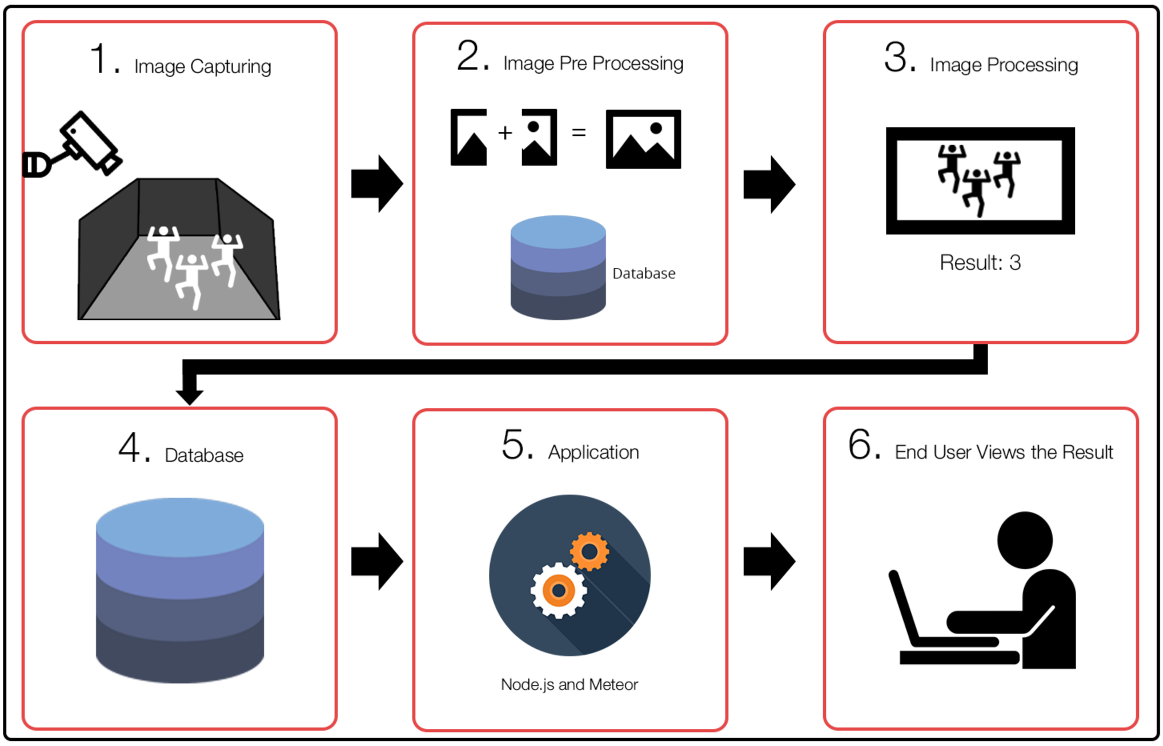
CHALMERS



Tracking Guest Flows at Night Clubs

Anton Bengtsson, Ulrik Börjesson, Oscar Evertsson,
Martin Fredriksson, Simon Gustafsson, Adam Wiklund

Bachelor of Science Thesis in Computer Science and Engineering

Chalmers University of Technology
University of Gothenburg
Department of Computer Science and Engineering
Gothenburg, Sweden, May 2017

Tracking Guest Flows at Night Clubs

Anton Bengtsson
Ulrik Börjesson
Oscar Evertsson
Martin Fredriksson
Simon Gustafsson
Adam Wiklund

Examiner: Arne Linde

Chalmers University of Technology
University of Gothenburg
Department of Computer Science and Engineering
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

Department of Computer Science and Engineering
Göteborg, Sweden May 2017

Abstract

Creating new solutions or optimizing already existing ones has been in the human nature as far history can tell. Necessarily it does not always have to be the revolutionary, such as flying to the moon. It could be smaller things as optimizing the travel time by a couple percent. In businesses today, one of the most expensive costs are personnel. Therefore, optimizing this resource could be a good way for companies to further develop their businesses. Nightclub Data AB (VNU) makes digital clickers for tracking the flow of people at the entrances of night clubs. To further track the flow of people within the night clubs, rather than just the entrance, the company has commissioned a research regarding how this could be achieved.

The goal of this project was therefore to develop a prototype able to count the amount of people inside a night club. Furthermore this data was supposed to be visualized in an intuitive way for night club managers and staff in order to optimize their business.

A pre-study was carried out in order to explore and evaluate different possible methods and technologies. The methods and technologies that were found to be most suitable was then tested in the process of developing a prototype.

The resulting prototype captures thermal images which are then processed by binarization and white pixel area calculations in order to count the amount of people in them. This data is then sent to a database that is accessed and visualized for the end-user in a web interface that integrates with VNU's existing system.

In conclusion a prototype was successfully developed for tracking the guest flows at night-clubs. The prototype fulfills the requirement specified early in the project with exception of cost. However, creating a complete system for tracking the guest flow was harder than expected and contains room for possible improvements.

Keywords: Camera, tracking, night clubs, Matlab, image analysis, human movement.

Sammanfattning

Att skapa nya lösningar och optimera redan existerande har varit en del av människans natur så långt som historien visar. Det betyder inte nödvändigtvis att det alltid måste vara stora, revolutionerande steg så som att flyga till månen. Det kan istället vara små steg så som att optimera en restid med några få procent. I dagens företag är en av de största utgifterna personalkostnaden. Därav kan det till stor vinst för ett företag om man kan optimera dessa resurser. Nightclub Data AB (VNU) utvecklar och tillverkar digitala räknare för att följa hur gäster flödar igenom entrér till natklubbar. Som en vidareutveckling letar de nu efter ett sätt att spåra människors rörelsemönster även inne på nattklubben. Det är här detta projekt kommer in.

Målet med detta projekt var därför att utveckla en prototyp som kan räkna antalet människor i olika delar av en nattklubb. Vidare ska datan som samlas in visualiseras på en intuitivt sätt för nattklubbarnas personal för att de ska kunna vidareutveckla sin affärsmodell.

Inledningsvis gjordes en förstudie för att utforska och utvärdera olika möjliga metoder och teknologier. Metoderna som visade sig vara mest lämpade testades sedan i utvecklingsfasen av prototypen.

Den resulterande prototypen fångar bilder med en värmekamera som sedan binäriseras. Baserat på hur stor del av bilden som innehåller vita pixlar görs sedan en uppskattning av hur många personer det är på bilden. Denna data skickas sedan till en databas som ett webbgränssnitt integrerat med VNU's system. Detta webbgränssnitt visar datan intuitivt och visuellt för slutanvändaren.

Sammanfattningsvis så utvecklades en prototyp för att spåra gästflöden på nattklubbar. Prototypen uppfyller kraven som specificerades tidigit i projektet med undantag för kostnad. Vidare så gick det att konstatera att det finns större svårigheter i att utveckla ett system för att spåra gästflöden än vad som först var trott. Det finns därav också möjligheter till vidareutveckling och förbättringar.

En prototyp har utvecklats som analyserar mängden personer inom ett visst område. Detta sker med hjälp utav en termisk kamera, som efter en förstudie visade sig vara det bästa sensorvalet. Bilderna bearbetas sedan genom att binäriseras och arean av antalet vita pixlarna summeras och resultatet skickas sedan till en databas. Visualiseringen sker sedan i en nyskapad webbapplikation som integrerades med den nuvarande infrastrukturen hos VNU.

Nyckelord: Kamera, spårning, nattklubbar, Matlab, bildanalys, rörelsemönster.

Acknowledgements

This report is a bachelor's thesis conducted at the institution of Computer Science at Chalmers University of Technology, and was written during the spring of 2017. We would like to give a special thank you to our supervisor Lennart Hansson and our client, the company VNU, for access to their code and for helping us with the project.

In figures 4.1, 4.2, 4.4, 4.9, 4.10 and 4.12 icons under the Creative Commons 3.0 licence (Creative Commons, 2017) were used. Credit for those goes to their respective authors: (madebyoliver, 2017), (Freepik, 2017) and (Maxim Basinski, 2017).

Contents

Chapter 1

Introduction

How people move in a given space has always been valuable information. With this sort of information it is easier to make better decisions regarding how to manage the workforce or how to structure the layout of a store, mall or nightclub (Wood, 2017). A vital component of this information lies in its accuracy. Therefore, optimizing factors that results in a more accurate reading is crucial, in order to increase profits and to help organizations to identify new opportunities (Dillon, 2015).

1.1 Background

Initially, the evolution of people counters included only purely manual solutions, by counting or rough estimates. Those were not always accurate due to human error or incorrect calculations. Through the years though, more sophisticated solutions, usually consisting of various sensors, have been developed to remove these uncertainties (Kepler Analytics, 2016). With the help of these new technologies the result is more accurate, but there is also the possibility of monitoring other useful information, like the flow of people inside a building.

In order to monitor the flow of people entering and leaving a nightclub, the company VNU have developed a digital clicker. For the past two years they have helped nightclub owners, mainly in Stockholm and Gothenburg, to get a better view of their activity. This makes it easier for managers to position workforce and has also enabled night clubs to have multiple entrances, since the counts at different entrances are synced in the cloud.

Lately nightclub owners have requested the ability to monitor the flow of people not just at the entrance, but also between rooms, bars and dance floors. That is where this project comes in.

Monitoring the flow of people inside night clubs is interesting for different reasons, stretching from managing workforce, how music affects the amount of people at the dance floor to space planning. Generally speaking, it all boils down to making the night clubs more efficient. For example, one bar with two bartenders barely have the customers to occupy one of them, whilst another bar with only one bartender has the customers that needs two to handle. In this case, the manager can relocate one bartender to the second bar. This will increase the number of drinks sold per time unit, making more revenue for the nightclub and make more customers happier as they do not have to wait as long. It will also distribute the workload on the employees so that they do not have to be as receptive to illnesses related to a heavy workload or stress.

Currently, there are several systems being developed to track people in both indoor and outdoor environments. The conditions in which they work are unfortunately very narrow, with near-perfect light and clear air. Inside a nightclub there is usually a lot of flickering lights, smoke in the air and narrow space between people.

1.2 Purpose

The purpose of this project is to research methods for tracking the flow of people inside night clubs and to create a simple prototype. This includes not only to determine what type of sensor to use, but also to create the infrastructure around and then a presentation of the data collected. The following project specifications are derived from the specifications set by VNU and requests from nightclub owners (Jansson, 2017):

- Evaluate which sensor/sensors are appropriate for the purpose.
- Create conditions for mounting and installing these sensors in rooms of different sizes.
- Communication from the sensors to a web server.
- Manage as well as calculate the data on a web server.
- Visualize the result in a web application.

A final criteria that we have chosen to have in our specification is ethics. The tracking should not invade peoples privacy or make their experience at the nightclub worse in any way. Therefore it is important that the data is processed in a way that removes the ability to identify individuals in a very early state. Data should also be transferred and stored securely.

1.3 Problem

The main problem to solve is tracking people's movement in a nightclub environment. In order to determine a suitable sensor for monitoring people in a nightclub environment, both a theoretical study and field tests has to be made. The result from those studies will result in a brief specification for a prototype that VNU can develop further after the end of this project. T§he prototype should be able to determine the number of people in a room with an accuracy of over 60 percent.

A web application will be developed to visualize the data retrieved by the sensors. It shall be possible to get statistics from different nights and rooms. The application should be easy to integrate with the VNU Dashboard [1].

The infrastructure should be modular so the web application can display data from any type of sensor. The information has to be received from the sensor, processed into a suitable format and thereafter pushed to a database. This infrastructure will be designed to suit different locations and with a focus on economy and privacy. Problems such as not counting people multiple times with different sensors will have to be addressed.

1.4 Scope

The theoretical technical possibilities would likely allow us to very precisely track the movement of people inside a nightclub, however the purpose of this project is more narrow. The project focus is split between the infrastructure around the sensors, as well as finding a suitable sensor candidate. Due to limitations of time and budget, not all sensors can be tested. For example, sensors that are expensive ($500 and above) will not be tested.

