better and the professionals are able to do their work more easily and efficiently. [1].

1.2 Thesis Statement and Research Questions

Presumably a new information system should change the shift leader nurses' and physicians' mobility patterns in hospitals, because they can get all the needed information for running the unit in one place easily and effectively. This thesis will evaluate this presumption by examining the collected data, introduce the results as heat maps to health care professionals and then answering the following research questions:

1. Were the mobility patterns of hospitals' shift leader professionals changed by a new information system?
2. Which is the best way to visualize the data, collected from hospitals concerning shift leader nurses' and physicians' mobility?

To be able to answer these research questions, I will code a user interface for the collected data. With that user interface, I can get the information, I need from the collected data. Based on that data, I will make three (3) different heat map models. By comparing data before and after the new information system from those heat map models, I will be able to answer the question, were the mobility patterns of hospitals' professionals changed. The ideal situation would be, that I could count walked distances from the collected data, too. To be able to answer the second research question, I will make and send by email a survey to eight (8) health care professionals. I will ask a few background questions and an opinion, which of those three (3) different heat map models is the clearest, when it becomes to visualizing the collected data concerning hospital shift leader nurses' and physicians' movement patterns.

1.3 Data about the research

The data were collected from emergency departments of three hospitals in Finland. The smartphones were carried by both nurse and physician shift leaders around the clock during five data collection intervals, which lasted one month each, two times before and three times after the system implementation.

1.4 Thesis Structure

In the first section, I am introducing reasons and need to do this thesis. The second section is for related work. In the third section, I am introducing a few different indoor positioning systems and tell more about the means, which were selected to do the research in hospitals. In the fourth section, I am telling about the data analysis and data visualization. In the fifth section, I am telling about the data, collected from three hospitals and examined in this thesis. In the sixth section, I will introduce the results of my data examination in this thesis. In the seventh section is the conclusion of this thesis and comments about possible future work are presented.

2 Related work

Even though there has been a lot of investments in health care information systems in recent years, there is not much research about how the implemented system impact on hospitals' personnel work. There is already one Master's thesis of the same collected data from those three (3) hospitals, but the data has been examined from a different angle. To examine the collected data, three (3) different models were created: Markov chains, average weeks of visit counts for each room and average visit durations for each room. These three (3) models were enough for uncovering the differences in the patterns before the information system was deployed and after the deployment was done. No clear differences before and after information system implementation was not found, even though the thesis is very profound. There are results from all the three (3) models, but the results are in many different tables. It makes the results a little hard to interpret and compare. [6].

A need for researching the shift leader nurses' and physicians' mobility was well justified [1 - 5]. That is why, it is a little surprising, that there are no similar studies about this theme before. However, there are studies about personnel's mobility in hospitals. One research is based on efficiency. It has been noticed, that nurses need to move a lot in hospitals, when they are working. All that moving time is wasted time and it is away from the actual work, taking care of the patients. By examining the movement of the nurses, they hope to find out, in which areas the nurses need to visit. Based on that data, new hospitals will be built in a way, that the most visited areas and rooms, are close to each other. That way nurses' movement can be reduced and they will have more time to do the actual caring. [7].

Another research, quite close to my thesis theme, handles also nurses' mobility in hospitals. However, the approach is a little different. It handles mobile and desktop computers and how the latter ones tie hospital personnel to one place. This thought in mind, they have researched, what are the situations where, why and when nurses need to move while working. They have made mobility work and standard operation configuration (SOC) and tested it to mobile work at a hospital. A hospital was a good place to test it, because they are hectic work places; there are always a lot of things going on at the same time. My aim is to examine, how nursing and medical shift leaders moved before the new information system was deployed and how they moved after the deployment. In this related research, there is a table, in which there are walked distances by hospital physicians and nurses. The distances are by different kinds of clinicians and by work shifts. [8].

Yet another research handles nurses' mobility in a hospital. This is similar to my thesis, because the mobility was examined before and after, but the main theme was hygiene and how the nurses take care of it. They examined, how many times nurses wash they hands before a kind of game was installed and how many times after the installation. The game gives credit according to the times nurses wash their hands. An examination was made to know, whether the game increased the amount of hand washing or not. [9].

Another very close research to my thesis examines the mobility of physicians and nurses, but it was done to examine, how long and to which assignments the hospital personnel uses their work time. However, this study justifies, too, why it is so important, that hospital personnel has easily available tools and efficient information systems. [10]. This issue has been examined in other research, too. An interesting research handles the substantial growth in mobile handheld technologies in hospitals. Also this research's motivation is efficient hospital work. The starting point is, that there are more and more mobile devices everywhere – in all people's everyday life. They are there to help our everyday life. This can be seen in hospitals, too. Nowadays, there are a lot of mobile devices to help the hospital personnel do their work more efficiently. Hospital personnel don't have to look for needed information everywhere, because it is always available in those mobile devices, they carry with them. So, in this research, this has been examined: is hospital personnel able to do their work more efficiently, when they have all the information they need in a mobile device, they carry with them. This makes the research also close to my thesis theme. [11].

As the research of hospital shift leader professionals' mobility patterns, handled in this thesis, was done with Bluetooth beacons, there are several reported researches of the applicability and accuracy of Bluetooth beacons for hospital environments [12 - 13]. The difference is, that although these Bluetooth beacons are there for tracking hospital personnel, the reason for that is, that hospitals are big buildings and there are situations, when a certain personnel member is needed immediately. With Bluetooth beacons and smartphones or other device receiving Bluetooth signals, these persons can be found quickly. The same idea is used for tracking patient, so precious time is not wasted, when the next patient to be treated, is found quickly and easily. That goes for the patients already in the hospital, too. For example, if a patient with Alzheimer's disease accidently leaves the hospital, that is noticed at once. The same principle is used for precious and expensive hospital equipment. The needed equipment can be retrieved quickly and efficiently and on the other hand, if someone tries to steal it, it is noticed immediately.

Of course, other systems than Bluetooth beacons, can be used for tracking hospital staff, patients and equipment in hospitals, too. There are several reported studies of different systems and their accuracy [14 - 17]. However, quite common feature of these researches is, that they are not done in hospitals, but usually in, for example, office environments in ideal circumstances. That is why their results may not be as reliable as those made in hospital environments. There are a lot of furniture, equipment and people in hospitals, which effect on the results of indoor positioning. Also the hospitals' devices can alter indoor positioning measurements by interfering, for example, signals. There are radio waves, radiation, x-rays and so on. It cannot be forgotten, that it is the same situation the other way around, too. Some indoor positioning devices can interfere hospitals' devices. In one study, made in a hospital, it was mentioned, that it was quite difficult to do the study there. That was, because hospitals are usually quite full and there was just not enough space to install the needed devices to be able to do the research. [14].

When the amount of collected data is very large, graphical presentations are a good way to introduce the results. That is why in this thesis, the results of the research are displayed by visualizing the collected data. The aim is to make the results easier to understand and to remember just by looking results as heat maps. It has been proven, that especially when dealing with big data, results are easier to understand and assimilate as images and pictures. One very interesting research is the one, which concerns visualizing healthcare data. This describes, how data visualization has become more and more important in recent years, as also the amount of collected data has grown enormously over the last years. One very big industry collecting data is healthcare. The amount of collected data is so enormous, that it has started to be almost impossible to handle, interpret and assimilate the results. That is why data visualization has become so popular. In the research, several ways to visualize healthcare data are introduced. These different ways, different models, are divided into groups based on how many variables there are to be plotted. Each model has an image, so every model is easier to perceive. Every methods' advantages are introduced, but also weaknesses are told. This research has a common feature with my thesis. The methods, introduced in that study, has been shown to healthcare professionals, so that they have had a change to tell their opinion about the models. The main criteria for their opinion has been, how clear and easy to understand each model is - how easy each of the result is to interpret. [18].

Movement data can be collected for many reasons and for many purposes. There are several researches, in which movement data has been collected and analysed for further studies. One of these concerns people suffering depression. Its main purpose is try to prevent people committing suicides. There are several applications available for smartphones, with which individuals can themselves report and make notes about their mental health. However, these applications require quite a lot activity and when an individual is really depressed, activity goes down. These researchers have made an application, which automatically collects movement data. This is quite easy in that sense, that nowadays almost everybody carries a smartphone with them and these phones already uses, for example, Global Positioning System (GPS) for location information. It has been investigated, that when an individual is depressed, one's movement decreases. The research contains very accurate calculations and results of them. They manage to prove, that it is possible to identify depression marks in an individual. As more similarities to my thesis, there is also a mention of intervention, although in that research, the intervention could be made as digital mobile intervention. Also other than GPS could be used to collect location information. [19].

Yet another research concerning tracking individuals is very current now, due to the COVID-19 pandemic. It has been researched, how people are exposed to diseases. This has been examined by collecting data as movement patterns, how people move in their home areas and anywhere else, they move during the day. This information is combined with the data of people, who has got some kind of disease and data about areas, where certain diseases occur. They used, for example, data from Twitter to be able to track individuals' movement patterns. When areas, where people are exposed to diseases, are found, the data can be supply to authorities. Then authorities can concentrate to a certain area and, for example, to decimate mosquitos, which spread diseases. [20].

Of course, spatial data and data about movement patterns can be exploited for other than healthcare purposes, too. One research concerns safety issues in carnivals and street parades. In these kinds of events, when there are a lot of people gathered together, there must be good planning for keeping people safe in every situation. These events can be also rock concerts and matches or places like airports or high buildings. When something happens, people tend to panic and that alone is a big risk, when rescuing people. By simulating peoples' movement with agents and using mathematical formulas, peoples' typical movement patterns are revealed. However, despite of all these preparations, the research ends to a conclusion, that it is impossible to take into account every single situation, that can happen in this kind of events and places. [21].

There are also several other fields and industries, where spatial data and especially heat maps are used in examination. For example, there are different kinds of traffic issues, like traffic accidents and traffic safety. Also internal traffic has been examined. [22 - 25]. In the research concerning traffic accidents, it is said, that nowadays, due to the amount of collected data, it is sometimes difficult to make sense of it and its results. However, heat maps, are quite commonly acknowledged method to make the results easier to understand and assimilate. I have used this idea in my thesis, too. In the earlier thesis from the same data I examined, the results are introduced as numbers in tables. Because, originally, there are data over 7 megabytes, there are a lot of numbers and tables, too. The results are quite hard to understand and the differences between periods cannot be so easily seen. That is why, there was a need for this thesis, too. Instead of plain numbers and tables, I am using heat maps to introduce the results of the data examination.

As a summary, there is no exactly similar research as mine, done before, despite the one done for the same collected data; the thesis done by Åbo Academy's student. However, there are several researches in which spatial data has been examined, even hospital personnel's movement data. By examining related work, I got confirmation, that heat maps are the right way to visualize spatial data. There are several markings in researches, that heat maps are a good choice, when the amount of collected data is big. There are also several researches, where spatial data is visualized as heat maps.

3 Indoor positioning

3.1 General about individuals' location information

Nowadays, the need for individuals' location information has grown enormously. That concerns both individuals' personal lives as well as in commercial sense. Individuals use more and more wearable Internet of Things (IoT) devices, which use positioning information. That information can be used for commercial purposes, too. Shopkeeper wants to know, which route the customers take in a shop. A shopkeeper arranges the merchandise in a way, that the customers notice and buy them. Also hospitals use indoor positioning with their patients. Patients have to queue sometimes a long time and move around the hospital area. When it is their turn, they can be found easier with some kind of indoor positioning system.

To get individuals' location information outside is quite easy with the GPS, originally NAVSTAR GPS, which was developed in the 1970's and launched in 1978. It was first developed for military purposes, but has already been for years available for all people all over the world. It is not the only, but one of the Global Navigation Satellite Systems (GNSS). It is a radio navigation system and is based on satellites. It provides geolocation and time information. GPS receivers catch the information quite efficiently - only the weakest signals can be blocked by, for example, buildings or mountains. GPS has been developed over the years and that has made it more accurate. In 20 years the accuracy has been improved from 5 meters to 30 centimetres. Even though GPS is a very good and accurate system, it has no use indoors. Its signals simply just cannot penetrate the walls and ceilings and GPS needs line-of-sight transmission between satellites and receivers. [26].

3.2 Indoor positioning

Indoor positioning has become very popular over the last years. That is why there has been and still is a lot of developing work for creating new systems and examining existing systems for it. There are quite many systems already, but their problem mainly is, that they are not accurate enough. There are systems, that can find out in which room a person is, but more often one needs to know the exact location - room level is just not enough. Earlier indoor positioning required a lot of devices, but nowadays, almost every smartphone contains technique, which enables to track, where a smartphone is. Indoor positioning can be used, for example, when an expensive equipment must be tracked, as a navigation system for blind people, finding a lost child in a crowded place, for museums' guiding or finding exit in a burning building.

In any case, indoor positioning is much more challenging than outdoor positioning. Indoors, there are many different obstacles, which make the positioning harder to execute. There are human beings and equipment, which can interfere the measuring electromagnetic waves. There can be also noise and interference from other wireless and wired networks.

Indoor positioning systems can be separated in groups by many different approaches. For example, there are systems, which exploits existing infrastructure, like wireless networks, but not all of them. In this sense, there are two (2) kinds of systems: network-based and non-network-based. A network-based is a cheaper solution, because the needed network already exists and requires no other infrastructure. This has another side, too. Using network-based systems, the position of the network cannot be altered. When using non-network-based systems, like Bluetooth beacons, the placement can be planned so, that the best possible accuracy is achieved. [27].