It is worth noting that a lot of systems today implement machine learning to evolve an algorithm. Because of time restrictions combined with a lack of knowledge in the field of machine learning, this will not be implemented nor evaluated despite being a technology with very high potential.

1.5 Method

For an optimal workflow, the project was divided into four phases; a pre-study (see appendix A), an implementation phase, a test phase and finally an evaluation phase. Before the pre-study took place, a shorter span of time was used for planning the project. During this time, different parts of the project were assigned to group members with relevant competence in order to make the most out of the time available.

The pre-study was used to gather information on possible sensors to use for tracking people. This information made it easier to make a decision on what sensor to use for tracking guest flows.

In the implementation and testing phases, a system architecture was designed and implemented to work with the given sensor. This system was then tested to evaluate its performance.

[1] The graphical interface for customers of VNU

Chapter 2

Pre-study

This chapter intends to explain the reasoning behind making a pre-study, the results of said pre-study and a discussion in regards to the result. A detailed breakdown of the different technologies that were researched during the pre-study can be found in appendix A.

2.1 Purpose

One of the main problems with the project was what sensor were to be used to track movement. The pre-study was conducted to gain an understanding of what has already been done in the field as well as finding possible solutions. The pre-study explored the following technologies: Wi-Fi, Bluetooth, pressure sensors, active- and passive infrared, camera solutions and laser radar (LIDAR). The choice of picking these technologies came from reading literature about tracking human movement, thus there are possibilities that other solutions exists.

2.2 Method

To get an understanding of the nightclub environment and other possible obstacles, interviews were conducted with night club owners and personnel with the help of VNU. Research and requirements of the difficult environment that is a night club resulted in a few possible candidate technologies.

Before any implementation or selection of sensor could begin, the specification of the problem had to be clear. The pre-study was conducted in two parts. The first to understand the domain and what the customer was asking for, and the second part consisting of determining a suitable sensor based on the specification. This pre-study was crucial in order to select only a limited number of sensor candidates after weighing their pros and cons against the project specification. The pre-study therefore allowed us to maximize the time spent on actual candidates instead of having a trial and error kind of work flow.

Interviews with night club owners and personnel was conducted with the help of VNU to provide insight into the real world environment. This helped to understand its problems as well as possible use-cases for the real time tracking. Subsequently this was to great help when further defining the problem and specification for the product.

When the specification and problem definition was clear, the research to find a suitable sensor took place. The research was done by reading academic literature and articles within the field to get an understanding of what had already been done when it comes to tracking the flow of people. The research was also focused on taking a closer look into a variety of sensors to see if their specification and properties could be viable in the nightclub environment.

2.3 Discussion

The results from the pre-study indicates that a lot of available technologies present problems for the cause of tracking people inside a room with harsh lighting conditions. While Wi-Fi used to be a potential reliable mean of tracking peoples movement inside a room but this is no longer the case (appendix A). The recent changes in Android and iOS operating systems, making devices harder to track, heavily restricts the possibilities as these mobile operating systems make up 99.3 percent of the smart phone market. (International Data Corporation, 2016)

However, when using cameras there is no risk of the implementation to become unsustainable in the same way. Cameras are not dependent on the choices and devices of the people that are being tracked. Furthermore the cost of IR-cameras today is relatively low and over time it is likely to see even lower prices and increased image resolutions. A camera would therefore, unlike Wi-Fi, likely improve over time as technology continues to develop. After conducting interviews with night clubs, it surfaced that real time calculation was not as important as initially was thought. Research was made in regards of image processing and the possibilities of counting people in an image. Based on this new research, information and requirements it was concluded that tracking via cameras was a viable option.

While the other researched technologies showed very low potential for this application today, some of them such as LIDAR and pressure sensors are likely to have good potential in the future. Scanning a room with LIDAR or using pressure sensors seems to have potential to give good results. However it is too expensive and complicated to be economically feasible for this application today. (John Shackleton, 2010)(Velodyne LiDAR, 2017)

2.4 Conclusion

In conclusion it turns out most of the researched technologies show either low potential or unsustainable cost for the intended application. During this elimination process it was however concluded that the best way, seen from a perspective of both cost, performance and the lighting conditions, would be to use a camera with the capability of capturing images in low light conditions.

Chapter 3

Theory

This chapter describes the different theory components vital to further understand the report. It does so by going through the different components one by one.

3.1 Camera

A camera in a nightclub environment might sound like bad idea, as there are a lot of flickering lights and possibly some smoke. But, there are cameras taking advantage of light with wavelengths other than visible light. Therefore there can be special lighting turned on all the time, making it easier to get great images. Two different camera types that do not rely on visible light are infrared (hereafter referred to as IR) and infrared thermography (hereafter referred to as thermal).

3.1.1 IR

IR cameras are not much different from regular cameras. Actually, most consumer cameras are able to capture infrared light, but this is filtered away before it even hits the lens (Yue M. Lu & Süsstrunk, 2009). The advantage of an IR camera is that infrared light is not visible to humans and therefore a scene can be perfectly lit by IR-diodes, whilst appearing to be pitch black for a human. If the IR camera also is fitted with a daylight filter, the opposite of an IR filter, this makes it immune to changes in light outside the infrared spectra. Therefore, the IR camera should not be blinded or affected by flickering or moving lights. A downside using IR only cameras are that infrared images comes in only black and white, which makes the dynamic range much smaller than on a colored image. However, if the regular camera is blinded, the images will not be of any use at all.

3.1.2 Thermal

Another type of camera is the thermographic camera that tracks infrared radiation which is emitted from all bodies with a temperature above absolute zero (Cetas, 2008). This data is then used to create a coloured image representing different temperatures in an area. The downside of these images is the resolution which often is a small fraction of a regular image. But, as the thermal image contains more data per pixel due to the color, the differences in raw data might be smaller than one may think. Which camera is best depends on the situation, as you sometimes just need to know if there is a person and sometimes need to know who that person is.

3.2 Node.js

"Node.js® is a JavaScript run time built on Chrome's V8 JavaScript engine. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient. Node.js' package ecosystem, npm, is the largest ecosystem of open source libraries in the world." (Node.js Foundation, 2017a)

The single-thread nature of Node.js is useful when working with smaller calculations and high amounts of I/O requests due to performance advantages when using I/O asynchronously. This is due to the fact that creating new threads consumes valuable system resources (Node.js Foundation, 2017b). JavaScript presents a simple way of handling asynchronous calls which makes the use of such functionality intuitive in Node.js.

3.3 Meteor

The Meteor framework is a free, open source, full-stack JavaScript platform which is used for developing web and mobile applications. When building applications in Meteor the developer only need to know one programming language, JavaScript that works both for the front end and the back end(Meteor.com, 2017).

The Meteor core is written in JavaScript, C++ and C. The open-source code can be found at (Github, 2017) and used under the MIT license. Compared to other platforms Meteor uses the Distributed Data Protocol (DDP) to update the data between the server and client (Stubailo, 2017). The DDP protocol is a protocol between the client and the server. The protocol supports two operations, one for the client and one for the server. The protocol gives the client the possibility to make remote procedure calls to the server. The server on the other hand, can keep the client informed of changes in the database or other states that the client has subscribed to (Stubailo, 2017).

3.4 MySQL

MySQL is the worlds most popular open-source database and conforms to the SQL standard (Oracle Corporation, 2017). Data is stored in tables and columns that can refer elements in other tables, thus creating relations. MySQL is developed and maintained by Oracle and the open-source community.

3.5 MongoDB

MongoDB is a non-relational database that uses a "flexible document data model that is similar to JSON" (MongoDB, 2017). Documents themselves can contain other documents but also one or more fields. As a result MongoDB is modular in regards of what data is stored. Data types can change rapidly without forcing the developer to update old data to the new structure. MongoDB also supports more restrictive data types which then is specified beforehand.

3.6 Image processing

Image processing is a complex tool used to retrieve information from a photo or video. Digitalized images is usually treated in three different ways: The point operation; which is where the input value of a single pixel determines the output value, the local operation; where an area around a single pixel determine the output value and the global operation; where all of the input values determine the output value (Smith, 2014).

3.6.1 OpenCV

One method for image processing is OpenCV, a powerful tool written in C/C++ released under a BSD license, making it free to use for all purposes (OpenCV-Team, 2017). It has support for multiple operating systems including Linux and MacOS as well as support for hardware acceleration using OpenGL. Furthermore there are interfaces for Python, Java and C++. In this project, OpenCV was mainly used for comparison with Matlabs image processing functions.

3.6.2 Matlab

Another tool for image processing is Matlab develeoped by Mathworks (Mathworks, 2017). Two big differences compared to OpenCV is that Matlab is a proprietary software, but on the other hand it has interfaces for Java, Python, C++, .NET, SQL, Hadoop and Microsoft Excel. Matlab also provides powerful tools for signal analysis and image processing.

Chapter 4

Implementation

This chapter gives an overview of the system and its components. Thereafter it describes the implementation procedure in more detail for the each component.

After doing a theoretical study on different sensors, a few alternatives emerged based on the specification. To further analyze those alternatives, minimal prototypes were developed and tested. The thought behind those prototypes were to evaluate if the theoretical performance could be achieved with relatively cheap hardware and within the time frame.

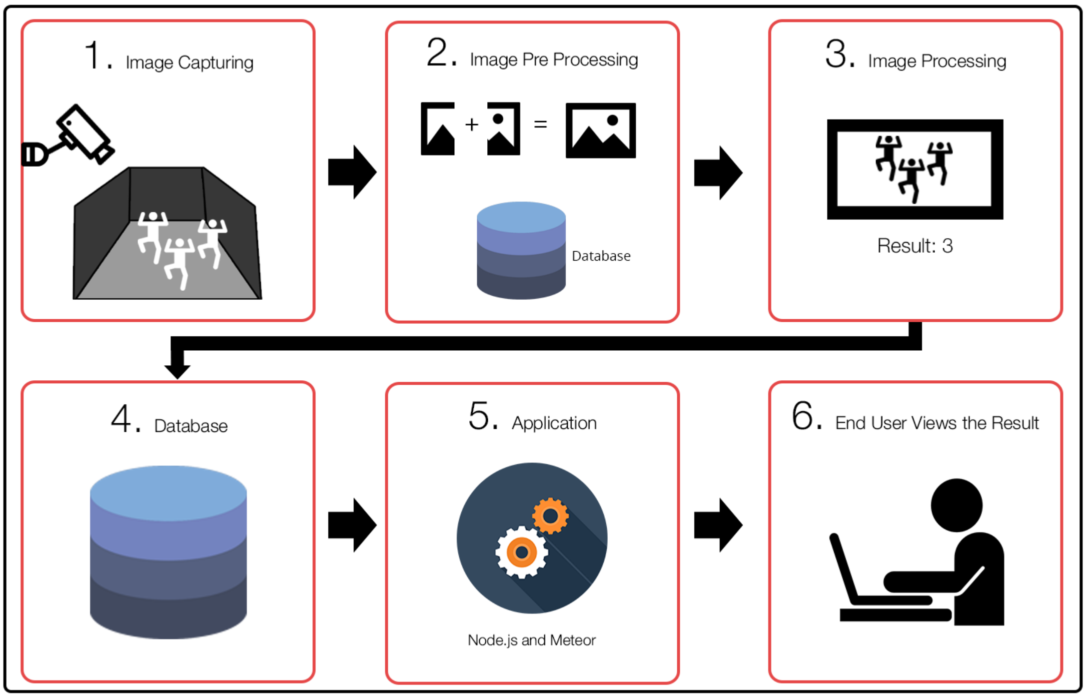


Figure 4.1: The system infrastructure.

In figure 4.1 an overview of the system as a whole can be seen. The system consists of six main components. The first component *1* represents different cameras. Since one camera might not be able to cover a whole room of interest, a method for combining images in to one was of interest. This is where part *2* of the system comes in, image pre-processing.

Image pre-processing takes care of combining pictures taken from different cameras, this is to make sure that people are not counted more than once. When the image pre-processing is done, the images are then passed on to part *3* in the figure. This part is then calculated with help of Matlab, the amount of people in the room and uploads the result to a remote database *4*. This leads us in to one of the last parts of the system, Meteor *5*. Meteor listens to changes in the database *4* and provides the end user with visualization *6*.

The following parts of this chapter intends to give a detailed description of the implementation process for the different components of the system.

4.1 Sensor: Camera

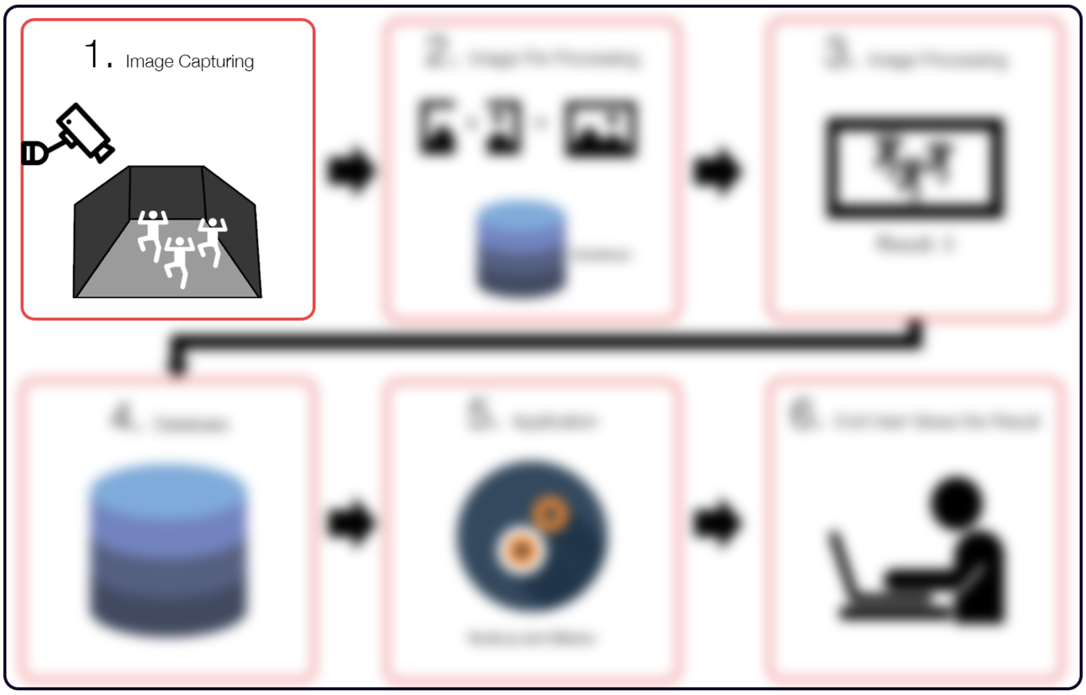


Figure 4.2: Part one of the system infrastructure.

From the pre-study found in appendix A, the conclusion was made that a camera was best suited for the needs of this project. As cameras comes in different types, two options where selected for this project; IR and thermal. The difference between these two cameras can be seen in figure 4.3. Those cameras both have the advantage of not needing visible light to capture an image, which makes them perfect for a nightclub environment where light can differ a lot. Images from the cameras are sent to a server for processing, where each camera has its own folder.

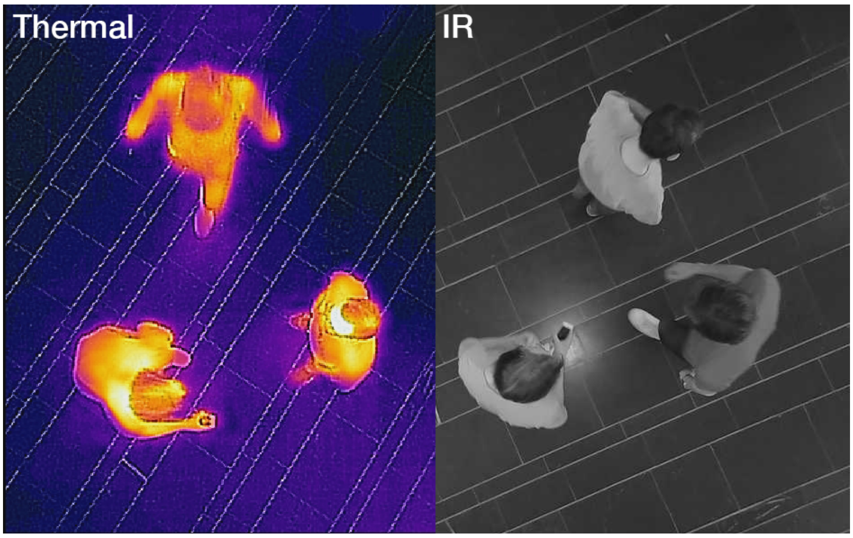


Figure 4.3: Two similar images taken with a thermal and IR camera.

4.1.1 IR

The IR camera used in this project is a Foscam Fi9900P with a 2 megapixel sensor and a cluster of IR-diodes for good lighting (Foscam, 2017). It is also equipped with both Wi-Fi and Ethernet interfaces for information transfer. Combine this with the capability to take images on pre-configured intervals and sending them to an FTP-server and therefore this camera was a suitable sensor for this project.

4.1.2 Thermal

For comparison with the IR technology the Flir One for Android thermal camera was used (FLIR, 2015). This is a relatively in-expensive thermal camera with a resolution of 160 x 120 pixels. It has the ability to see temperatures between
-20 and 120 degrees Celsius, which should be more than enough for a nightclub environment. This camera is connected to an Android smart phone via a single micro-USB cable.

4.2 Image pre-processing

Night clubs are usually divided into several zones which typically requires multiple cameras to cover the whole area. It would be practically difficult to position the cameras in a way where their images would not overlap while still covering the entire zone. A correct estimation can only be made if the amount people are only detected once. To avoid overlapping, an algorithm is needed to calculate exactly how much area each camera's images are supposed to cover.

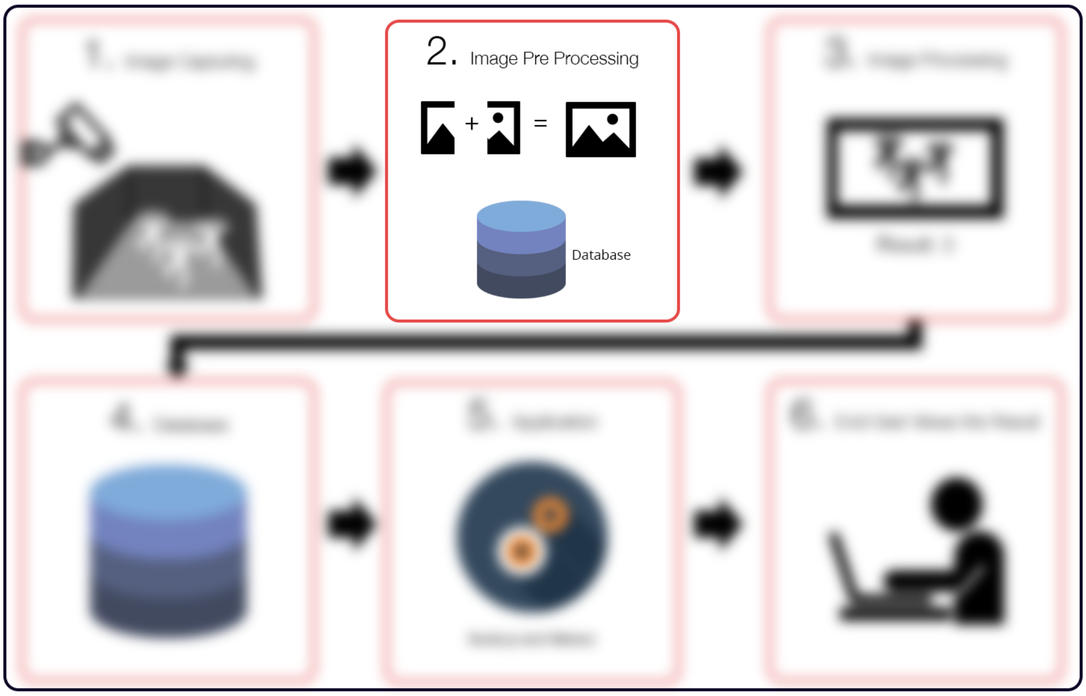


Figure 4.4: Part two of the system infrastructure.

Another issue that arises when multiple cameras are involved is the fact that it is impossible to guarantee that all images in the same zone are taken at exactly the same time. Consequentially an algorithm is required to adjust the time stamps of images that differs at most by one second. Images taken within the specified time frame can be paired with other images taken in the same zone by different cameras.

The image pre-processing was implemented as an application running on Node.js. The following modules were used:

Jimp[1]**:** A library that was used for cropping images.

MySQL[2]**:** A library that was used for connecting to a MySQL database.

Async[3]**:** A library that can simplify the handling of asynchronous calls which in our case was used for handling large amount of non-blocking I/O requests.

The pre-processing program can be divided into three parts:

1. Initiate cameras with correct data in order for the images to be cropped correctly.
2. Adjust the time stamps of images from the same room.
3. Crop the images from the same room and with equal time stamps correctly.

[1]More infomation about the Jimp library: https://www.npmjs.com/package/jimp
[2]More infomation about the MySQL library: https://www.npmjs.com/package/mysql
[3]More infomation about the Async library: https://www.npmjs.com/package/async

4.2.1 Database structure

The data calculated by the initiation process has to be stored for the cropping method to work later on. This is done by using a MySQL database. Figure 4.5 is an entity relationship diagram (ERD) of the structure of the database. An ERD is, by defining relationships between the different data components, a convenient way of illustrating the logical structure of the database (Chen, 1976). The nightclubs consists of one or more zones, which can contain one or more camera. Every zone has its own coordinate system in which each camera has a coordinate, which is utilized when calculating the cropping values for each camera.

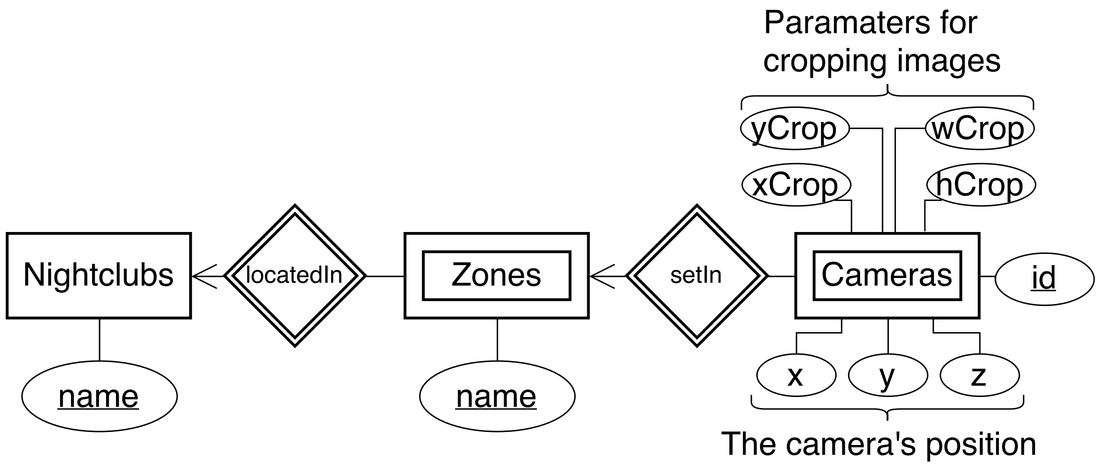


Figure 4.5: ERD of the database containing the camera data.