Indoor positioning systems can be grouped by their system architecture, too. In this sense, there are three (3) different categories: self-oriented infrastructure-assisted architecture, infrastructure positioning architecture and self-positioning architecture. The most complicated is the first one: self-oriented infrastructure-assisted architecture. The systems, which use this architecture, need to get a request from a tracked target. If the system does not get one, there will be no tracking either. Infrastructure positioning architecture can estimate the target's position, if it is in coverage positioning area. It uses existing infrastructures, which track devices automatically. Self-positioning architecture uses highly private and secure positioning system infrastructures. It can calculate the positions by the targets themselves. [27].

Yet another way to separate the existing indoor positioning systems to the groups is used in a study. They have been divided into four (4) categories: triangulation, direct sensing, pattern recognition and dead reckoning. For these triangulation based system, for example, Wireless Local Area Network (WLAN) and direct-sensing-based infrared systems, need assistance from existing infrastructure. Bluetooth beacons must have ideal positions. The best accuracy is achieved with radio-frequency identification (RDIF), Ultra Wide Band or Bluetooth Low Energy (BLE) beacons. [28].

When choosing the right indoor positioning system, a few things must be considered. For example, how accurate it should be? Is room level enough or should it be even more accurate? How much the system can cost? And should the system be compatible with existing systems? There are many systems, which can exploit already existing systems, like Wi-Fi, so those systems can cause less cost. Is it going to be used just in one place or multiple places? If the aim is to use it in multiple places, for example, Bluetooth beacons are a good choice, because they can be located in many places and can be used many times. Do the users need to be trained, how to use the system? There are many systems, which are easy to use and in practice, need very little training.

3.3 Examples of existing indoor positioning systems

3.3.1 The Active Badge system

One of the first indoor badge positioning systems was the Active Badge system. It was developed in 1990 by a company called Olivetti. The system is based on infrared (IR) signals. There are one or several sensors, which catch globally unique IR signals. The signals are sent every 15 seconds. It provides symbolic information of each active badge. Sensors are connected with wires and they send the data to a central server. This collected information can be handled, for example, in a built application. [29].

The used sensors are quite cheap, but the connecting cables are expensive. One more disadvantage is that an IR signal can be disturbed by sunlight and fluorescent light. In its early years, it was widely used, for example, in office buildings to locate office personnel. It was a quite advanced system comparing to the earlier system: pager. The active badge system has much longer range and it doesn't require any call-backs. Although the active badge system provides quite good accuracy, it is no longer widely used. The main reason are the smartphones with which the same indoor positioning can be reached even more efficiently. [29].

3.3.2 Pedestrian dead reckoning

Pedestrian Dead Reckoning (PDR) is a technique, which is based on estimations using the pedestrian's known starting point and the latest position. As every step's length varies, the amount of taken steps must be known. This makes PDR technique a bit hard to use, because not only the steps' length value varies, but also every human being has different steps' lengths. Another difficult feature of PDR is, that it is hard to detect, in which direction a step was taken. If this is not clear, there will be location errors. To be able to get information from PDR, some kind of analysing method is needed, too. There are two common methods for that: zero-crossing detection and peak detection. The system actually uses 3-axis acceleration, which is relative to the smartphone. These measurements are mirrored against world coordinate system, which uses magnetic sensors. After this, the signal must still be filtered. [30 - 31].

Earlier, accelerometer sensors were needed in shoes to be able to use PDR, but nowadays the newest smartphones have accelerometer sensor inside. This is very practical, because smartphones are easy to carry and they can be taken everywhere. It is also cheaper solution, because there is no need to purchase other equipment. Nevertheless, it requires quite a lot of work to get Received Signal Strength (RSS) to measure properly, because it is sometimes hard to reject false step detection. However, when everything works fine, PDR is quite accurate for indoor positioning. Even without any calibration, with a smartphone accelerometer sensor inside, the average error percent in only 2.925%. This system is used, for example, among fire fighters, who need to know, where they are in the burning building. [30 - 31].

3.3.3 Magnetic field fingerprinting

The magnetic field fingerprinting has two phases: offline mapping and online positioning. Offline mapping is done of the magnetic field measurements at known locations. Online positioning is done by matching the measured magnetic field with the fingerprints from the database. Magnetic field fingerprinting is quite good for the indoor positioning, because magnetic field is everywhere. Other advantages are, that it requires no installations and it is relatively stable, although sometimes there are magnetic interferences. That is why positioning of devices must be considered carefully. Being magnetic based, iron equipment can interfere measurements. This makes this technology difficult to use in hospitals. [32].

There are also other challenges when using the magnetic field for positioning. The fingerprints, which this system provides, has very little information. Also, there are many kinds of smartphones and it has been tested, that they give different results even the other circumstances are the same. Even the same smartphone can give different measurements depending on how high it is located. To avoid these differences, the used magnetic field map must be three-dimensional. Magnetic field fingerprinting needs a lot of preparations, such as calibration. Magnetic field fingerprinting is at its best, when it is combined with some other indoor positioning system. [32].

3.3.4 Ultra wideband indoor positioning technologies

Most of the indoor positioning systems are compatible with the BLE system or Wi-Fi, but there are also technologies, which are not. One of these is Ultra wideband indoor positioning technology. It uses so called Time of Flight (ToF) methodology, which measures the running time of light between an object and several receivers. To be able to get as good accuracy as possible, there should be at least three (3) receivers. They are necessary, because the accuracy is based on trilateration. In addition to that, there must be direct line-of-sight between a receiver and a transmitter. There is a little tag on the target, which is being tracked. It sends data - that is, its ID, Time of Flight and a timestamp. Carefully placed Nodes receive this data. When there are several Locator Nodes (at least three (3)), the data they have collected are combined. This way a very high accuracy is achieved. [33].

Not being compatible with BLE or Wi-Fi is in some cases certainly a disadvantage, but on the other hand, ultra wideband indoor positioning technology can offer an accuracy even between 10 and 30 cm. That is significantly better result than with Wi-Fi, which can offer only 5 – 15 meters' accuracy or Bluetooth beacons, which can offer only 1 – 3 meters' accuracy. Ultra wideband indoor positioning technology has also very low latency, but because in addition to not be available for Wi-Fi or Bluetooth beacon systems, it also requires components. For this reason, it is usually used in special industry applications. [33].

3.3.5 Combining indoor positioning techniques

To be able to get as accurate position as possible, the best solution for collecting the data, is to combine different techniques. One technique is map-aided navigation. There are three (3) different ways to utilize this technique: building cardinal headings are compared, wall constraints are filtered based on probabilistic map matching and link-node representation of building plan based on topological map. Map-aided navigation indoors helps a lot to perceive, where a person could be, because simply, a person cannot walk through the walls and one can go from floor to floor only by elevators and staircases. [27].

Also Ultrasound-based Positioning Systems are usually combined with radio frequency signals. The signals perform synchronization and coordination in the system. Ultrasound-based Positioning Systems give a kind of inexpensive positioning solutions and they increase the system coverage area. However, ultrasound-based positioning systems have lower measurement accuracy (several centimetres) than Infrared-based systems (several millimetres). Ultrasound positioning systems suffer from reflected ultrasound signals and other noise sources such as jangling metal objects, crisp packets, etc. One very commonly used method is trilateration. It uses several reference points to estimate the mobile node location and geometry of circles to compute the node location. However, it is known, that even trilateration can help to get more accurate location positions, this is not the case with RSS measurements and WLAN based positioning. This is because, walls reflect WLAN signals and human bodies weaken them. In turn, smartphone orientation affects RSS measurements. [27].

3.3.6 Indoor positioning systems elsewhere

Nowadays, indoor positioning is used practically everywhere, even without people knowing it. They are used for maybe same purpose, tracking individuals, but the motivation varies a lot. For example, in shopping centres, the shop owners want to know, how many people visit their shops or they want to send direct commercials to certain people. In parking garages, indoor positioning can be used for finding a free parking place. In work places, owners want to know, how and exactly where workers spend their working hours. In environments, where there is expensive equipment, that equipment can be monitored with indoor positioning systems.

There is no simple rule or pattern, which indoor positioning system is used in every shopping centre or parking garage and so on. The chosen system depends on, for example, has the existing system, like Wi-Fi, already been installed there. It depends on also, how accurate information is needed.

Nowadays, there has been increased usage of Google Maps. This system can be used in public places, like airports, hotels, malls, shops, railway stations and museums. It can be used in private places, too, if they have provided their floor plan. [34].

3.4 Bluetooth

Bluetooth is a short range wireless data transfer technique, which is based on radio technique. Its main purpose is to replace cables between mobile phones, personal computers, printers and other peripheral devices. It is an open standard for devices to wireless communication at close quarters. Every single device with Bluetooth readiness can freely join or leave the Bluetooth net. Also infrared connections have been replaced with Bluetooth, because it has more reliability and is more versatile transfer technique. Also, it doesn't need optical contact between the unity devices either. [35].

Bluetooth was initiated by a man called Nils Rybeck in 1989, former CTO at Ericsson Mobile. At that time, wireless headsets were invented, so there was a need for this kind of technology.

3.4.1 Bluetooth beacons

Bluetooth beacons are small battery powered radio transmitters. They transmit BLE signals and the smartphones, which recognize Bluetooth, are displaying and scanning these signals. Signals are not strong, because beacons are very low energy. That is why signals can be almost lost, when there are, for example, human beings. Signal's range is about 30 meters, so it is very important to place the beacons correctly and rationally.

Bluetooth beacons consist of three (3) major components. They have a Bluetooth Smart connectivity module, a small Advanced RISC Machine (ARM) computer and batteries for powering the entire circuit. The ARM computer has a Central Processing Unit (CPU), which has an antenna. This antenna broadcasts electromagnetic waves. These waves have specific length and frequency. Beacons transmit data packets, which consists of a component indicating the status of the beacon and an identifier (ID) with spatial data. So called Eddystone beacons have a Uniform Resource Locator (URL), which correspond to data in the nearby server. BLE beacons have forty (40) channels. The width of these channels is two (2) megahertz (MHz). BLE uses only three (3) channels for broadcasting. This way it doesn't need to work so hard and that saves batteries. Inside buildings there are people, furniture and walls. These all can impact to the accuracy of BLE indoor positioning. Also, if a human being is tracked, a human being moving slowly gives a different result than a human being moving fast.

There are two kinds of Bluetooth beacons: a classic Bluetooth and BLE. Classic Bluetooth is used in Bluetooth speakers and headsets, because it transmits to long ranges and consumes high power. BLE consumes less power, but transmit less data over a smaller range. They transfer small amounts of data at regular intervals of time. There has sometimes been suspicions about beacons' information security, but beacons cannot store or even access the data from smartphones. Their only purpose is to send contextual messages to users, which happen to be nearby. On the other hand, it could be technically possible to do the tracking other way around. Then the smartphones would send signals and beacons would receive and register them. However, that would be against the General Data Protection Regulation (GDPR), which came into effect in 25.5.2018.

3.4.2 Advantages of Bluetooth beacon

1. There is no need for extra hardware.
    a. Only BLE beacons must be installed.
    b. Only BLE-enabled smart phone is needed.
2. BLE beacons are cheap.
3. They use very little power.
4. They are suitable for most of the devices, unlike Wi-Fi.

3.4.3 Bluetooth beacons versus Wi-Fi

There are many studies about how accurate the existing indoor systems are, especially Bluetooth beacon based ones. For example, Ramsey Faragher and Robert Harle, has done studies, in which they have studied systems, which are based Wi-Fi fingerprinting schemes. They wanted to know whether BLE beacons are better option for indoor positioning. Such systems are known to give few metres accuracy, when there is an ideal environment, Wi-Fi signals are well and Wi-Fi has dense coverage. But because the circumstances are rarely so ideal and Wi-Fi protocol uses a lot of power, there is a need for other measurement systems. Both Wi-Fi and BLE Beacons use the same 2.4 GHz ISM radio band. The other common thing is, that either of these is available everywhere, but for example rapid localisation, asset tracking, route guidance and unrestricted navigation need systems, which are everywhere. If the system is based on Wi-Fi, if has to be established and if you want to use BLE system, beacons has to be installed. [36 – 37].

When comparing Wi-Fi and BLE Beacons, the latter has more flexible options. Wi-Fi access points are usually already there and they are typically near power sources. And when installing Wi-Fi, it is usually not ideally installed, when it becomes to radio positioning. You can get better coverage with beacons, because they can be placed where ever you want and as many as you need. However, according to a study, around 6 – 8 beacons is enough to get good accuracy. Adding more beacons does not improve the accuracy. There is also difference in how Wi-Fi and BLE beacons return measurements. Wi-Fi returns data batches and BLE returns every measurement at a rate they are detected. Sometimes Wi-Fi can cause troubles to BLE fingerprinting by causing errors in BLE signal strength measurements. [36 - 37].

3.5 Selected methods for collecting movement data from the hospitals

There are a lot of different methods and equipment, when it comes to collecting movement data indoors. Which should be selected, depends on several things, for example, cost, accuracy and usability. When methods for collecting data from three (3) hospitals concerning hospital staff movement before and after a new information system was deployed, was selected, there was a few things, that influenced on the decision. It has to be accurate enough, easy to install and has low costs. Accuracy was important, because there are a lot of rooms in hospitals, and it was needed to know, which rooms the hospital professionals visited. It has to be easy to install, so it would not disturb the hospital work. And because the chosen methods would be there only for the research, there was no sense to use a lot of money for them. From many options, Bluetooth beacons and smartphones with developed application were chosen, because they fulfilled these needs. Before these methods were put in use in three (3) chosen hospitals, they were tested in university environment. They did not give always the best possible result, but they were good enough. [38].

3.5.1 Evaluation of the selected methods

The arguments for selecting Bluetooth beacons and smartphones were fine and understandable. It was very good, that these methods were tested before they were actually put in use in hospitals, because these tests revealed also their weaknesses. Also methods to avoid these weaknesses, were discovered. Maybe the most important observation was, that smartphones did not always record the actual nearest beacon as nearest, but the beacon in neighbour room. This was because the beacons were installed too close to each other. In hospitals, this weakness could be avoided.

Unfortunately, it turned out to be, that these methods have other weaknesses, too. The research was done in a way, that individuals could not be identified. This was done so, that same professionals did not carry the smartphones – on the contrary, the professional could change even during a shift. This chosen way is understandable, and this way the research was done according to law, but it led to a situation, where the collected data are uneven. That is because the professionals did not engage to the research and each one of them carried the smartphone with different intensity. The unevenness was discovered, when the collected data was examined.

If the research was done again, the methods selected before would still be a good choice. The arguments for choosing them are still there. There are good indoor positioning systems based on Wi-Fi technology, too, but the places Wi-Fi covers, cannot be chosen. However, to be able to have as comprehensive research as possible, it would be good to engage the professionals to it. It will not be important, who is carrying the smartphone, but it should be carried in every shift all the time, except charging times. Even that could be managed by having several phones, so they are charged in turns. This way, there will always be replacement smartphones, which are functioning, even in cases, one breaks.

4 Data analysis and visualization

4.1 Data analysis

Data analysis is a part of data analytics. Analysis techniques are based on statistics and mathematics. There are two (2) kinds of statistics: descriptive and inferential statistics. When data is just summarized, usually by diagrams or characteristic values, that is descriptive statistics. Because that is only a summary of data, no specific assumption is done by it. On the contrary, when more profound statistics is needed, more detailed methods are needed for doing that.

One way to describe different types of data analyses is to divide them in six categories: descriptive, dispersion, regression, factor, discriminant and time series analyses. Descriptive analysis has a benchmark and it mirrors the indicators towards it. It also uses past trends, past results as historical data and evaluates, how they are going to influence performance in the future. Dispersion analytics helps data analysts by determining factor's variability. This way the data is spread in many areas. Regression analysis acts with relationships between variables, for example, a dependent variable can be modelled to many independent variables. Also factor analysis deals with the relationships between data variables. When factor analysis is done, classification and clustering procedures can be done. Discriminant analysis is mostly used in data mining. It helps to identify new items by examining, how two groups differ from each other.

4.1.1 The phases of data analysis

There are several ways to divide a data analysis process. One commonly used is called CRISP-DM. It is also a standard in this field. It has six phases: project understanding, data understanding, data preparation, modelling, evaluation and deployment. These phases are not like a waterfall, but like a sprint, where all the phases are done repeatedly. Project understanding is also known as business understanding. Its aim is to evaluate, what kind of benefit a successful project can produce and on the other hand, what kind of risks there are. In data analysis process, the first phase is designing the experiment. When this phase is done successfully, the obtained data can be handled in a way, that analysis are authentic and reliable. To be able to obtain that, typically two kinds of studies are used: experimental and observational studies. They differ from each other quite well. In experimental study the data generating process can be controlled and manipulated, whereas in observational studies, the generating process cannot be controlled. Despite of what kind of study is used, the most important thing is the actual collected data. It should be independent and representative. That way can be confirmed, that the assumptions based on the data, are well-founded. In most cases, there are already some kind of views and expectations, what kind of result the collected data will give. [39].

Next phase is data understanding. When the purpose of the project is understood, one must examine, whether the collected data will give results and answers to the research at hand. Unfortunately, one will not find out this, not until at the end of the project, but one must have at least some kind of notion, whether the collected data is suitable or not. In data, there can be, for example, errors and empty fields, but these either cannot be ignored. They, too, tell something and by ignoring them, maybe valuable data is lost. Maybe just the angle or aspect of the research must be changed, if the data is not perfect. After understanding the project and the data, the next is phase data preparation. In spite of one may think, data must be prepared before it is usable. Of course, data cannot be changed in a way, that it endangers the whole reliability of the research, but sometimes handling the data is not possible before preparations. Sometimes one may have benefit from another data or if there are totally empty fields and modelling tool won't accept that, one should fulfil empty fields with zeros, if that does not distort the result. [39].

When data has been prepared, next phase is modelling. This is done with a modelling tool or in other words, a technique. There are many kinds of models and the right one depends on the result. For example, a so called black-box model is quite simple, but it can be enough due to its good performance. However, black box models are not very comprehensible. They can be used, for example, for predicting things concerning phenomena, but people cannot interpret that kind of model. Overall, if the result is not pleasing, the model can be improved. This is done by going back to the previous phase, data preparation. It is quite common, that one must do these phases multiple times to be able to get the best result. Overall these phases can take a lot of time, but it is worth it. It brings even new ideas, how to handle the data and what aspect should be taken to it. [39].

After the data has been prepared and modelled well, it is time to move to the next phase, which is evaluation. This is a very important or even critical phase, because in this phase the results are analysed. It is done from the angle of the problem owner. If the results don't fulfil the needs, the whole project could be stopped. However, it is still possible to, for example, alter the settings to be able to gain satisfactory results. Overall, if the results are satisfactory, one will move to the next phase. Although the last phase is deployment, it doesn't mean, that the project is finished in every case. The deployment phase consists of many different tasks from creating a software system to writing reports of the results. If the project is used continually, it is important, that these steps are updated constantly, too. [39].

In my thesis, in the project understanding phase, I started with examining, what is the actual problem and how could I try to resolve it. With my instructors we planned, how the result should look like. The data was already collected, so I moved to the data understanding phase. I made a simple user interface to be able to see the actual data. I evaluated it and found out, that I can find the answers to my research questions. In data preparation phase, I handled the data so, that it was divided in many pieces based on unit, time period and professional. We decided, that I would concentrate on data about the nearest beacons. This was part of modelling, too. In the first evaluation phase I realised, that the data is quite uneven and I needed to go back to the data preparation phase. In the deployment phase, I created a user interface and wrote about the results to my thesis.

4.2 Definition of data visualization

> "We define *visualization* as the communication of information using graphical representations. Pictures have been used as mechanism for communication since before the formalization of written language. A single picture can contain a wealth of information, and can be processed much more quickly than a comparable page of words. This is because image interpretation is performed in parallel within the human perceptual system, while the speed of text analysis is limited by the

sequential process of reading. Pictures can also be independent of local language, as a graph or a map may be understood by a group of people with no common tongue." [40]

"Data visualization is a new term. It expresses the idea that it involves more than just representing data in a graphical form (instead of using a table). The information behind the data should also be revealed in a good display; the graphic should aid readers or viewers in seeing the structure in the data. The term data visualization is related to the new field of information visualization." [41].

"Data visualization is an important part of any statistical analysis and it serves many different purposes. Visualization is useful for understanding the general structure and nature of the data, such as the types of variables contained in the data (categorical, numerical, text, etc.), their value ranges, and the balance between them. Visualization is useful for detecting missing data, and it can also aid in pinpointing extreme observations and outliers. Moreover, unknown trends and patterns in the data are often uncovered with the help of visualization. After identifying such patterns, they can then be investigated more formally using statistical models." [41].

All the above definitions for data visualization have very good points. In summary, they all define the thing, that one image tells more than a thousand words. Of course, data visualization is not a new term anymore, but it is still relatively new. However, people have used images for communication even before a written language was discovered. Images are quite universal, too. When there is no common language among people, images are usually interpreted in common way.

A good data visualization makes the data understandable and easy to assimilate. It gives the right and needed information and is reliable. Also its appearance is appealing and clear, so that people, who need the information, find it easy to look at. Individuals, who have made the visualizations, have understood the data and know the audience, to whom the visualizations are for. A good visualization is universal, so people all over the world can understand, what it describes and what is the result. When it is as its best, also people with colour blindness can interpret it.

My heat maps would be more understandable, if the layouts could have been there, too, but being layouts from three (3) Finnish hospitals, that was not possible due to safety issues. Also, I am not familiar with healthcare setting and this is why, I made a survey letter, in which I asked healthcare professionals' opinion, which is the clearest choice, when is becomes to visualizing hospital professionals' movement data. Also the versions scatter plot heat map coloured by density as seen in figure 1 and mesh grid plot heat map as seen in figure 3 does not take into account colour blindness. For that, the version scatter plot heat map as seen in figure 2 is the best choice.

4.2.1 Choosing form of data visualization

"There are barcharts, piecharts, histograms, docplots, boxplots, scatterplots, roseplots, mosaicplots and many other kinds of data display. The choice depends on the type of data to be displayed (e.g. univariate continuous data cannot be displayed in a piechart and bivariate categorical data cannot be displayed in a boxplot) and on what is to be shown (e.g. piecharts are good for displaying shares for a small number of categories and boxplots are good for emphasizing outliers). A poor choice graph type cannot be rectified by other means, so it is important to get it right at the start. However, there is not always a unique optimal choice and alternatives can be equally good or good in different ways, emphasizing different aspects of the same data. Provided an appropriate form has been chosen, there are many options to consider. Simply adopting the default of whatever computer software is being used is unlikely to be wise." [41].

When choosing the right form of data visualization, the data must be familiar and known. The right form depends on what variables and results presenter wants to be shown and what presenter is trying to tell with the results. Also the target audience must be recognized. Often it is better to use several different visualization types instead of one containing many variables and results.

There are a lot of different kinds of diagrams, charts and plots, when it comes to data visualization. The models to be used should be picked carefully. They are not all suitable for every occasion. As Härdle and Unwin states in the above description, the more there are variables in data, the more challenging picking up a form of data visualization becomes. New graphic types have been developed for that, for example, trellis displays, mosaicplots, the grand tour and parallel coordinate plots. Also the type of variable matters. Different kind of variables are vice to visualize in different way. If the variables are continuous, boxplots or histograms are right choices. If variables are categorical, piecharts or barcharts are right choices. Of course, other models can be used, too. Overall, when choosing the graphic, dependencies between variables should be examine first. If there are dependent variables, they are plotted last – in scatterplot they are usually on the vertical axis.

In addition to scatterplot, boxplot, histogram, barchart and piechart, there are dotplot, roseplot and mosaicplot and many other kind of graphics. Some just cannot be used with certain types of data, like piechart is not useful for univariate continuous data, but it is good for small number of categories. Boxplot is not suitable for bivariate categorical data, but it works well, when outliers are emphasized. In addition to interaction between variables, also the presentation scale is very important. The data could be shown even as wrong, if the scale is not right.

In data, examined in this thesis, there were three (3) different variables: x-coordinates, y-coordinates and the amount of pieces, how many times each beacon has been the nearest beacon. Instead showing the results in tables, I present the results in a graphical way. I used heat maps, because they are used, for example, to help and ease the operational decision making in health care field. [42]. It was also a wish from the thesis subscriber.

Of course, data visualization could have been done with other techniques, too, but they are not so suitable for visualizing spatial data as heat maps are. For example, with bar charts, frequencies about how much there are events per room, can be shown, but it lacks the information of how hospital personnel moves between different rooms. The same thing is with pie charts. Quite often spatial data is also illustrated as lines, but that technique is not the best choice, when visualizing data collected with Beacons. Data collected with Beacons is not very reliable, when it comes to location and with the long term, this technique produces scruffy and unclear visualizations.

There are many kinds of heat maps. They look different depending on with which tool they are made. The heat maps including in this thesis were made with Python. Also with Python, many kinds of heat maps can be created. From Python libraries, I used Pandas for data manipulation and analysis. As a plotting library, I used Matplotlib and its numerical mathematics extension called NumPy. I chose Matplotlib, because I used Tkinter and NumPy. I had multidimensional matrices and arrays and NumPy is made for supporting those structures. For heat maps, I used also SciPy, which contains many modules – one for image processing.

4.2.1.1 Heat maps

Heat maps are one form of data visualization. They take two (2) or more variables and illustrate their relation to each other with colours in two (2) dimensions. Roughly taken, there are two (2) kinds of heat maps: cluster heat maps and spatial heat maps. Cluster heat maps consists of a kind of tiles. Tiles can change their size or colour due to a value it represents. Spatial heat maps' results are more versatile. The main thing is, that there is a space, which is fulfilled with some kind of figures depending on the chosen form and variable's value. Heat maps reveal quite efficiently patterns in data and they are also good choice for revealing possible abnormalities.

Heat maps have become increasingly popular nowadays, because they are extremely suitable for plotting big data. Another reason for their popularity is, that they can display data both in two and three dimensions. Heat maps became familiar in 1970s and 1980s. First they were seen in weather maps. [43]. However, they have been in use even earlier than that, but nobody called them heat maps. The concept "heat map" became known in 1991, when it was trademarked by software designer Cormac Kinney.

Here are the chosen heat map models. They are all from intervention unit shift leader physicians' movement pattern before the deployment of the new information system.

- Figure 1: scatter plot heat map coloured by density. The more red a dot is, the more that spot has been visited.
- Figure 2: scatter plot heat map. The bigger the blue circle is, the more that area has been visited.
- Figure 3: mesh grid plot heat map. The more red the area is, the more that area has been visited. In blue areas the professionals have visited, too, but less than in red areas.