4.2.2 Initiate cameras

To initiate the cameras with correct data the algorithm first have to check all the cameras in the same zone. The first step is to choose a camera, which is the first it finds in the current zone in the database. This is illustrated with an example shown in figure 4.6. The algorithm will start by choosing the camera at position 1.

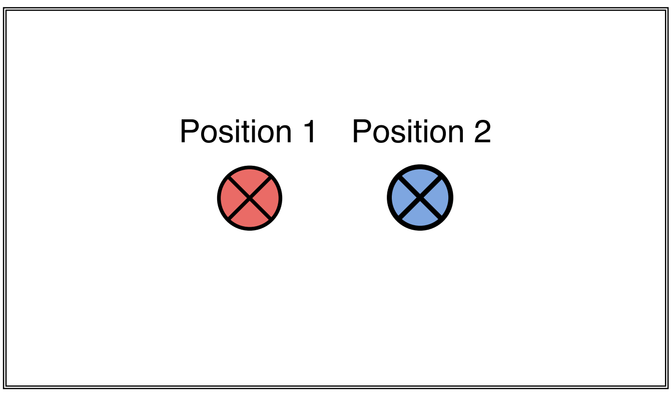


Figure 4.6: First step of the camera initialization algorithm example.

In the second step the selected camera will be allocated the entire area it covers, which is shown in figure 4.7.

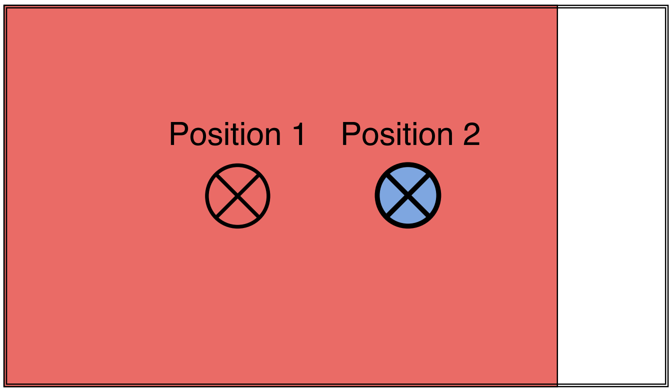


Figure 4.7: Second step of the camera initialization algorithm example.

In the third, and last step in this example, the second camera will be allocated the remaining area. This is shown in figure 4.8.

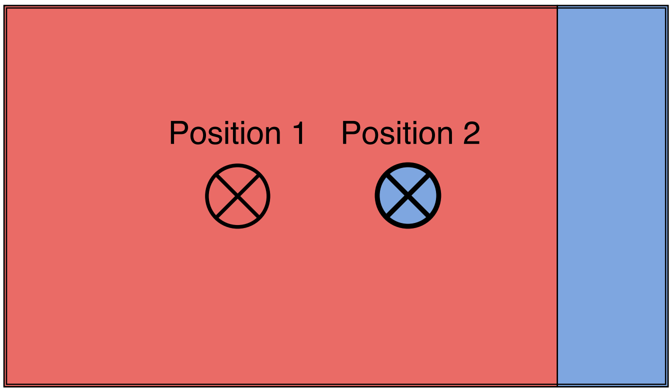


Figure 4.8: Third step of the camera initialization algorithm example.

If the zone is more complex and consists of more cameras than illustrated in the example above each camera will be assigned as much area as possible without overlapping areas of previous cameras. When no more cameras can be found, in the current zone, the initialization process is finished. The algorithm is executed on every zone in every nightclub. If it detects that a camera has been moved, added or removed it will re-calculate all cropping values to avoid incorrect information in the database. This ensures that the sizes of the cropped images are calculated correctly.

4.2.3 Adjust time stamps

When the initiation part of the program has finished, the timestamps to pass to the image-processing program of each image that will be cropped, has to be modified.

Each nightclub has its own directory with zone-directories as it's sub-directories. Each zone-directory contains directories for each camera in that particular zone. The folder names in the directory structure matches the corresponding information in the database.

All of the camera directories in each zone directory are read and the first file in each camera directory will be added to an array of image-filenames to crop for that particular zone. If a camera directory is empty the program will re-read the directory after a set delay. In each set of files for a zone the first file's modified-time is used as the timestamp to include in the filename after the image has been cropped. The program ensures that the modified-time between the files within is less than one second to further ensure that images are taken within a reasonable time frame of each other.

Lastly a list of JSON objects containing the camera-ID, filename and the new filename is passed to the image-cropping method of the program. The new filename is a string that contains information about it's corresponding nightclub, zone, camera-ID and timestamp.

4.2.4 Crop images

In the last part of the pre-processing program the images are cropped. At this stage all the relevant information needed to crop the images correctly is stored in the database and new filename for each image is available for the the cropping method. For each camera entry in the database an image is cropped with the corresponding entry in the JSON object that was passed to this method. The cropped image is saved in a folder where all cropped images reside with the "newFileName" format presented in the previous section and the original image is removed from the file system.

4.3 Image processing

Figure 4.9: Part three of the system infrastructure.

To be able to count people in an image there was a need of processing the captured images. OpenCV was used early in the implementation phase to process images and recognize the amount of people in each and every frame. While the pre-study in appendix A showed that OpenCV without a doubt seemed like the best alternative for image processing focus was later on moved to Matlab. The reason for this being that experience of image processing within the development team was higher in Matlab than in OpenCV. Furthermore, in the methods tested Matlab was slightly better at counting how many people there were in a picture "out of the box". These slight advantages meant that OpenCV eventually was replaced by Matlab for image processing.

4.3.1 OpenCV

OpenCV was used together with its bundled Haar cascades[4] to detect objects with different properties. There are for example Haar cascades for detecting upper bodies, faces in profile, eyes and faces viewed from the front. These pre-defined Haar cascades were used on a selection of test images from different cameras, with different resolution and in environments with differing lighting and distances to the subjects. This detection was done by using OpenCVs "detectMultiScale" function (OpenCV Documentation, 2017a). The arguments for this function was modified to find what parameters would give the best result.

4.3.2 Matlab

The end implementation uses Matlab to process images. Different types of methods to separate the people from the background was considered and tested, but due to the groups restricted knowledge of image processing the number of different methods where limited.

A simple and effective method when the floor was of a dark color, was to binarize the images with an tested threshold to achieve an image with only two colors, black and white. First, an empty image with only the "background" was binarized and the white area was calculated. Then an image of one person was processed the same way. Next, the white area of the empty image was subtracted from the white area of the image with one person to achieve an estimated number of the white area value of one person. Finally, this value was then used to divide the following white area calculations to retrieve an estimated number of people in the images.

The method of using a white area to count the number of people is used since it is less difficult to implement whilst still delivering good results. Since objects only need to reflect or emit enough light to become lighter than the background. However, when people have dark hair or clothes they do not reflect as much light when bouncing IR light of them. This problem is solved when using a thermal camera, as all bodies above absolute zero degrees emit infrared radiation, regardless of hair color and clothes.

[4] "Object Detection using Haar feature-based cascade classifiers is an effective object detection method proposed by Paul Viola and Michael Jones in their paper, "Rapid Object Detection using a Boosted Cascade of Simple Features" in 2001." (OpenCV Documentation, 2017b)

4.4 VNU integration

This section will describe the implementation of the graphical interface and the database connected to it. Both of them are integrated and built within the already existing system of VNU.

4.4.1 Database for visualization

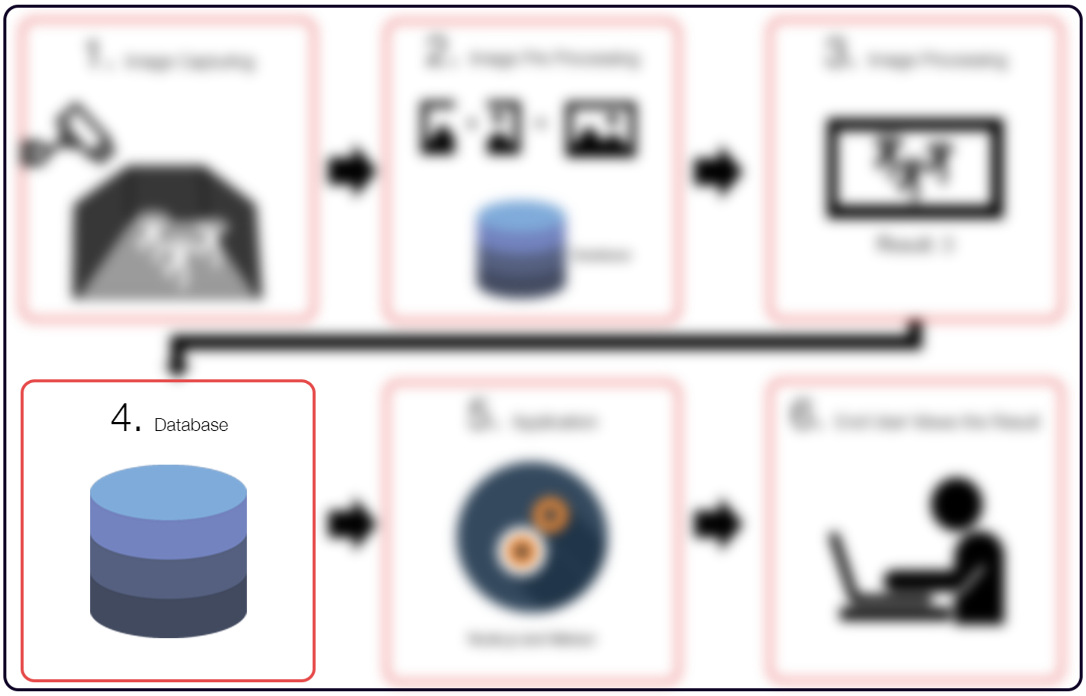


Figure 4.10: Part four of the system infrastructure.

One of the first decisions that was made regarding the database was that MongoDB would be used. There are two main reasons why MongoDB was picked. MongoDB which is named after the word "humongous" is made to handle large data sets, which is the case here (Wheeler, 2016). It is also very well supported with Meteor which at the time of this report is written, is what VNU used as their web framework. This made integration simpler within the time span of the project and was therefore the choice.

When designing a MongoDB database it is important to structure your data depending on what type of queries you will do to the database, but also how often you do them. This is to make sure that the database is fast, but also to store the data effectively (Runkel, 2014) (Angerman, 2014). To do this, VNU was consulted in how their customers would like the data visualized. According to VNU, their customers are interested in having a day to day visualization in their graphical interface, and therefore the database is structured accordingly.