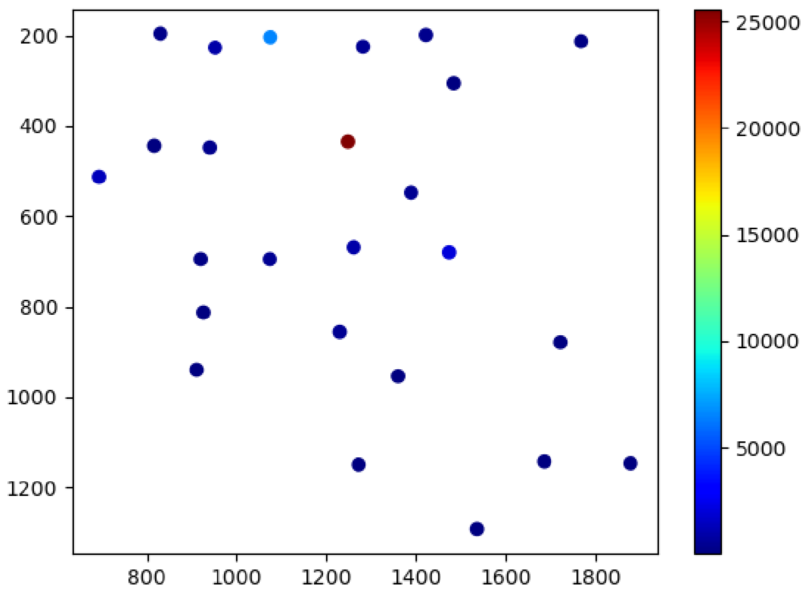


Figure 1

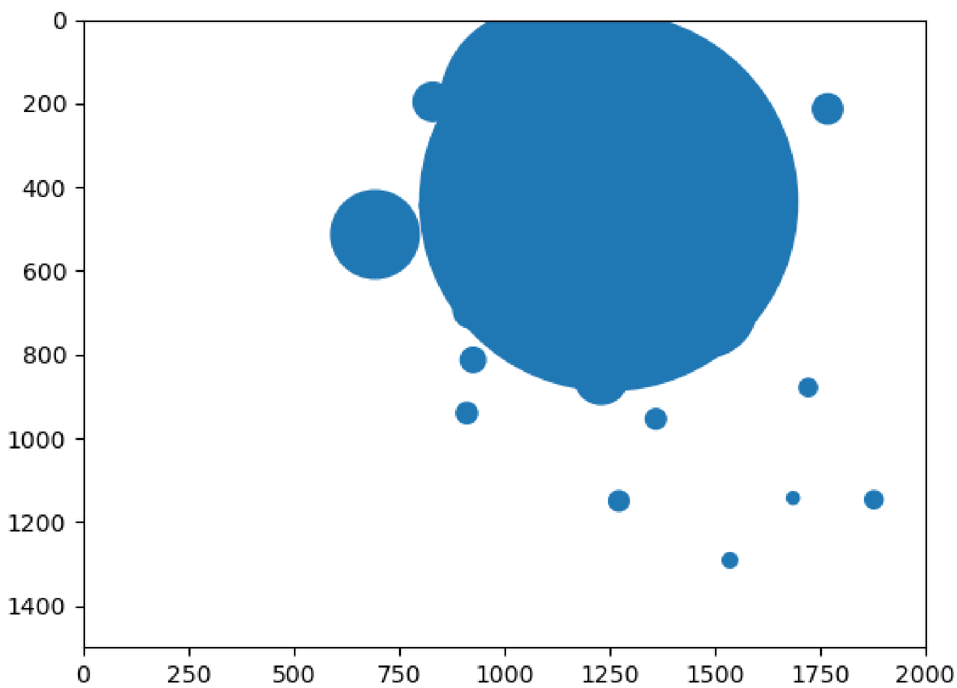


Figure 2

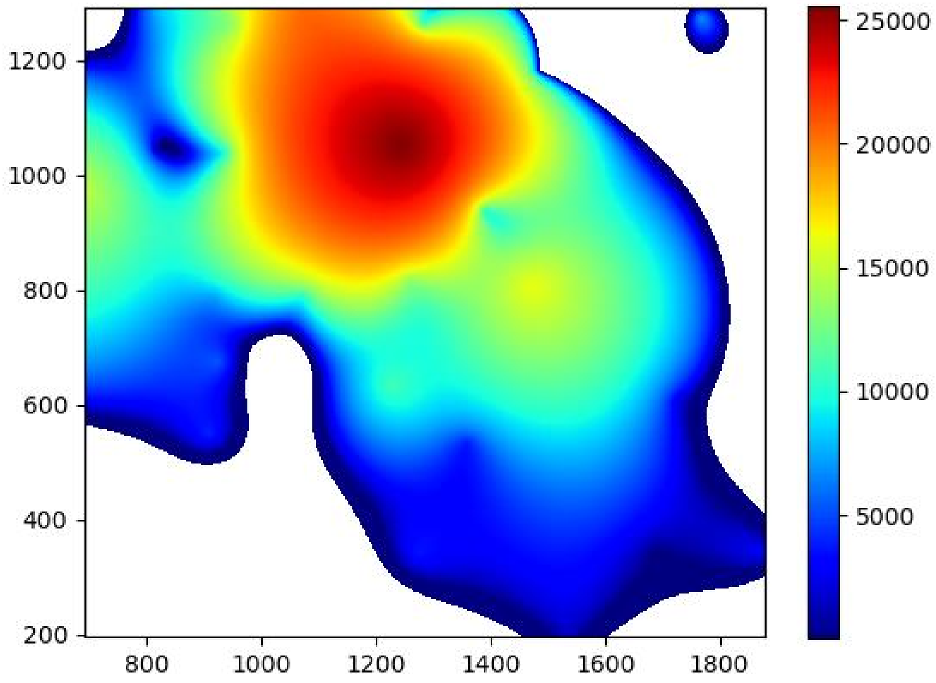

1200
1000
800
600
400
200
800
1000
1200
1400
1600
1800
25000
20000
15000
10000
5000

Figure 3

5 Data

In this section, I describe, how the data were collected in the three (3) hospitals and what kind of features it has.

5.1 The data collected from three (3) hospitals

The data, examined and evaluated in this thesis, were collected with Bluetooth beacons and smartphones in three (3) Finnish hospitals during the years 2015 - 2016. For safety and ethical reasons, in this thesis, the hospitals are called control unit A, intervention unit and control unit B. In every unit, the data was collected from emergency departments.

The smartphones, receiving the Bluetooth beacons' signals, were carried by a nurse and a physician in charge of each specific shift. They were not the same professionals every time - on the contrary, the professionals changed every shift. That makes it sure, that the involving professionals cannot be recognized. Data were collected anonymously for ethical reasons. The study had an ethical statement from the University of Turku and research approval from all three hospital districts.

A new information system (Columna Clinical Care Logistics) was implemented during the research in the intervention unit. There were also two (2) control units, one with the system already in place and the other without this system. The aim of the new information system was to help shift leader nurses and physicians to do their work more efficiently. Before the new system, the professionals needed to walk a lot as they tried to collect all the information they needed to be able to treat the patients. Data were collected before the intervention of an information system and after deploying it in intervention unit, so that it could be examined, whether the new information system changed the mobility of the shift leaders.

5.1.1 JSON (=JavaScript Object Notation)

The collected data for the research is in JSON format. JSON is an abbreviation for JavaScript Object Notation. It is an open standard file format and it is used for storing and interchanging data. JSON's syntax consists of commas, brackets, colons and braces. It is widely used, because many programming languages can handle JSON format data. Maybe most commonly it is used as an alternative to XML, that is to transmit data between a web application and a server. It is also user friendly for its human-readable text. [44].

In data, collected in a research, one JSON object (=event) consists of Bluetooth beacon's measured values. In figure 4, there is an example of one event.


```
"battstat": 3,
    "bcn": [
      {
        "d": 19.077451114128795,
        "id": [
          "0x5475726b75204f626f416b6164656d69",
          "0x0110",
          "0x0040"
        ],
        "rssi": -102,
        "tx": -58
      },
      {
    ],
    "charge": 0.88,
    "did": "186e52e1f939dbc89b895f60b7b5d797",
    "t": "2016-08-16T11:49:06.500Z"
  },
```


Figure 4

As can be seen in figure 4, there is one timestamp and then there is one or more markings about detected Bluetooth signals the smartphone has received. In practise, the signals sent by Bluetooth beacons, are received by any smartphone, which are inside Bluetooth beacons' range.

Table 1 Descriptions for Json events

BLUETOOTH MARKING	MEANING
battstat	level of the beacon's battery status
bcn	information of beacons
d	distance between a beacon and a smartphone
id	first line: UUID (Universally Unique Identifier) identifies large group of beacons second line: identifies the hospital third line: identifies the beacon
rssi	received signal strength indicator
tx	level up to which a beacon can transmit signals
charge	charge level of the smartphone
did	id of the smartphone receiving the Bluetooth signal
t	timestamp of the event

5.1.2 Data collection time-points

Data collection time-points in control unit A, intervention unit and control unit B:

Emergency department

BEFORE	AFTER
01.06. – 30.06.2015	01.06. – 30.06.2016
15.02. – 15.03.2015	15.08. – 26.09.2016
	15.11. – 15.12.2016

- The information system was installed 15.04. – 01.05.2016 in intervention unit.
- The smartphones were charged from 3 to 6 at nights.

The amount of the data involved in this examination is 6,327 Mb. Being 3 different units, 2 kinds of tracked professionals and 5 different time periods, there are totally 30 different combinations of the collected data.

5.1.3 Pieces of events in the study

Table 2 Pieces of events in the study from every unit

EMERGENCY DEPARTMENT	CONTROL UNIT A	INTERVENTION UNIT	CONTROL UNIT B
NURSE			
Before 1.6. – 30.6.2015	53515	37138	24012
Before 15.2. – 15.3.2016	42263	13737	26328
After 1.6. – 30.6.2016	54110	17115	26491
After 15.8. – 26.9.2016	65179	53517	41649
After 15.11. – 15.12.2016	25103	12090	1084

PHYSICIAN			
Before 1.6. – 30.6.2015	36306	48460	22508
Before 15.2. – 15.3.2016	32106	8385	19529
After 1.6. – 30.6.2016	26154	11534	9980
After 15.8. – 26.9.2016	14688	8416	33747
After 15.11. – 15.12.2016	1346	26658	9438

5.1.4 Description of the work phases examining the collected data

First, the data was grouped by the hospital, the professional and timestamp, so that each Excel file contains data, for example, of a physician, in intervention unit, after the deployment of an information system. This way the overall amount of each combination was discovered. There were events, which had a “depr” abbreviation in the end of the smartphone ID. These events have been left out, because presumable “depr” means, that the event is deprecated. There are also events, which has only timestamp, but no information of any beacons. These events have also been left out.

The second phase was to examine, where the professionals have been, when the smartphone they were carrying, have received Bluetooth signals. There are several ways to do that. The chosen approach method was to examine each event so, that the shortest distance from all the received distances was searched. At the same time, the ID of signal sent Bluetooth beacon was collected, too. By combining the ID with known Bluetooth beacons’ positions, the placement of the smartphone was discovered.

The third phase was to count, how many times each installed beacon has been the nearest beacon. In this way, the most visited places in each involving hospital, was found.

5.1.5 Challenges with the collected data

One way to examine, whether the new information system changed professional's mobility, would be counting the walked distances. However, that would require a lot of collected data and approximately the same amount of it from each unit, each period and each professional. In that way, the walked distances could be calculated and different periods, before and after, could be compared.

When examining the collected data, it soon became clear, that the data is quite uneven due the intense lack of motivation to carry the smartphone among the professionals. For the comparison, I wanted to choose days, which had events in 24 hours. Unfortunately, there was not enough data to compare in every unis. There are days, when there are no events at all. There are also many days, which has pauses in events during the 24 hours' time. These days are impossible to compare with each other. To get at least some kind of results, in this phase the before periods and after periods were combined.

6 Data analysis

6.1 The aim of this thesis

By analysing the collected data from three (3) hospitals, I am going to examine, whether the new deployed information system changed hospital professionals' movement. By doing this I will be able to answer my first research question. For my second research question I will create a survey. I will write a survey letter in which I will ask a few background question and then ask an opinion about those three (3) heat maps, I created from the collected data. I will send the survey letter to eight (8) healthcare professionals and after receiving the answers, I will evaluate them and make conclusions based of them.

6.2 The software used for data analysis

For making the data analysis, I used Unix for cutting data to smaller pieces, Notepad++ for formatting files to JSON-format, Python for coding, PyCharm to run the code and Microsoft Excel spreadsheet in storing, organizing and counting data.

6.3 Survey to health care professionals

To be able to answer my second research question, which is the best way to visualize the movement data, collected from hospitals concerning leading nurses' and physicians' mobility, I made a survey letter and sent it as email to eight (8) health care professionals. The survey letter is as attachment in this thesis. All the eight (8) professionals answered. Their professions were charge nurse, two (2) nurses, nurse working as application specialist, two (2) experts in clinical nursing, physiotherapist and doctor. The average of their working years was approximately 14 years.

As can be seen in table 3 below, 6/8 health professionals chose option B as the clearest model to describe shift leader nurses' and physicians' movement patterns. The arguments were, that it has just one colour, so it is clear and the contrast is lucid. Also the changes and the scale of changes can be seen just by one glance.

Table 3 Result of the survey letter

Years in healthcare field	Chosen alternative
11	B
8	B
2	B
35	B
12	B
17	B
15	C
15	C

6.4 Data analysis results as heat maps

As can be seen in the table 3 above, 6/8 of the professionals, I asked opinion of my created heat maps, chose the alternative B as the clearest choice to describe movement patterns. That is why the results below are as scatter plots images.

Figure 5 and figure 6 are from control unit A emergency department. They are both shift leader nurses' movement patterns. In control unit A, the new information system was never deployed. Figure 5 is from the before periods and figure 6 is from the after periods. The shift leader nurses' movement pattern has changed, but not much. Movement has focused a little bit more to a same area.

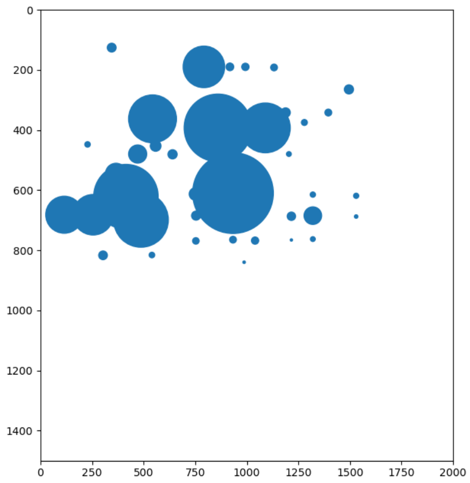


Figure 5

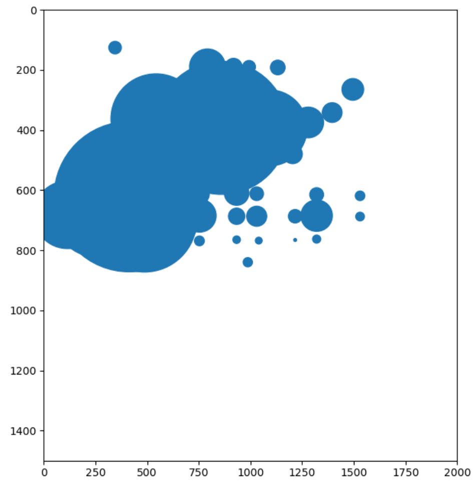


Figure 6

Figure 7 and figure 8 are from control unit A, too, but they are both shift leader physicians' movement patterns. Figure 7 is from the before periods and figure 8 is from after periods. The shift leaders' movement pattern has also changed, but not much either. Movement has focused more to certain area.

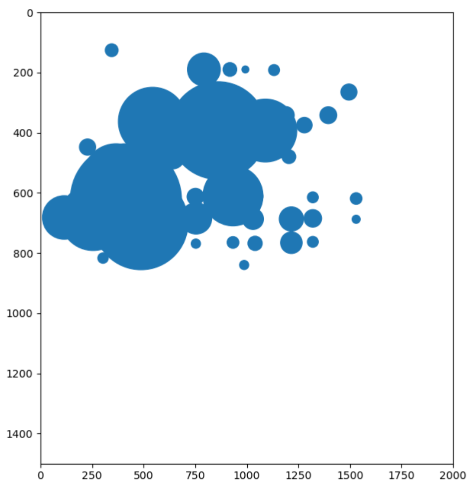


Figure 7

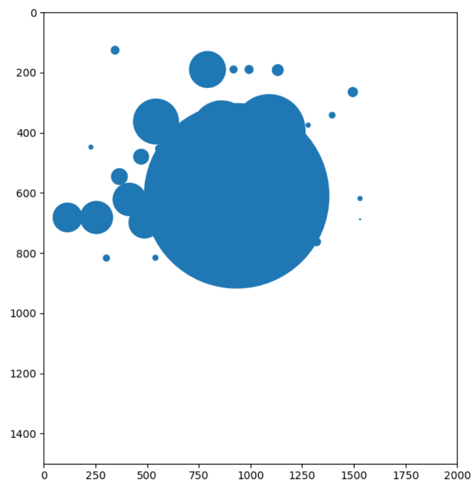


Figure 8

Figure 9 and figure 10 are from intervention unit. In intervention unit, the new information system was deployed in 15.4. – 1.5.2016. Both figures are shift leader nurses' movement patterns. Figure 9 is from before periods and figure 10 from after periods. Movement pattern has changed, but not very much. However, the movement has concentrated more to a certain area.

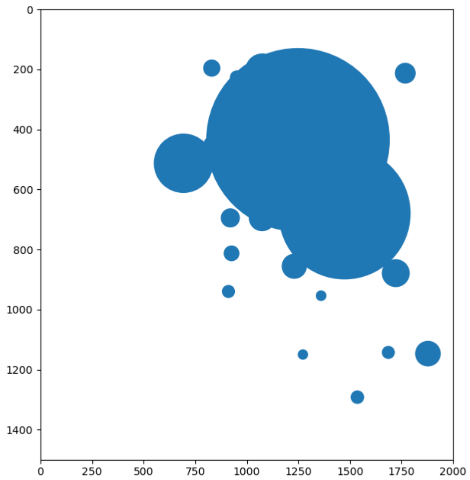


Figure 9

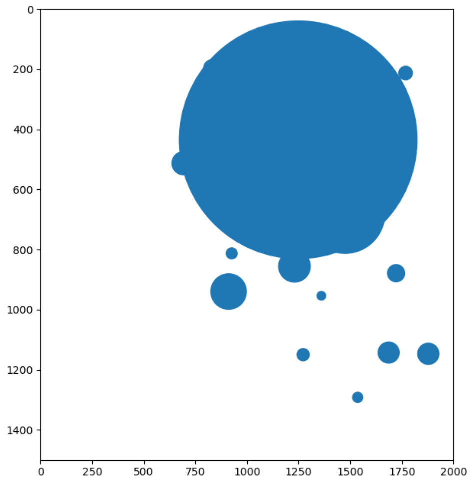


Figure 10

Figure 11 and figure 12 are also from the intervention unit, but they are both shift leader physicians' movement patterns. Figure 11 is from periods before the new information system was deployed and figure 12 is from periods after the system has been deployed. The movement pattern has changed, but maybe surprisingly, it seems, that leading physicians move more after the new information system has been deployed.

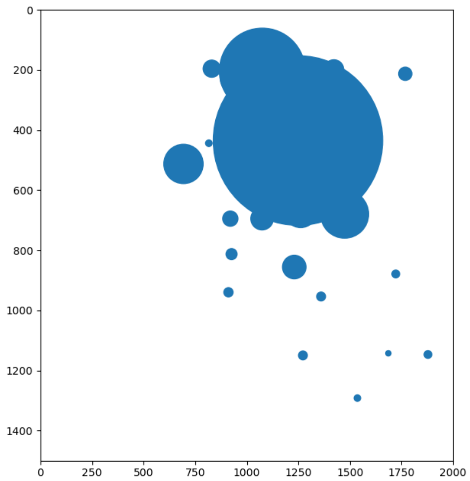


Figure 11

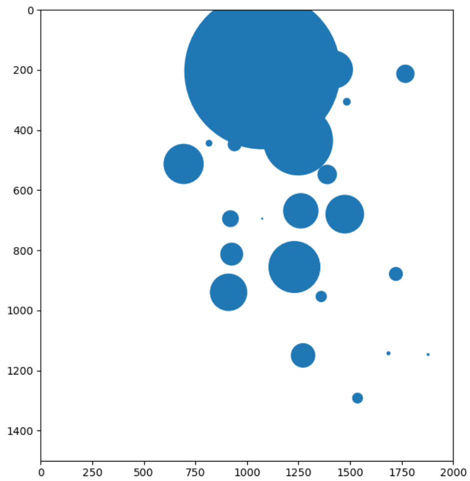
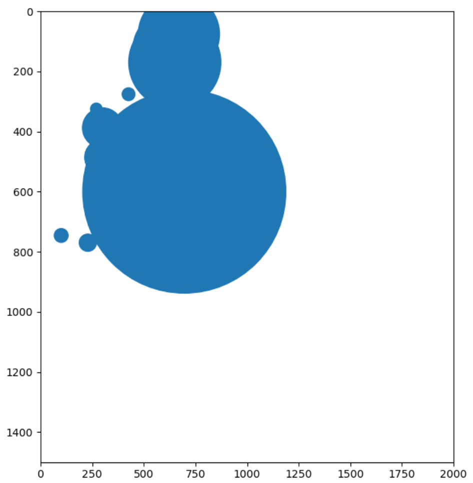


Figure 12

Figure 13 and figure 14 are from control unit B. In this unit, the new information system was already in use. Both figures are shift leader nurses' movement patterns. Figure 13 is from before periods and figure 14 is from after periods. The movement pattern has changed. Figure 14 shows, that movement has been even increased, but at the same time, it has focused more to a certain area.



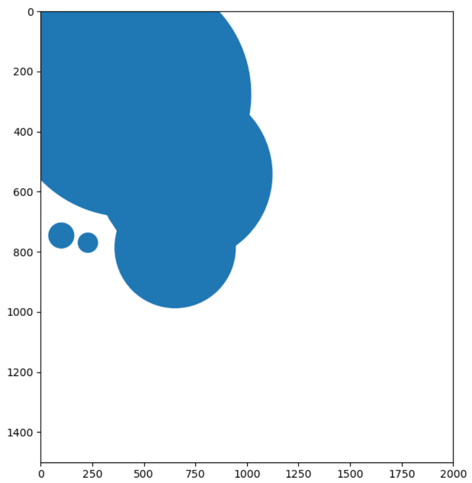
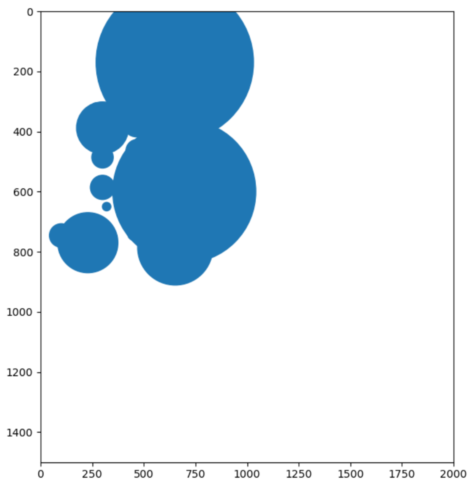


Figure 13 Figure 14

Figure 15 and figure 16 are from control unit B, too, but they are both shift leader physicians' movement patterns. Figure 15 is from before periods and figure 16 is from after periods. The movement pattern has changed. In this unit, leading physicians' movement has been focused more to one area.



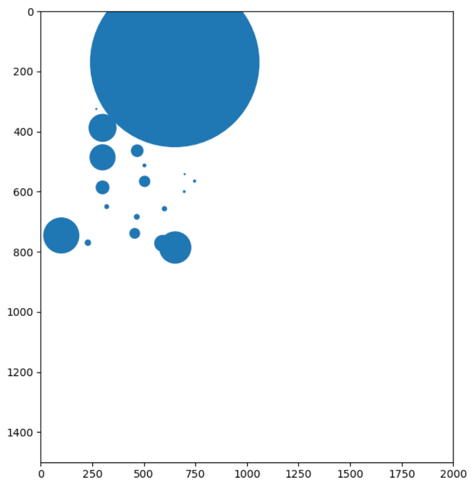


Figure 15 Figure 16

7 Conclusion

7.1 Summary

The aim of this thesis was to examine, whether a new information system changed the hospital shift leader nurses' and physicians' mobility patterns. It was done by examining the data collected from three (3) hospitals in the years 2015 – 2016.

When I started to examine the collected data, I assumed, that the result will be quite obvious: the new information system changed hospital leading physicians' and leading nurses' mobility patterns. I expected, that just by counting the events before and after the deployment of the new information system, I could justify, that their mobility decreased noticeably. It soon became clear, that that was not the case.

The data were collected in periods: there were two (2) before periods and three (3) after periods. While gathering data by periods, I noticed, that there are notable differences even between two (2) periods before the deployment. These differences required closer look. It turned out, that the data were quite uneven. No single one period is fully covered. There are days, when there are no events at all or days, when there is a long break without any events. The reason to this is, that the leading nurses and physicians carried smartphones with different intensity. That made the examination of the data quite hard.

It is not unusual, that the examined data has weaknesses. In this case, the missing events was the weakness of this examined data. A lack of events was so serious, that to be able to do at least some kind of reliable data examination, the before periods were combined and after periods were combined. In this way, there was enough data to get results. However, it was impossible to count walked distances reliable, so the results are just for comparing the visualised movement patterns before the new information system was deployed with after the new information system was deployed.

My research questions originally were:

1. Were the mobility patterns of hospitals' shift leader professionals changed by a new information system?
2. Which is the best way to visualize the data, collected from hospitals concerning shift leader nurses' and physicians' mobility?

1) Based on the heat maps, movement patterns have changed in every unit with every professional, but not so much as I expected. I expected, that the movement patterns would have changed the most in intervention unit, but those movement patterns are quite the same before and after the new information system deployment. The most have changed the shift leader physicians' movement pattern in control unit A and shift leader nurses' and physicians' movement patterns in control unit B. The least have changed shift leader nurses' movement patterns in intervention unit and control unit A. Data being too uneven, I was not able to count walked distances.

2) To be able to answer my second research question, I wrote a survey letter and sent it by email to eight (8) health care professionals. All of them answered. Option B got

six (6) choices and option C got two (2) choices. This means, that health care professionals chose option B, a scatter plot heat map, as the clearest choice to describe the hospital shift leader nurses' and physicians' movement patterns.