With the structure visible in figure 4.11 it is easy for MongoDB to fetch data on a day to day basis which is the current use case. It is also fast to determine which dates data are available which also is used in the interface.

```
"openingTimestamp": ISODate("2017-03-14T10:30:43.062Z"),
"nightclub" : "bachelor",
"Zones" : {
        "Zone A" : {
                1 (Hour) : {
                        1 (Minute) : {
                                15 (Second) : {
                                        "Amount": 10,
                                },
                                30 (Second) : {
                                        "Amount": 11,
                                },
                                .
                                .
                        },
                        .
                        .
                },
                .
                .
        },

}
```

Figure 4.11: The database structure

4.4.2 Graphical interface

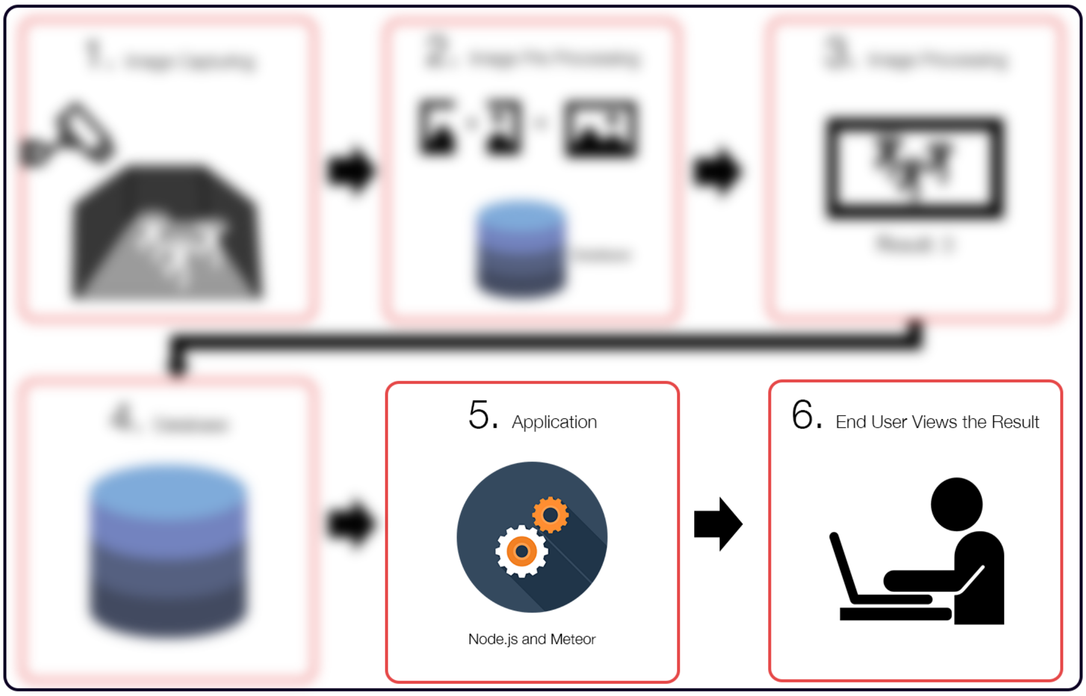


Figure 4.12: Part five and six of the system infrastructure.

The graphical interface refers to the part of the system responsible for visualizing the data for the customers of VNU, further on it will be referred to as: "interface". The interface is implemented using the Meteor framework, the reason for this is because of the already existing system at VNU, runs Meteor both on the front- and back-end. Using something else for the visualization would have been very time consuming and outside the scope of this project. It was also convenient to gain things like login and user handling for free. The interface consists of the following two parts which are both open source libraries: A *datepicker* for the user to chose a date to view data and a *graph* for visualizing the data.

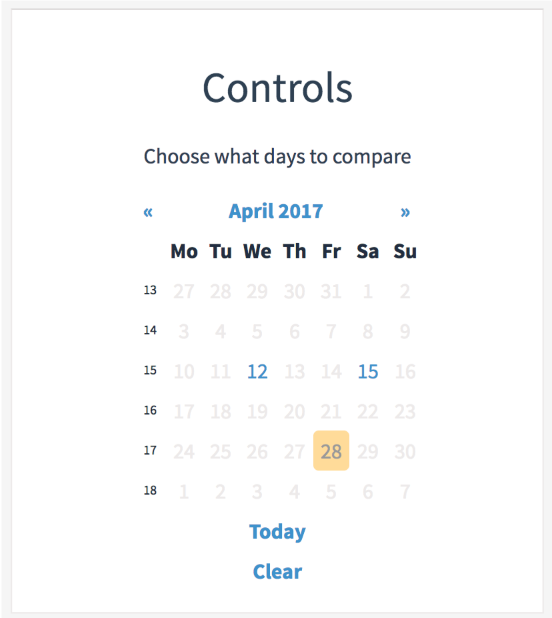


Figure 4.13: The datepicker

As visible from figure 4.13 the date-picker provides a hint to the user for which dates you can and can not find data. This is done by graying out the dates which contains no information. Furthermore the user can not click on the grayed out dates to make sure no mistakes are done. Another factor in making sure that the user understands what is going on is to make sure that the system responds quickly. This is where the decision of using a Canvas based graph comes in.

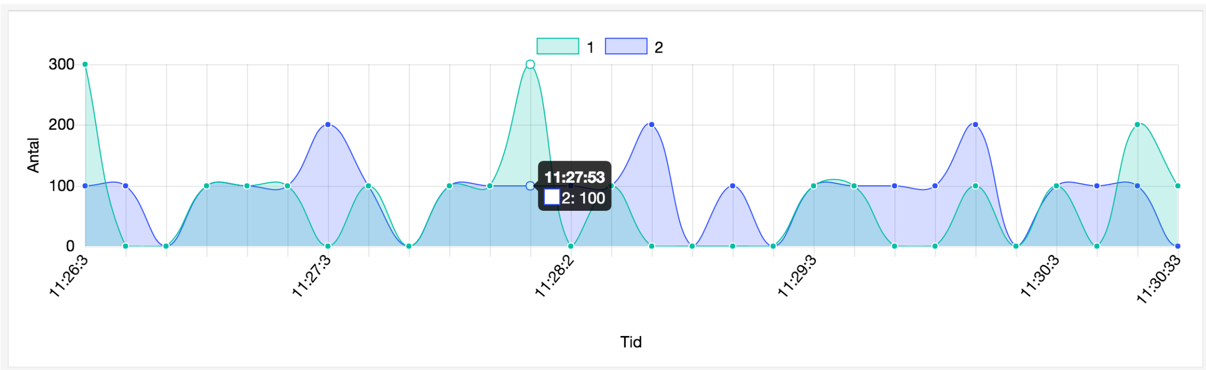


Figure 4.14: The graph for displaying data using Chart.js

When deciding about what type of chart library to be used for plotting, performance was of biggest concern. Since the knowledge of having to plot approximately 2880 data points per zone. Half a day of data, each hour has 60 minutes and for each minute four data points are taken. This means that depending on how many zones a specific nightclub has, the amount of data points that needs to be plotted are increasing rapidly. According to Microsoft developer's network the time for rendering increases more swiftly with usage of SVG rather than Canvas for many data points (Microsoft, 2017). Therefore a library based on Canvas was chosen to make sure that the user gets a fast response on picking a date. Thanks to the decision of using canvas the graph have the possibility to always load with all zones for a nightclub. This is mainly to give the user an instantaneous overview of the day and to remove unnecessary clicks to get anything presented. The user then have the possibility to disable certain zones to easier look at the remaining ones.

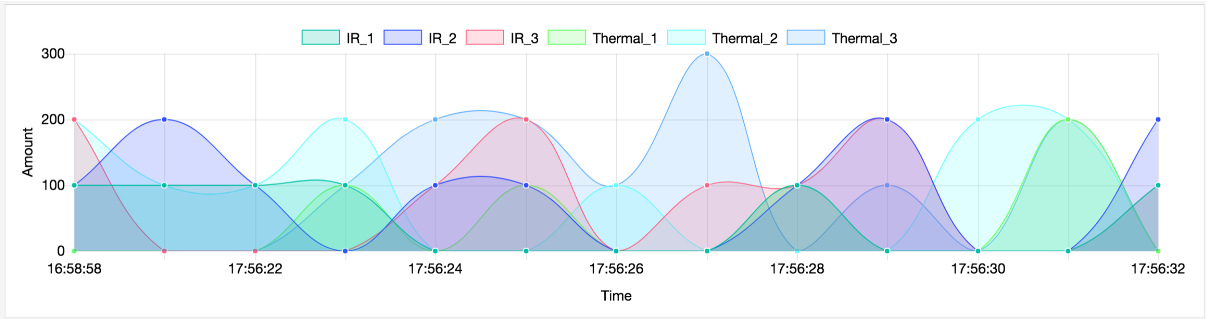


Figure 4.15: A graph with several zones

To present the data two main options occur in how to do so. One was to have the whole nightclub modelled with it's zones. Then creating bigger or smaller circles on the specific zone to represent that there were a lot of people at the specific zone. In addition you would have a way to transition over time, to get an understanding of how the flow was changing over time. The other option was to have a graph as the one in figure 4.15, which was chosen for this project.

One of the goals with the project was to create something intuitive, the graph alternative felt in our subjective view, as the best choice. Mostly because of the fact that it required less from the user, and with the graph you have an easier overview rather than using the solution with big and small circles.

Both the date-picker and the graph are two open-source, free to use projects (Eternicode, 2017)(Chart.js, 2017) and this is the main reason why they were picked. The choice to pick these specifically are based on the high amount of contributors to the separate projects and the fact that the documentation was very well written. Another factor as earlier mentioned in this chapter is the rendering time when picking Canvas over SVG.

4.5 Testing

The testing of the product was an important order of business, since it was directly connected to verification of all the sub-components in figure 4.1. The tests were a powerful tool for evaluating the performance in a timely fashion and with ease. Another aspect was that the environment could be altered to gradually generate more difficult settings when needed. This was accomplished by changing how many people would appear in images by using different light settings.

4.5.1 Testing environment

In some cases, sensors had to be authorized by the agencies when placed in a nightclub. This is due to Swedish surveillance laws, which requires a permit to conduct tests with camera-sensors in a nightclub environment. This takes time and resources and therefore this type of testing has not been done.

Instead, testing was conducted in two locations; at Chalmers and the Stena Center. Testing conducted at Chalmers had a near-perfect environment, with single-colored floor and walls, a distance between the floor and ceiling of up to five meters and controllable test case of people. The number of people appearing in the images were between zero and three.

Compared to Chalmers, Stena Center had a different environment to work with. The floor was made of black and white tiles with only about two and a half metres to the ceiling. There were also large windows making it impossible to control the light. The room was furnished like a typical break room with a coffee-machine, sofas, tables and chairs. The number of people varied from zero to over 50. Therefore, this was a challenging environment.

4.5.2 Camera placements

Several possible placements of the IR-camera was considered and evaluated. The initial idea was to have the IR-camera in a corner between a wall and the ceiling, but this was problematic since the low angle from the ceiling would allow the people within the field of view to cover parts of each other. This made it hard for a detection program to find the outline of each person when they are blocking each other. Such an angle also made it difficult to use a detection program for faces, since the people may be turned away from the IR-camera when the photo is taken. In figure 4.16 the discussed problem with the IR-camera at a low angle from the ceiling is shown.

The simple solution to the problem of partially covered objects therefore seemed to be to place the IR-camera at an orthogonal angle from the ceiling, which is shown in figure 4.17.

Figure 4.16: The IR-camera is at a low angle from the ceiling at Stena Center, which results in people being partially covered and their faces possibly obstructed.

Figure 4.17: The IR-camera is at an orthogonal angle from the ceiling at Stena Center, which prevents the objects from coverings each other at the same extent.

Another difficulty with the orthogonal angled IR-camera is that people are compared to the floor, which meant that a bright floor would make it hard for the detection program to single out people.

To test the program fully, including the usage of multiple cameras, we placed the camera at two different positions at Stena Center. Figure 4.18 is an illustration of the two different positions the camera was positioned at.

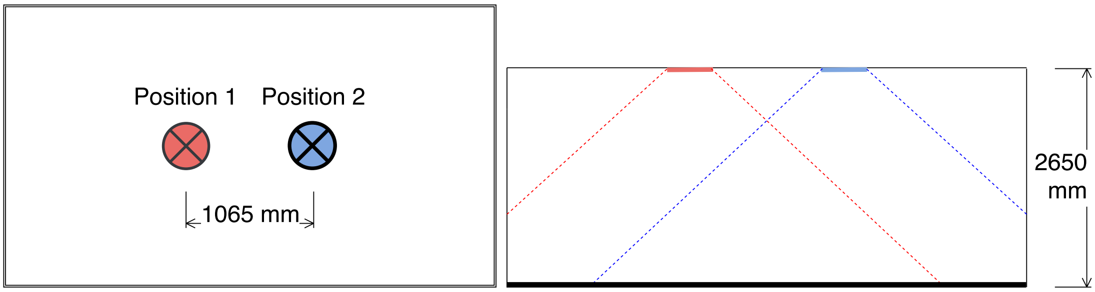


Figure 4.18: The two camera positions at Stena Center with given dimensions. To the left is a top-view and to the right is a side-view.

4.5.3 Image processing

The usage of an IR-camera seemed to cause the biggest challenge since a black and white image only has combinations of two colors and therefore gives fewer gradations than a usual color camera. An example of this is when a person wears a light pink sweater and another one wears a light yellow one. These two people would be easier to distinguish from each other in a colored image but are given the same grey shade in an image from the IR-camera.

Several different ways to detect objects in Matlab were tested. Matlab has built in algorithms to detect faces and upper bodies, but these use a threshold value between the object and the background, which was not very effective on black and white images. The result from the tests using the Viola-Jones[5] algorithms is shown in figure 4.19.

Figure 4.19: Matlab's built in algorithm code, based on the Viola-Jones algorithm, is having a hard time detecting faces in black and white images. Faces are blurred out for integrity purposes.

[5]Viola-Jones is an effective framework which includes several detection algorithms and uses boxes of different sizes to scan for patterns of black and white pixels over the image. (Jensen, 2008)

A decision where therefor made to use an easier and mathematical way, where the black, white and grey images were transformed to binary images with an estimated threshold. The course of action of the image analysis is shown in figure 4.20.

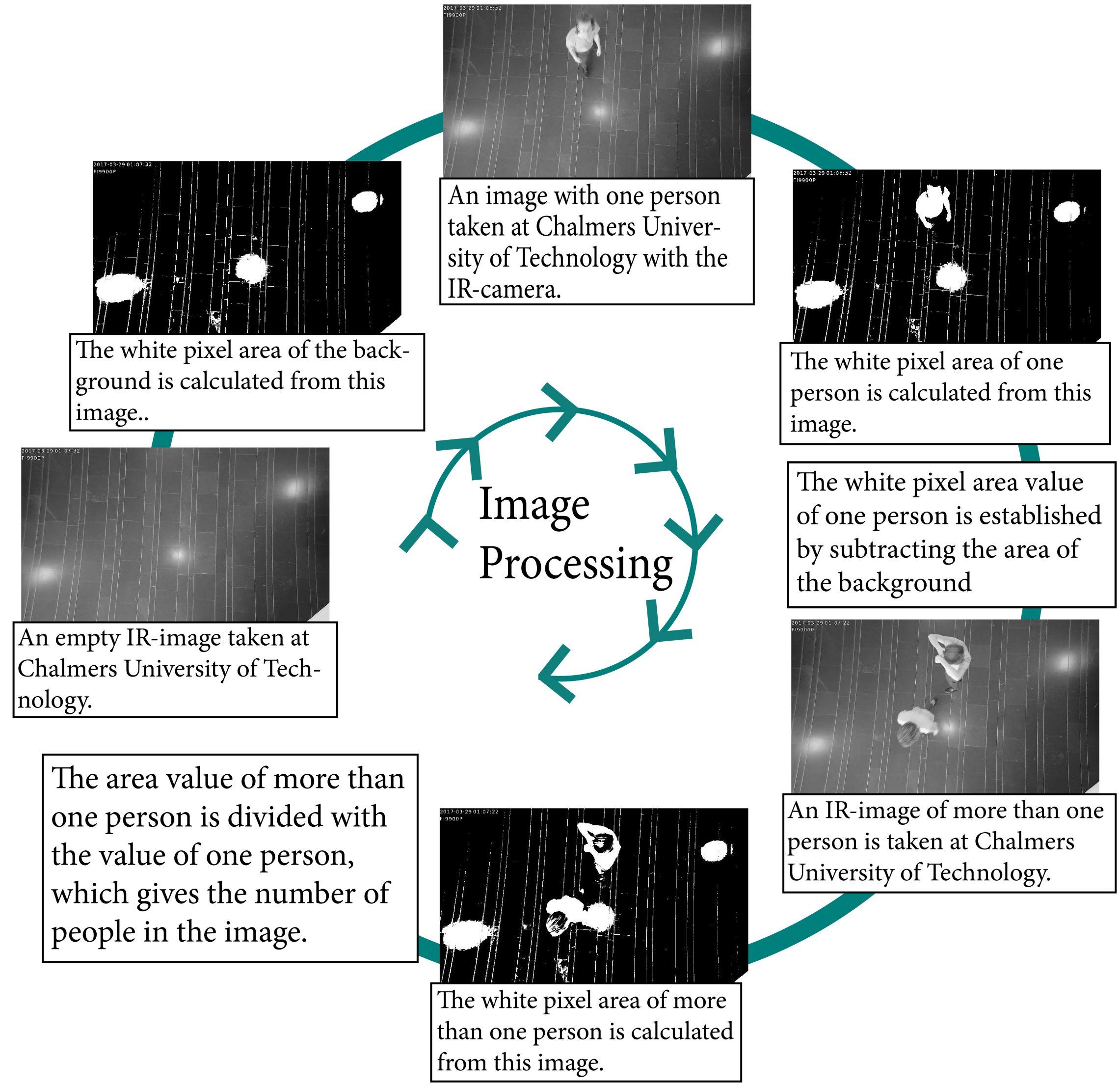


Figure 4.20: An illustration of the work flow of the image processing.

Chapter 5

Results

This chapter's purpose is to present the results and the performance of the different parts of the system. The chapter will describe the different components one by one, thus providing a complete view of the system as a whole.

5.1 Image pre-processing

The results from the pre-processing part of the project was retrieved by running the algorithm described in section 4.2 on the testing environment defined in section 4.5.2. The pre-processing algorithm's task is to crop the images in such a fashion that multiple cameras in the same room do not overlap and adjust the timestamps of images taking at approximately the same time. After the initiation process have calculated how much area each camera is supposed to cover the images are cropped accordingly. Figure 5.1 and figure 5.2 are the original images taken from the cameras at position 1 and 2, in figure 4.18, respectively.

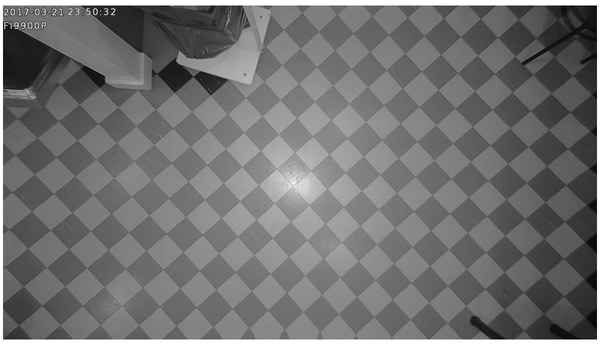


Figure 5.1: Image from position 1.

Figure 5.2: Image from position 2.

The result after the image pre-processing algorithm is done shown in figure 5.3. The result can be compared to the example in figure 4.8, which was derived directly from the testing environment.

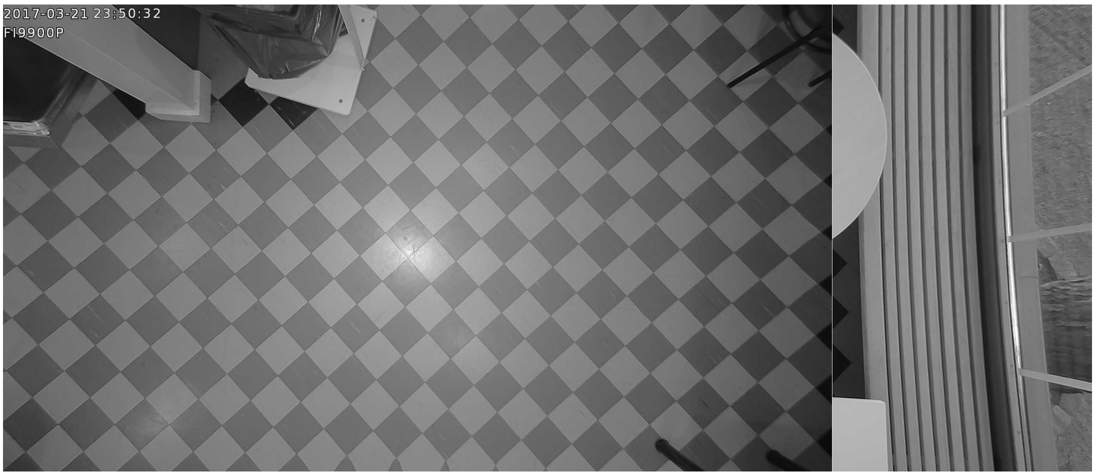


Figure 5.3: Result after the images have been pre-processed.

5.2 Image processing

After converting the images to black and white, including a binarization making the pixels of the image purely black or white, the number of people was estimated by comparing it to an image containing no people. This method was the most success-full of those we tried and the results can be viewed in figure 5.5 and 5.6

5.2.1 OpenCV

As a starting point images were taken from the side over the area of interest. The images were then analyzed using facial tracking in OpenCV. This method was then abandoned in favor of area analysis using Matlab on images taken from above. Results from running OpenCVs "detectMultiScale" (OpenCV Documentation, 2017a) function using the bundled Haar cascade (see footnote 4 on page 20) for frontal face detection can be viewed in figure 5.4.

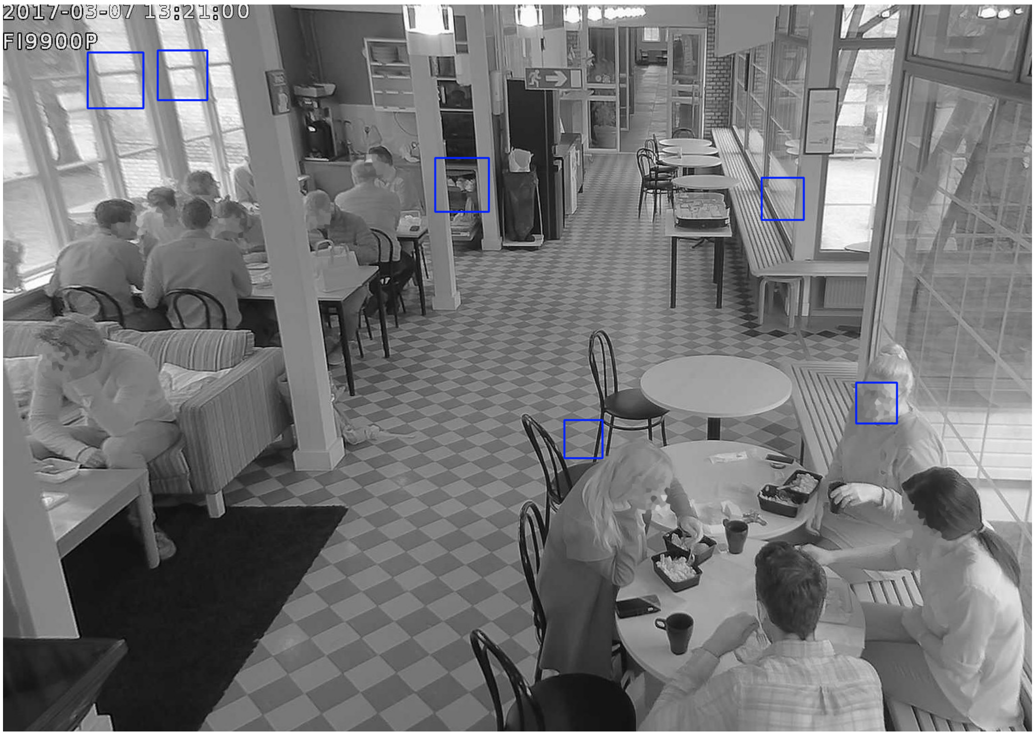


Figure 5.4: Results using OpenCVs facial tracking algorithm. Faces are blurred out for integrity purposes.

5.2.2 Area detection using Matlab

Using the method of detecting people by calculating the white pixel area, is a more simple solution than the one regularly used in image analysis. There are a few important factors to be considered for the chosen implementation to work properly. First and foremost the camera needs to be placed at a fixed angle to prevent the white pixel area of the background changing between images. Secondly the solution is very dependent of the floor of the desired location of implementation. If the floor is of a bright color the system wont be able to find any difference in white pixel area. This occurs when the binarization fuses the bright floor and the bright people into the same white pixel area. A bright floor would therefore make it hard for our system to work as desired.