7.2 Factors influencing on study

Even though my main assignment was purely to examine the data in a statistical way, I listed things, that could have influenced on unevenness of the collected data. In this kind of research involving human factors, at least these things should be taken to account.

1. Personal differences
    a. One likes to move, the other one does not.
2. Health issues
    a. One needs to use the toilet more often than the other.
3. Working years
    a. Working many years as a nurse or physician gives so much experience, that one does not necessarily need to use an information system as much as a junior colleague.
4. Permanent worker vs. substitute
    a. If a nurse or physician has worked for many years in a certain hospital, one does not need to search so much, for example, certain rooms, as maybe a substitute needs to do.
5. The time of the year
    a. In a winter (slippery road conditions), there might be more patients to be taken care of, so more information is needed, too.
6. Familiar patients
    a. Incoming patients are so called regular patients, so professionals already know quite much about their medical history.
7. The attitude towards the new information system
    a. Other people like to learn, how to use new systems, the other like to use the old system.
    b. Sometimes people get the feeling, that they must use the new system, because it has been supplied, even though they do not need to use it in every situation and so often.
8. A beacon or a smartphone has not been working properly.

The things most affected in this case, were the seventh (7$^{th)}$ and the eighth (8$^{th)}$ things on the list. There were professionals, who did not want to carry the smartphone. Also, there were times, when the smartphones were not working correctly. Even more, in some units, there were some beacons missing.

7.3 Future work

The study done in these three (3) emergency departments, was well-founded and needed. However, due to lack of data, the study should be renewed. This issue certainly needs more examination. The methods, Bluetooth beacons and smartphones, were suitable methods to do the research, but other indoor position systems could be considered, too. There are a lot of other indoor positioning systems, but maybe not each and every one is suitable for this kind of research [15]. Many of them need some kind of equipment, as was the case with

Bluetooth beacons and smartphones. For example, Wi-Fi based systems needs Wi-Fi and even if that exists in a hospital, it is not everywhere, so there will be places, which are not monitored. If it would be some way possible, there could be certain professionals to be involved in a study. This way the data should be more continuous.

References

[1] Peltonen, L. M. (2018) INFORMATION NEEDS IN THE DAY-TO-DAY OPERATIONS MANAGEMENT OF HOSPITAL UNITS. PhD thesis, University of Turku, Finland.

[2] Peltonen, L. M., Junttila, K., & Salantera, S. (2018). Nursing leaders' satisfaction with information systems in the day-to-day operations management in hospital units. *NURSING INFORMATICS 2018: ICT TO IMPROVE QUALITY AND SAFETY AT THE POINT OF CARE*.

[3] Peltonen, L. M., Junttila, K., & Salanterä, S. (2018). Front-Line Physicians' Satisfaction with Information Systems in Hospitals. *Building Continents of Knowledge in Oceans of Data: The Future of Co-Created eHealth Proceedings of MIE2018*.

[4] Vänskä, J., Vainiomäki, S., Kaipio, J., Hyppönen, H., Reponen, J., & Lääveri, T. (2014). Potilastietojärjestelmät lääkärin työvälineenä 2014: käyttäjäkokemuksissa ei merkittäviä muutoksia. *Suomen lääkärilehti*, *69*(49), 3351-3358.

[5] Saastamoinen, P., Hyppönen, H., Kaipio, J., Lääveri, T., Reponen, J., Vainiomäki, S., & Vänskä, J. (2019). Lääkärien arviot potilastietojärjestelmistä ovat parantuneet hieman. Lääkärilehti 34/2018. Vsk 73, 1814–1820.

[6] Liljebäck, M. (2018). Indoor Positioning for Evaluating an Information System Used in a Hospital Environment. Ms. thesis, Åbo Akademi University.

[7] Heo, Y., Choudhary, R., Bafna, S., Hendrich, A., & Chow, M. P. (2009, June). A modeling approach for estimating the impact of spatial configuration on nurses' movement. In *Proceedings of the 7th International Space Syntax Symposium* (Vol. 1, No. 1, p. 41).

[8] Bardram, J. E., & Bossen, C. (2005). Mobility work: The spatial dimension of collaboration at a hospital. *Computer supported cooperative work (CSCW)*, *14*(2), 131-160.

[9] Marques, R., Gregório, J., Pinheiro, F., Póvoa, P., da Silva, M. M., & Lapão, L. V. (2015). Improving Nurses' Hand Hygiene Compliance using Gamification. In *PAHI* (pp. 33-42).

[10] Moran, E. B., Tentori, M., Gonzalez, V. M., Favela, J., & Martinez-Garcia, A. I. (2007). Mobility in hospital work: towards a pervasive computing hospital environment. *International journal of electronic healthcare*, *3*(1), 72-89.

[11] Prgomet, M., Georgiou, A., & Westbrook, J. I. (2009). The impact of mobile handheld technology on hospital physicians' work practices and patient care: a systematic review. *Journal of the American Medical Informatics Association*, *16*(6), 792-801.

[12] Yang, J., Wang, Z., & Zhang, X. (2015). An ibeacon-based indoor positioning systems for hospitals. *International Journal of Smart Home*, *9*(7), 161-168.

[13] Mohsin, N., Payandeh, S., Ho, D., & Gelinas, J. P. (2019). Study of Activity Tracking through Bluetooth Low Energy-Based Network. *Journal of Sensors*, *2019*.

[14] Hansen, T. R., Bardram, J. E., & Soegaard, M. (2006). Moving out of the lab: Deploying pervasive technologies in a hospital. *IEEE Pervasive Computing*, *5*(3), 24-31.

[15] Van Haute, T., De Poorter, E., Crombez, P., Lemic, F., Handziski, V., Wirström, N., ... & Moerman, I. (2016). Performance analysis of multiple Indoor Positioning Systems in a healthcare environment. *International journal of health geographics*, *15*(1), 1-15.

[16] Hjalmarsson, A., & Johansson, H. (2017). *Localisation and mapping of received signal strength in a hospital environment* (Master's thesis). Chalmers University of Technology, Sweden.

[17] Shirehjini, A. A. N., Yassine, A., & Shirmohammadi, S. (2012). Equipment location in hospitals using RFID-based positioning system. *IEEE Transactions on information technology in biomedicine*, *16*(6), 1058-1069.

[18] Zhu, Y. J. Overview: Visualizing Healthcare Data.

[19] Canzian, L., & Musolesi, M. (2015, September). Trajectories of depression: unobtrusive monitoring of depressive states by means of smartphone mobility traces analysis. In *Proceedings of the 2015 ACM international joint conference on pervasive and ubiquitous computing* (pp. 1293-1304).

[20] Souza, R. C., Assunção, R. M., Neill, D. B., & Meira Jr, W. (2019, November). Detecting spatial clusters of disease infection risk using sparsely sampled social media mobility patterns. In *Proceedings of the 27th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems* (pp. 359-368).

[21] Batty, M., DeSyllas, J., & Duxbury, E. (2003). The discrete dynamics of small-scale spatial events: agent-based models of mobility in carnivals and street parades. *International Journal of Geographical Information Science*, *17*(7), 673-697.

[22] Chen, W., Guo, F., & Wang, F. Y. (2015). A survey of traffic data visualization. *IEEE Transactions on Intelligent Transportation Systems*, *16*(6), 2970-2984.

[23] Netek, R., Pour, T., & Slezakova, R. (2018). Implementation of heat maps in geographical information system–exploratory study on traffic accident data. *Open Geosciences*, *10*(1), 367-384.

[24] Hilton, B. N., Horan, T. A., Burkhard, R., & Schooley, B. (2011). SafeRoadMaps: Communication of location and density of traffic fatalities through spatial visualization and heat map analysis. *Information Visualization*, *10*(1), 82-96.

[25] Tomanek, D. P., & Schröder, J. (2017). Traffic load heat map–an innovative approach for the analysis and optimization of internal traffic.

[26] GBS, official technical information. Available online at https://gsb-international.de/en/information/technical-information/, 2014. Accessed 2020-06-07.

[27] Gu, Y., Lo, A., & Niemegeers, I. (2009). A survey of indoor positioning systems for wireless personal networks. *IEEE Communications surveys & tutorials*, *11*(1), 13-32.

[28] Kaustinen, M., Taskinen, M., Säntti, T., Arvo, J., & Lehtonen, T. (2015) MAP MATCHING BY USING INERTIAL SENSORS.

[29] Want, R., Hopper, A., Falcao, V., & Gibbons, J. (1992). The active badge location system. *ACM Transactions on Information Systems (TOIS)*, *10*(1), 91-102.

[30] Pratama, A. R., & Hidayat, R. (2012, September). Smartphone-based pedestrian dead reckoning as an indoor positioning system. In *2012 International Conference on System Engineering and Technology (ICSET)* (pp. 1-6). IEEE.

[31] Kang, W., & Han, Y. (2014). SmartPDR: Smartphone-based pedestrian dead reckoning for indoor localization. *IEEE Sensors journal*, *15*(5), 2906-2916.

[32] Davidson, P., & Piché, R. (2016). A survey of selected indoor positioning methods for smartphones. *IEEE Communications Surveys & Tutorials*, *19*(2), 1347-1370.

[33] Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M. A., & Al-Khalifa, H. S. (2016). Ultra wideband indoor positioning technologies: Analysis and recent advances. *Sensors*, *16*(5), 707.

[34] Mainetti, L., Patrono, L., & Sergi, I. (2014, September). A survey on indoor positioning systems. In *2014 22nd international conference on software, telecommunications and computer networks (SoftCOM)* (pp. 111-120). IEEE.

[35] Bluetooth, technical specifications. Available online at: https://www.bluetooth.com/specifications/. Accessed 2020-06-07.

[36] Faragher, R., & Harle, R. (2014, September). An analysis of the accuracy of bluetooth low energy for indoor positioning applications. In *Proceedings of the 27th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2014)* (pp. 201-210).

[37] Faragher, R., & Harle, R. (2015). Location fingerprinting with bluetooth low energy beacons. *IEEE journal on Selected Areas in Communications*, *33*(11), 2418-2428.

[38] Grönroos, S., Peltonen, L. M., Soloviev, V., Lilius, J., & Salanterä, S. (2017). Indoor positioning system for movement path analysis in healthcare institutions. *Finnish Journal of eHealth and eWelfare*, *9*(2-3), 112-120.

[39] Grönroos, S., Peltonen, L. M., Soloviev, V., Lilius, J., & Salanterä, S. (2017). Indoor positioning system for movement path analysis in healthcare institutions. *Finnish Journal of eHealth and eWelfare*, *9*(2-3), 112-120.

[40] Ward, M. O., Grinstein, G., & Keim, D. (2010). *Interactive data visualization: foundations, techniques, and applications*. CRC Press.

[41] Chen, C. H., Härdle, W. K., & Unwin, A. (Eds.). (2007). *Handbook of data visualization*. Springer Science & Business Media.

[42] Dinesh, A. S., Mathur, V., Ansil, B. R., Chandru, V., Chellam, R., Vanak, A. T., ... & Rajagopal, P. (2020). Health Heatmap of India: An Open Data Platform. *Journal of the Indian Institute of Science*, 1-16.

[43] Babicki, S., Arndt, D., Marcu, A., Liang, Y., Grant, J. R., Maciejewski, A., & Wishart, D. S. (2016). Heatmapper: web-enabled heat mapping for all. *Nucleic acids research*, *44*(W1), W147-W153.

[44] JSON format's official technical standard documentation. Available online at: http://www.ecma-international.org/publications/files/ECMA-ST/ECMA-404.pdf. Accessed 2020-06-07.

Appendix

RESULTS AS OTHER HEAT MAP MODELS

Next heat map models are scatter plot heat maps, which are coloured by density. The more red a dot is, the more that spot has been visited. This heat map model did not get any choices from health care professionals. They thought, that this model was the most unclear.

Figure 17 and figure 18 are from control unit A. Both figures describe shift leader nurses' movement patterns.

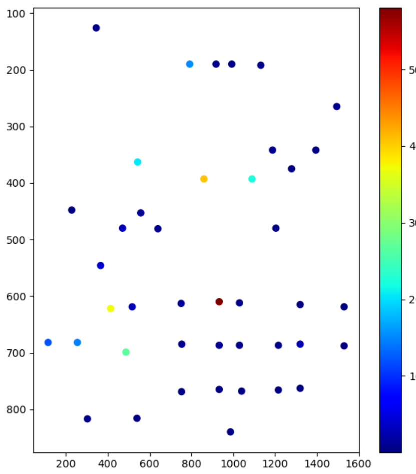


Figure 17

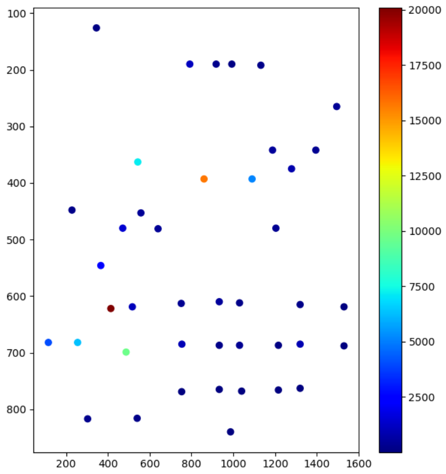


Figure 18

Figure 19 and figure 20 are also from control unit A, but they are shift leader physicians' movement patterns.

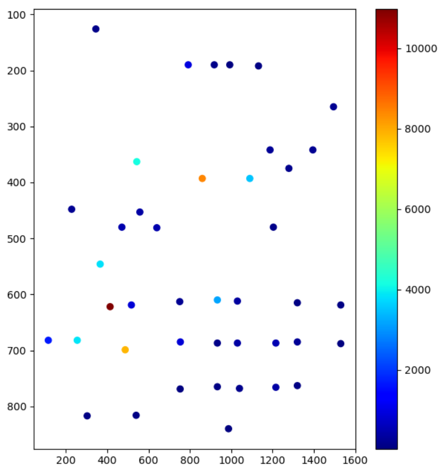


Figure 19

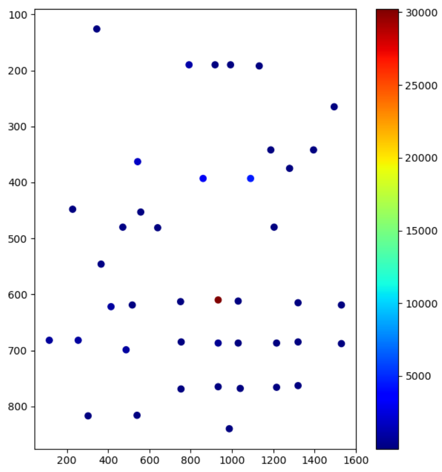


Figure 20

Figure 21 and figure 22 are from intervention unit. Both figures describe the shift leader nurses' movement patterns.

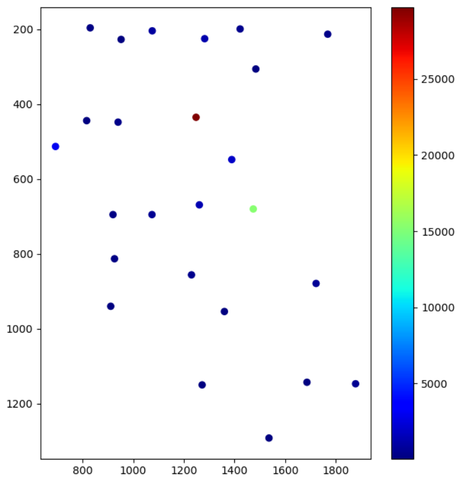


Figure 21

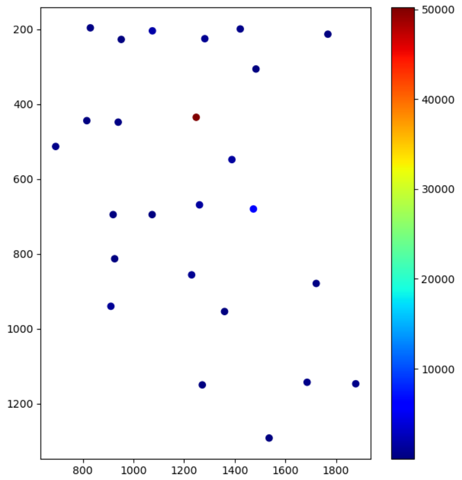


Figure 22

Figure 23 and figure 24 are from intervention unit, too, but they describe the shift leader physicians' movement patterns.

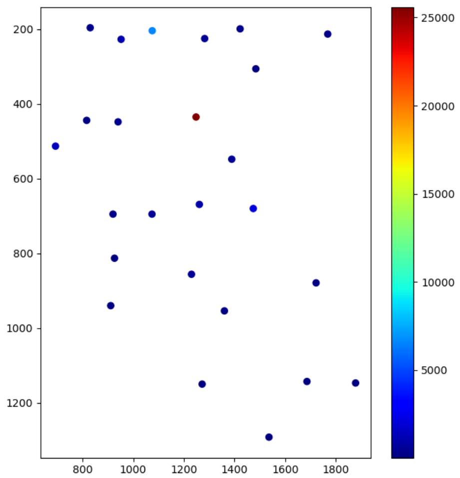


Figure 23

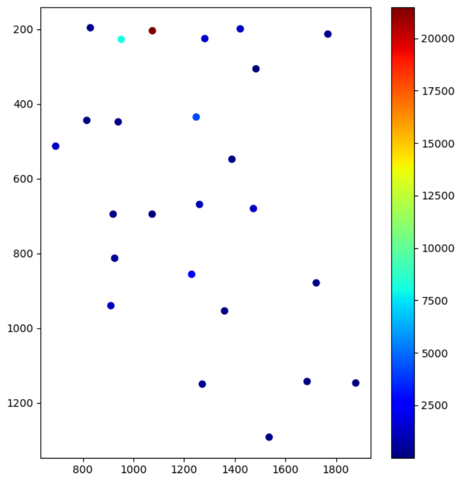
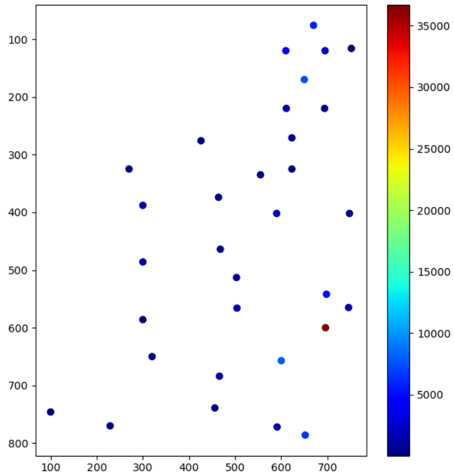


Figure 24

Figure 25 and figure 26 are from control unit B. Both figures describe shift leader nurses' movement patterns.



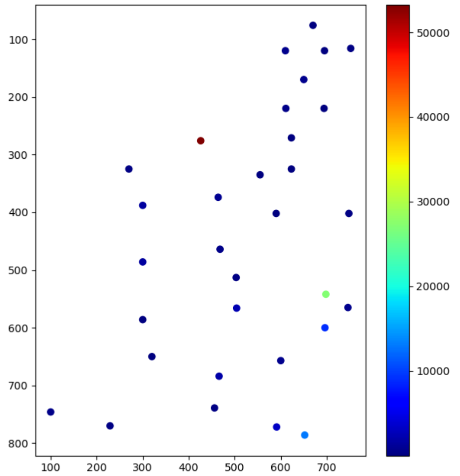
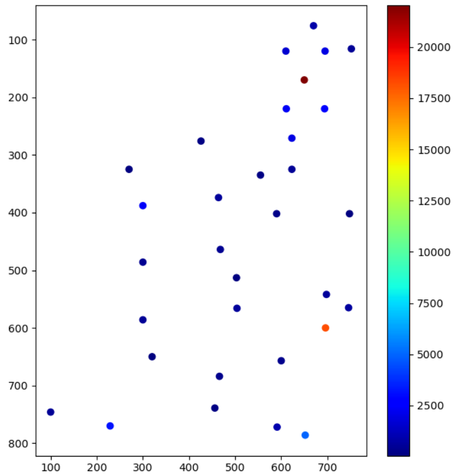


Figure 25

Figure 26

Figure 27 and figure 28 are from control unit B, too, but both describe shift leader physicians' movement patterns.



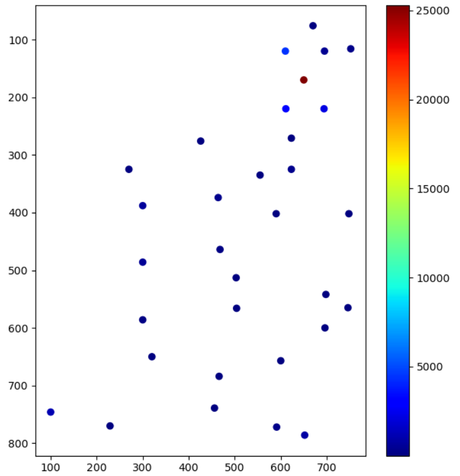


Figure 27

Figure 28

Next heat map models are mesh grid plot heat maps. The more red area is, the more that area has been visited. In blue areas professionals have visited, too, but less than in red areas. This heat map model got two (2) choices from health care professionals. As an argument was, that this kind of model is already familiar, for example, from weather maps and it is obvious, what colours mean on image.

Figure 29 and figure 30 are from control unit A. Both figures describe shift leader nurses' movement patterns.

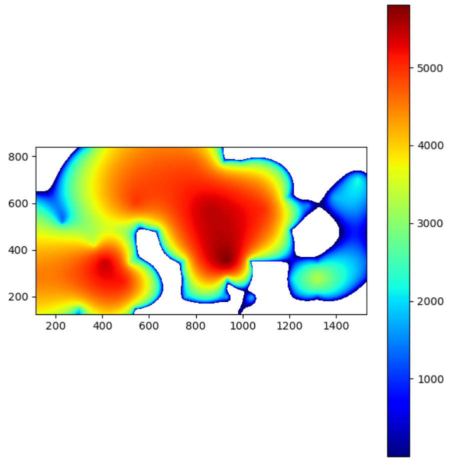


Figure 29

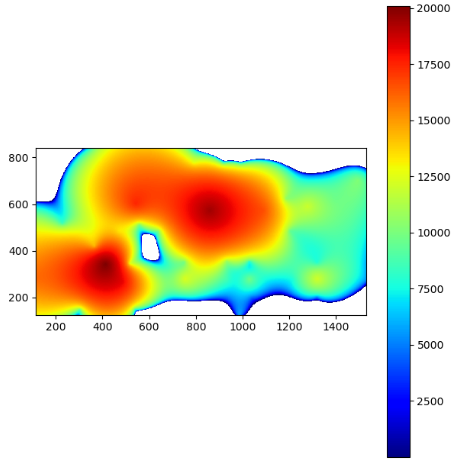


Figure 30

Figure 31 and figure 32 are from control unit A, too, but both figures describe the shift leader physicians' movement patterns.

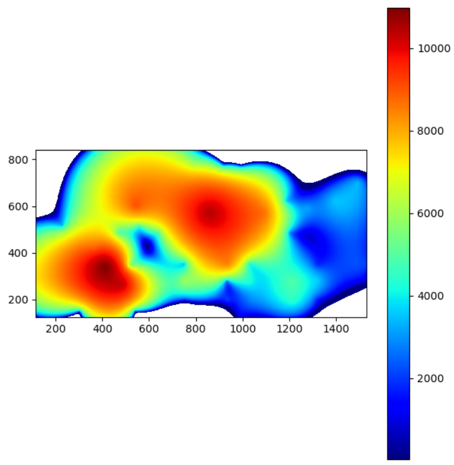


Figure 31

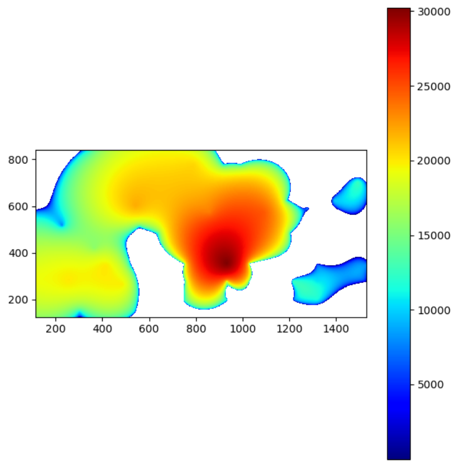


Figure 32

Figure 33 and figure 34 are from intervention unit. Both figures describe the shift leader nurses' movement patterns.

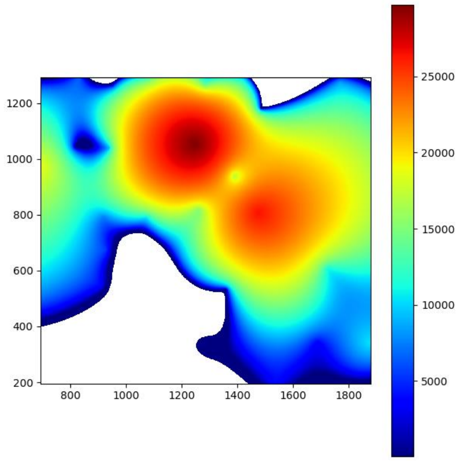


Figure 33

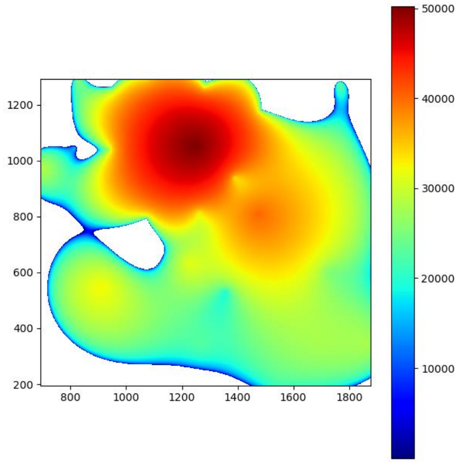


Figure 34

Figure 35 and figure 36 are from intervention unit, too, but both figures describe shift leader physicians' movement patterns.