Table 5.1: The accuracy in percent of area detection using IR or thermal images.

People on image \Camera type	IR	Thermal
1	37	80
2	53	90
3	30	73
Average	40	81

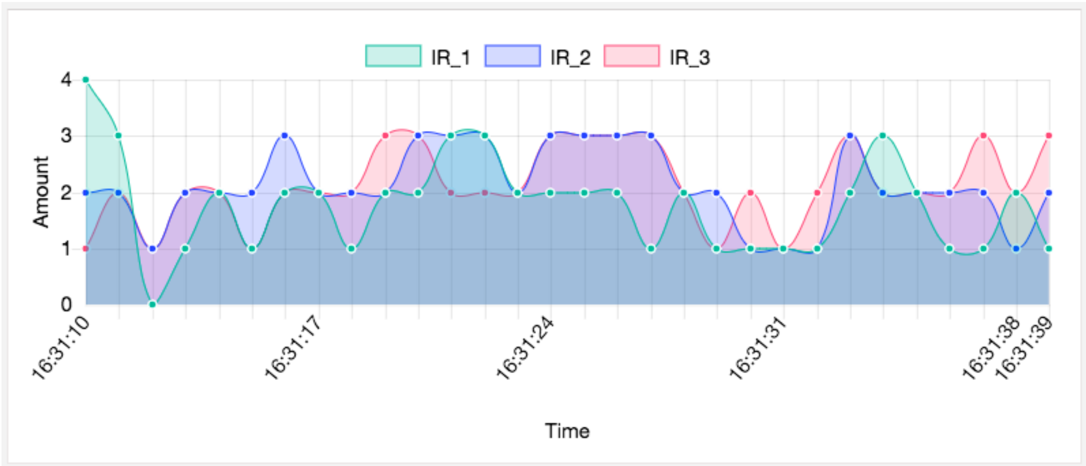


Figure 5.5: Matlab algorithm results for images taken with IR camera. The number in, for example, IR_1 marks the actual number of persons in the image.

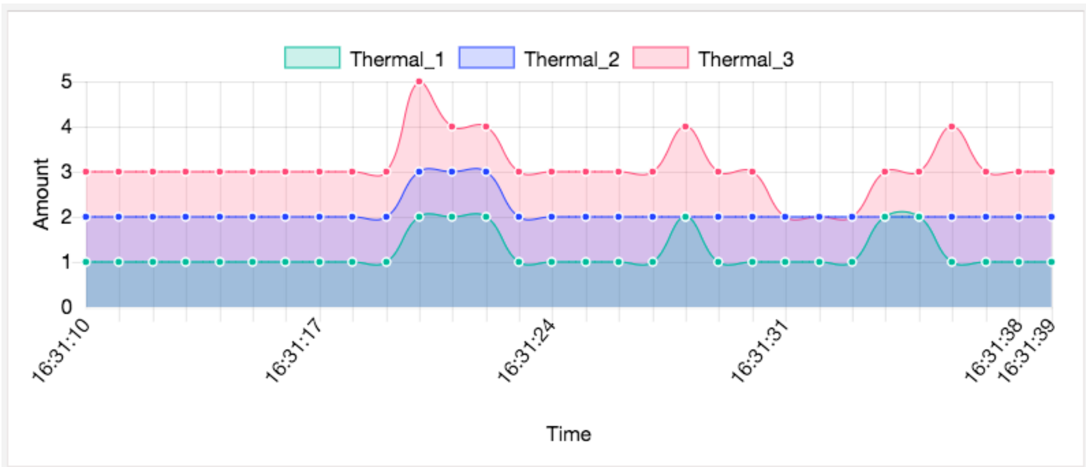


Figure 5.6: Matlab algorithm results for images taken with thermal camera.

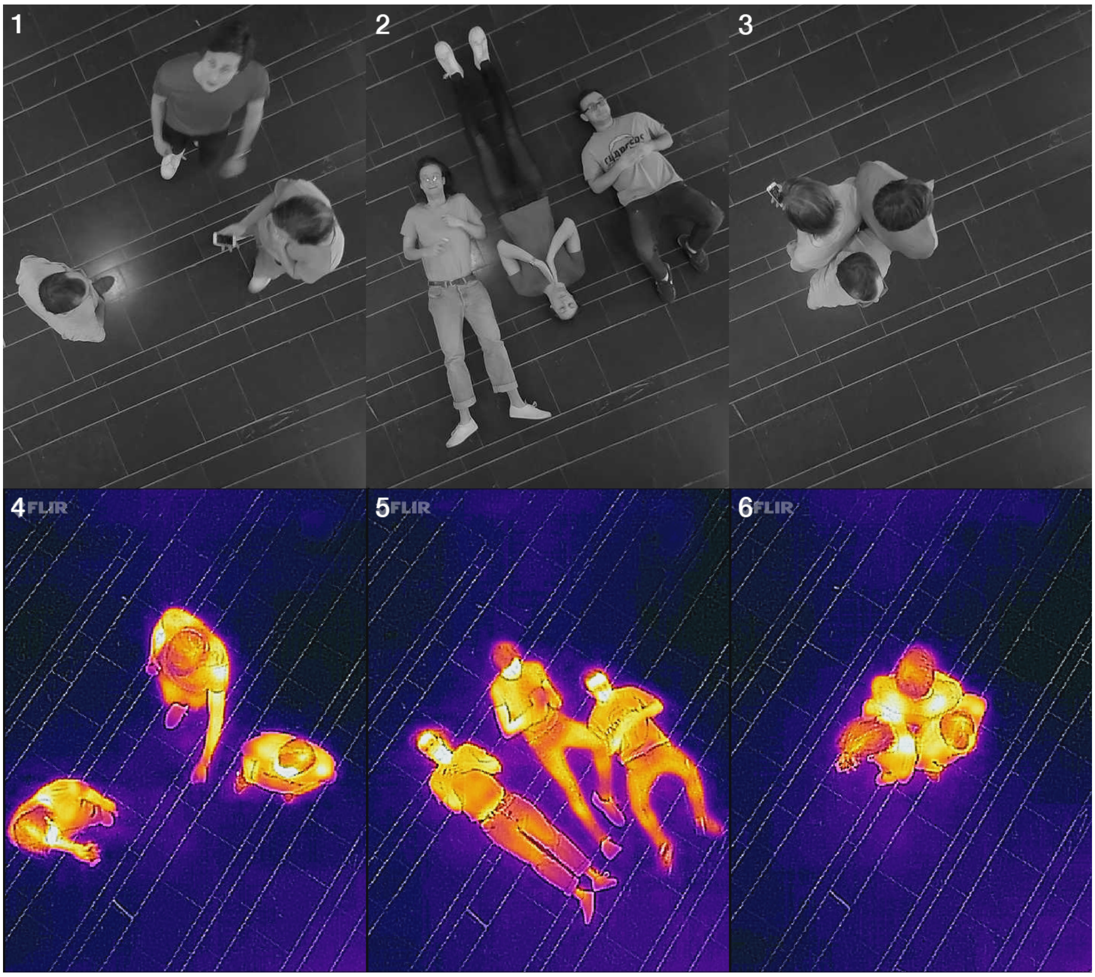


Figure 5.7: Images for the following points in figures 5.5 for IR and 5.6 for thermal.
1. 16:31:10, 2. 16:31:20, 3. 16:31:31,
4. 16:31:10, 5. 16:31:20, 6. 16:31:31

5.3 VNU integration

Before the project took place, VNU already had a system running. Within this system a graphical interface and a database has been integrated. This section will describe the final result for these two.

5.3.1 Database

The database is structured after making request on a day to day basis. Therefore each object that is stored in the database has an opening time stamp which represents the day to query for. Also within the same database object, the zones and their different data points are stored. The different objects are continuously filled with data, rather than having the whole object pre-allocated. The structure can be seen in figure 4.11

5.3.2 Graphical interface

The graphical interface is a single page on the pre-existing system at VNU. The system consists of two parts: the date-picker and the canvas based graph. They both can be seen below in figure 5.8.

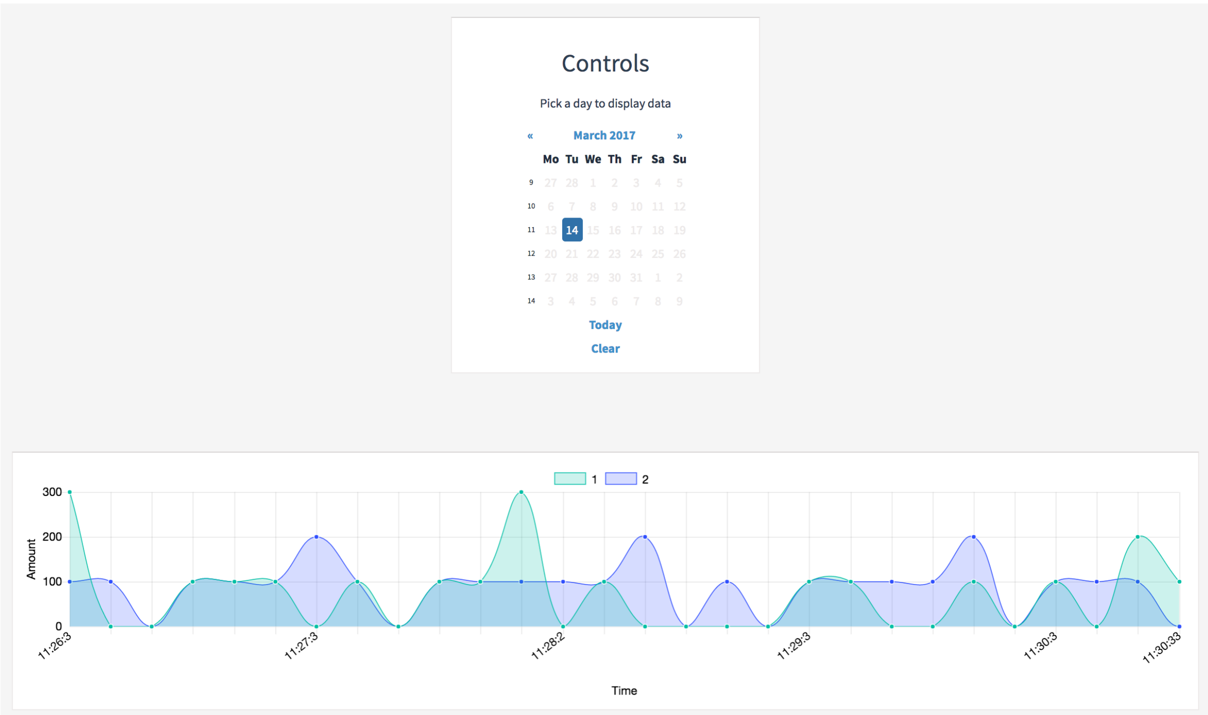


Figure 5.8: The date-picker and the canvas graph

The date-picker named "Bootstrap-datepicker" and the graph named "Chart.js" are two separate open-source JavaScript libraries (Eternicode, 2017),(Chart.js, 2017). They could be switched out without affecting the graphical interface as a whole. The date-picker and the graph have both been styled and visually formatted with the help of their respective documentation to fit this project specifically.

The graph's y-axis represents the amount of people, and the x-axis represents the time. This gives the user an overview of the chosen date, but also a possibility to look in to more detail. The graph library only supports equal amount of data points for the different zones. Practically speaking this means that, sending in ten data points for zone "1" and eleven data points for zone "2" would result in rendering problems. At the final stage of this project, no solution to this problem has been implemented.

To understand the usage of the interface more in detail, a more thorough explanation is done in appendix B. The interface is there walked through step by step.

5.4 System architecture

The above mentioned components and modules results in a modular system architecture. This system can use different cameras, as long as they are mounted from above, and still use the tool for image overlapping. However, some minor adjustments might have to be made for the image analysis algorithm to work. Finally, the data received by the database can come from any kind of input interface, as long as it has the correct format. This means that the data received from any sort of sensor, could then be evaluated and transferred to the database. Meaning that even though swapping a sensor, the visual interface would still function properly.

Chapter 6

Discussion

In the sections below, the results of this project are discussed and evaluated. This includes whether or not the results are expected or valuable.

6.1 Image pre-processing

During the development of the pre-processing algorithm different issues have occurred. In a retrospective the most significant ones are discussed below along with possible improvements. Most of those could be implemented but due to scope of this project they have been left out.

6.1.1 Sources of error

Figure 5.1 and 5.2 surroundings differs in how the furniture is located, the reason for this is because the same camera was used at two different positions at two different dates. To verify the result the floor tiles has to be inspected in figure 5.3. After examining this image it can be noticed that the tiles does not match correctly, this is due to the cameras not being angled identically when moved between the different positions. While the theoretical values calculated by the algorithm are correct, factors like what angle the cameras have, difference in height and errors in manual measurements all adds up to the practical result being incorrect.

6.1.2 Testing and verification

The tests conducted were performed at Stena Center, discussed in section 4.5. Since we only had one IR-camera available to us we could not perform a live test from the two positions. Instead we had to capture images from the two positions on different dates and then pre-process them retrospectively. The testing environment was somewhat limited by the fact that we only tested two positions that were on the same line. A more realistic test would include more than two camera position, placing them diagonally against each other and with different heights above the floor.

6.1.3 Error handling

The application doesn't handle a scenario where images are missing from cameras that are represented in the database and this would need to be handled to avoid displaying incorrect values for the end user. The same goes for images that fall out of sync.

6.2 Image processing

The image processing part of this task was a section that was not as developed as it might have been if the project groups skill set or experience within the field would have been higher. The selected solution is more mathematically primitive than most of the advanced algorithms used in other systems. This could make our system vulnerable to problems other systems might handle well but since it will be implemented in a known environment the system will be sufficient for our cause.

6.2.1 Camera placement and resolution

From the data in figures 5.4, 5.5 and 5.6 it can really be seen how big of an impact the camera placement has on the result. Although the results could be improved for facial tracking using a camera with higher resolution (Axis, 2017), the results from figure 5.4 indicates that facial tracking is not a reliable method. This was the main reason to why area analysis was investigated.

6.2.2 Thermal compared to IR

As seen in table 5.1, the accuracy is noticeably higher on a thermal imaging camera than on an IR. This is probably due to the lack of reflections when using a thermal camera. This is because a thermal camera uses heat dissipation to determine how to create an image, not the amount of reflected visible light.

Another edge for the thermal camera over the IR camera is color. Although our current algorithm does not take advantage of color in images, some algorithms have an easier way to determine objects from a colored image. As IR images are only in a gray scale those algorithms are useless on such images. But, as the thermal images are colored this might increase the accuracy noticeably.

Last, but not least, it is more difficult to identify someone on a thermal image than on an IR image. One goal of this project was to have the guests privacy in mind and therefore this is yet another argument for using a thermal camera.

6.2.3 People's poses

From figures 5.5, 5.6 and 5.7 it can be noted that what pose the people on the picture is in affects the output of the algorithm. For example, when all three are lying on the floor, their area is the same amount as if five people were standing up. The opposite thing happens when all three stand close together and the algorithm only recognizes two people. This is something that will always be an issue using a thermal camera. However, since the case where all people are laying on the floor is unlikely to occur at a nightclub, this is not seen as an issue.

6.2.4 Environmental differences and their impact on precision

The difference in environment makes a significant in the difficulty of counting people in images. The biggest issue is the fact that night clubs often use some form of strobe, light effect and/or smoke machines, making the usage of a regular camera impossible. An IR-camera is therefore a better choice than a regular camera, but this follows that the image processing becomes more difficult. The IR-cameras takes pictures in black and white, where the white part of the image reflects more light than the dark parts. But, with only two colors the images is flatter and contains less information than full colored images. This especially makes it hard for our solution to work when the floor is bright.

This problem however, does not apply to thermal cameras, as these apply artificial colors to its images based on the infrared radiation from an object. As humans are about 37 degrees Celsius and most floors are not, they will stand out in thermal images due to warmer objects sending out more radiation that colder objects do.

6.2.5 Testing

Unfortunately there has not been any tests performed in a nightclub environment. This is due to the strict Swedish laws and regulations regarding camera surveillance. Tests with large crowds has not been tested either, because of a more focused work on perfecting the algorithm. However, on a large crowd it can be presumed by the results of 5.6 that errors will have a larger impact with more people in the picture. With more people in one picture there is less room for poses like number five in 5.7 and therefore it might be more of an underestimate than an overestimate with more of a crowd.

6.3 VNU integration

The integration with VNU's already existing system worked well. The main reason for this was the help received from VNU. Another factor that made the integration easy was that the already existing code base followed the examples and tutorials presented at Meteor's web page. Therefore reading the documentation and implementing certain elements went without major setbacks.

Meteor's documentation contains clear examples on how to implement certain elements. It also provides tutorials to start working with the framework. The tutorials that mostly consists of creating a simple app, explains the more advanced concepts in a good, learn by doing manner.

The interface has not been tested in any way regarding the user experience. However, thought has been put in to the interface, to make sure that basic user experience principles are followed.

The creation of a new collection worked well in the already existing MongoDB hosted by VNU. MongoDB had well documented guides on how to get started. It was easy to find answers related to the different problems that occurred through out the project that involved MongoDB. This made the development process a nice experience.

6.4 Sustainability

Right away, this project might not help with the sustainability and environment of a nightclub. But, with the data about how many people are visiting a given space, the climate control of that area can be adjusted accordingly. This will increase the energy efficiency of the nightclub.

A possible improvement is to integrate other sensors with the camera to monitor air quality, temperature or maybe volume. This data can then also be used to further optimize the climate control of the space and thus further increase energy efficiency.

6.5 Possible improvements

There are always a possibility for improvements when working with projects of this size. Here in this chapter are some suggestions for possible improvements to aid further development.

6.5.1 Image pre-processing

In a finished product a more precise method to install and measure the dimensions of the zones would be required in order to achieve correct results.

In hindsight a more advanced test environment should have been designed beforehand to allow a better verification of the algorithm. This could however have led to us not getting to the point where the algorithm was developed far enough to be tested. One must also consider that if the application was to be setup in a production environment an extensive amount of error handling would have to be implemented, such as error handling of defect cameras or missing images.

6.5.2 Image analysis

The implemented solution is not optimal since it depends on environmental variables to work properly. A improvement to this would be to use blob detection, shape detection and/or foreground-background separation. This demands a higher skill set and/or more time to solve.

6.5.3 Camera

As thermal images seems to be the better choice, a thermal camera with a higher field of view could be a great saver in both pre-processing time and people detection. Although, thermal cameras are expensive and therefore a sweeping camera might be a cheap solution. Since our system only takes one picture every ten seconds, the time to take multiple images exists and should be used to either a more powerful algorithm or take more pictures.

6.5.4 VNU integration

As mentioned in section 5.3.1 the database objects at VNU are filled continuously with data, rather than pre-allocate a certain amount of space. This is something that could effect the performance negative according to Jake Angerman (Angerman, 2014). Angerman claims that objects could potentially have to relocate because of the fact that they have become bigger and would interfere with other objects space in the database. Moving objects are according to Angerman an expensive operation and should be avoided if possible. A possible solution or improvement to the problem would be when a completely new date is about to enter with data, the spot in the database is pre-allocated assuming that all available times on a day will be filled with information. This would create chunks of objects that are all of the same size to enable the database to fit the objects better in the common space, and therefore also never have to relocate an object.

The trade-off however, would be that there is a risk of space not being used. Unused space is not desirable, but this could be evaluated against the fact that the database will store the chunks of data more effectively. A compromise between pre-allocating and not doing it at all, could be to statistically look at the size of the objects. Then from the statistics try to find a value that both improves the factor in how often relocating of objects happen, and to how much extra space each object needs to take up.

As earlier discussed in 6.3, the interface was made with focus on creating something that followed the basic user experience principles, but that no tests were done to verify the result. To improve interaction with the system for the end user, more could be done on the graphical part. Further development of the project could involve looking at different user experience principles and test if that is the case.

Additionally a study could be done with focus on creating an optimal graphical interface for displaying the night club flow.

6.6 Ethical problems with image capturing

In our daily lives technology becomes more and more connected to the cloud. Even the dishwasher, car, TV and microwave are all inventions that are added to the cloud. This is a feature in many cases but it doesn't always come for free. The cost is often privacy and security of the devices, for example the Samsung's smart tvs has been widely discussed regarding their privacy (Hamill, 2015) (CBS Interactive Inc., 2017). The solution proposed in "how to track the guest flow at nightclub's" in this thesis has ethical aspects that needs to be taken in to account and further discussed in this section.

One of the main ethical problems with the solution using an IR-camera in the nightclub environment is that it gives a very high resolution on the images. This comes in handy when doing image analysis but is something that can cause problems ethically. If someone with a malicious intent were to gain access to the images, individuals could theoretically be identified due to the high resolution of these images. Therefore the images could be misused to either bribe or severely damage a person's reputation.

Even if the solution provided works strictly with deleting images continuously, to make sure that people never gain access to the images captured, it's hard to make a system one hundred percent safe. There is always a risk for a bug that stops the system from processing images which would result in giving people a possibility to look at the images. There are certainly possible solutions using encryption but also backup systems to make sure that the images are actually deleted and not kept if the system hangs, this is however outside of the scope of the project.

Another solution to the earlier described problems could be to lower the resolution of the images from the camera. That would make it harder for the human eye to identify a specific person which also results in it being hard to damage one's reputation. However, this could cause troubles for the image analysis if people become too unrecognizable. As earlier mentioned in 6.2.3, having an even higher resolution could be beneficial which makes lowering the resolution hard to motivate in a performance perspective, but a possible value to tweak from an ethical stand point. Using a thermal camera however solves this dilemma as thermal cameras capture heat dissipation rather than visible light. Subsequently faces become indistinguishable from each other without additional development effort.

Chapter 7

Conclusion

This project has resulted in a system that achieves every criteria in the project specifications in one way or another. While it has proven to be difficult to track people accurately, especially at a nightclub, some valuable data has been acquired.

First and foremost, the research conducted in order to determine whether any sensor could coupe with the harsh environment of a nightclub, revealed that Wi-Fi and Bluetooth was not viable options. This was due to the global privacy awareness, that made the biggest smartphone operating system developers turn off the ability to track devices with these methods.

In the pre-study it was concluded that a camera not needing a light source visible to the human eye, where the best option. Therefore an IR and thermal camera where selected. The thermal camera differs from the IR camera in relying on the reflectiveness of the object, but instead uses the object natural radiation. IR cameras has the edge of being a cheaper alternative.

After an extensive testing it can be concluded that a thermal camera is more suited for the task than an IR. Data collected with a thermal camera had an accuracy of up to 81 percent whilst the IR only achieved 40 percent. This is due to the difference in reflected light from people depending on clothes and angle towards the light source. Since all humans radiate infrared light, the angle or clothing is not relevant to the thermal camera.

Finally, this project has evaluated different sensors for the task, developed an infrastructure to collect and process the data where an accuracy of up to 81 percent was achieved. This data was then visualized in an application that is possible to integrate with the VNU infrastructure. Also, if a thermal camera is used, the privacy and integrity of those visiting the nightclub should not be invaded, as it is very hard to distinguish people on a thermal image. The thermal camera is also easy to mount. Thereby, this project has succeeded in a way with all its intended purposes.

Bibliography

Angerman, J. R. . J. (2014). *MongoDB for Time Series Data Part 2: Analyzing Time Series Data Using the Aggregation Framework and Hadoop.* Retrieved from https://www.mongodb.com/presentations/mongodb-time-series-data-part-2-analyzing-time-series-data-using-aggregation-framework