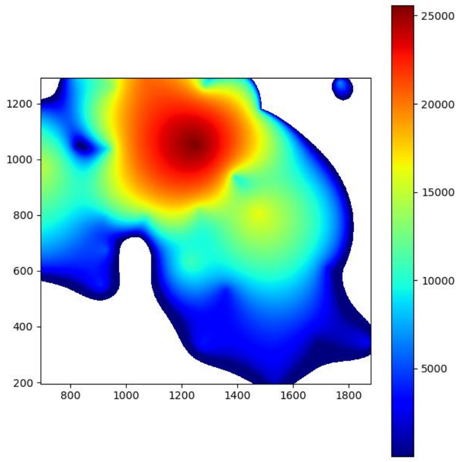


Figure 35

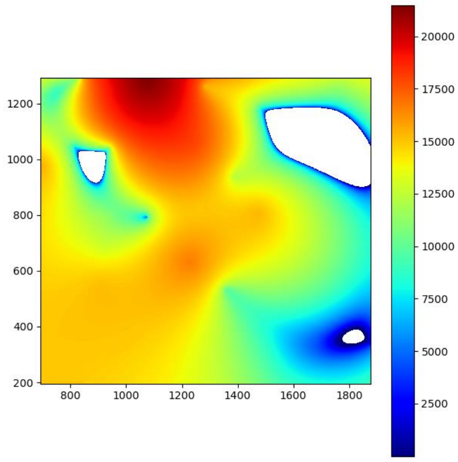


Figure 36

Figure 37 and figure 38 are from control unit B. Both figures describe the shift leader nurses' movement patterns.

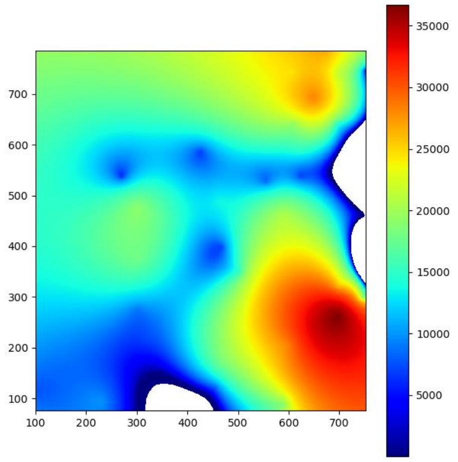


Figure 37

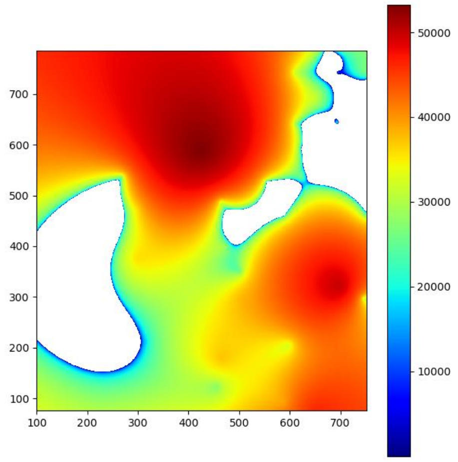


Figure 38

Figure 39 and figure 40 are from control unit B, too, but both figures describe the shift leader physicians' movement patterns.

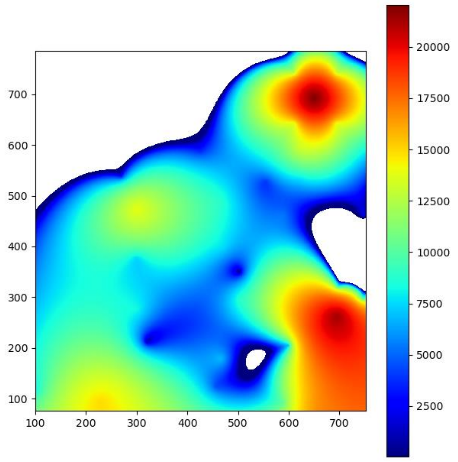


Figure 39

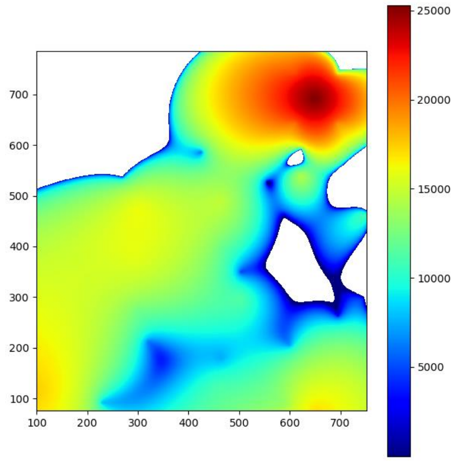


Figure 40

The survey letter

Hei!

Olen Marjo Kullanmäki ja opiskelen Turun Yliopistossa ohjelmistotekniikan diplomi-insinööri muuntokoulutuksessa. Diplomityöni aihe on Tietojärjestelmän vaikutus sairaalan henkilökunnan liikkuvuuteen. Työssäni arvioidaan kolmesta sairaalasta kerätyn datan perusteella, vaikuttiko sairaalaan hankittu uusi tietojärjestelmä sairaalan henkilökunnan liikkuvuuteen. Analyysiä varten tarvitsen tiedon siitä, mikä on paras tapa graafisesti esittää tällaisen tutkimuksen tuloksia ammattilaisille.

Olen tehnyt tuloksista kolme (3) erilaista mallia. Pyydän Sinua arvioimaan, mikä kolmesta mallista on selkein ja informatiivisin tilanteessa, jossa halutaan verrata liikkumista ennen ja jälkeen tietojärjestelmän käyttöönoton. Kerään aineiston sähköpostikyselyllä. Kyselyssä on myös muutama taustatietokysymys. Vastaaminen kestää arviolta 15-20 minuuttia.

Jos olet halukas osallistumaan arviointiin, pyydän Sinua vastaamaan liitteenä olevaan kyselyyn ja lähettämään sen minulle sähköpostiosoitteeseeni mkkull@utu.fi. En jaa mitään tietojasi kenellekään ja hävitän ne työni valmistuttua.

Osallistumisesi on täysin vapaaehtoista. Voit myös milloin tahansa keskeyttää osallistumisesi ilmoittamatta syytä keskeytykselle ilman minkäänlaisia seuraamuksia. Keskeyttäessäsi osallistumisesi siihen mennessä kerätyt esittämäsi arviot hävitetään, eikä niitä käytetä millään tavoin diplomityössäni.

Tulokset raportoidaan diplomityössäni siten, ettei yksittäisen henkilön antama tieto ole tunnistettavissa. Aineisto hävitetään, kun työ on valmistunut.

Olen saanut diplomityöni aiheen Turun yliopiston hoitotieteen laitoksen post doc -tutkijalta Laura-Maria Peltoselta (lmemur@utu.fi). Hän toimii diplomityöni ohjaajana yhdessä Turun yliopiston tulevaisuuden teknologioiden laitoksen apulaisprofessori Antti Airolan kanssa.

Toivoisin Sinun vastaavan 20.11.2020 mennessä.

Suuret kiitokset jo etukäteen!

Ystävällisin terveisin,

Marjo Kullanmäki

mkkull@utu.fi

TIETOJÄRJESTELMÄN VAIKUTUS SAIRAALAN HENKILÖKUNNAN LIIKKUVUUTEEN

TAUSTATIEDOT

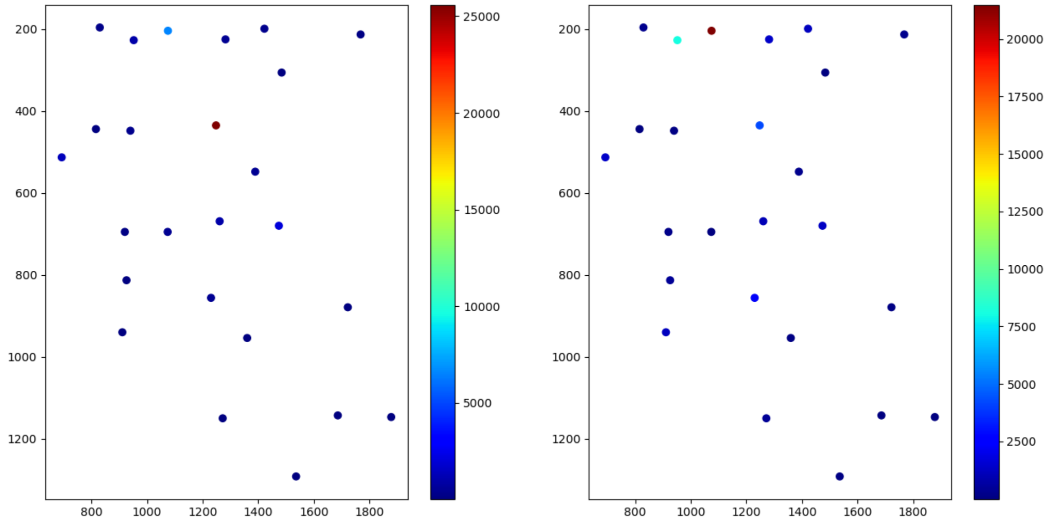
AMMATTI:

TYÖTEHTÄVÄ:

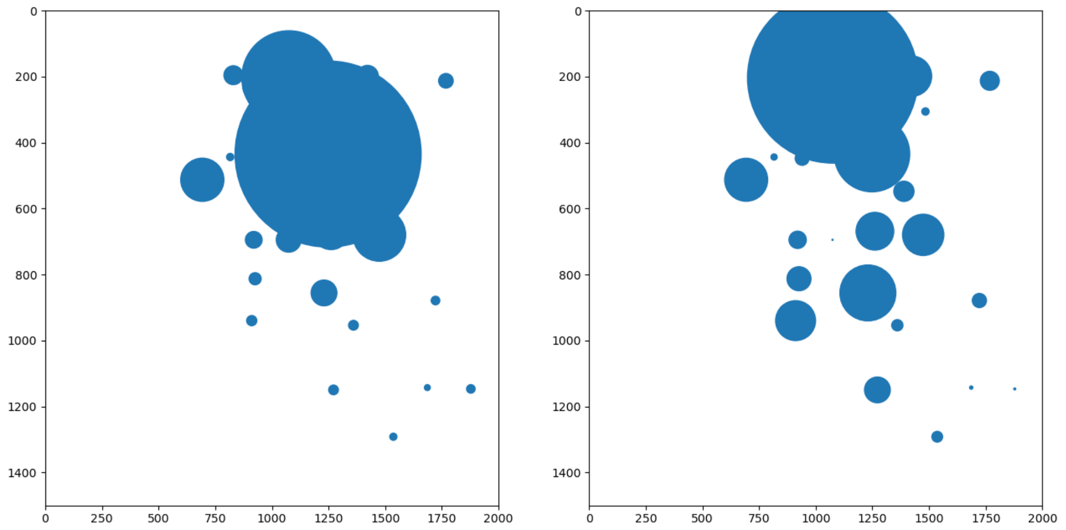
TYÖKOKEMUS VUOSINA:

MIKÄ SEURAAVISTA MALLEISTA ON MIELESTÄSI SELKEIN KUVAAMAAN TILANNETTA, JOSSA VERRATAAN SAIRAALASTA KERÄTYN DATAN PERUSTEELLA, VAIKUTTIKO SAIRAALAAN HANKITTU UUSI TIETOJÄRJESTELMÄ HENKILÖKUNNAN LIIKKUVUUTEEN?

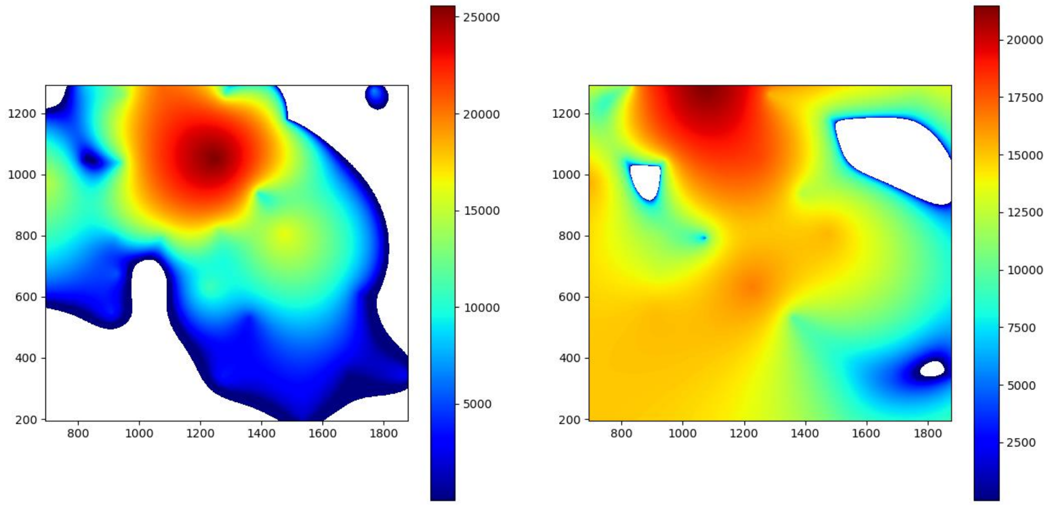
- Kaikki mallit ovat samasta sairaalasta samalta ammattilaiselta samalta ajanjaksolta kerätystä datasta, jotta ne olisivat keskenään vertailukelpoisia.
- Malleissa vasemmanpuoleinen kuva on ajalta ennen tietojärjestelmän käyttöönottoa ja oikeanpuoleinen kuva tietojärjestelmän käyttöönoton jälkeen.
- Mallit on esitetty tietoturvasyistä ilman sairaaloiden pohjakarttoja.
- Merkitse rasti valitsemasi mallin kohdalle. Voit halutessasi perustella vastaustasi kyselyn lopussa kohtaan ”Perustelut valinnalleni:”.



VAIHTOEHTO A: _____



VAIHTOEHTO B: ______



VAIHTOEHTO C: _____

PERUSTELUT VALINNALLENI: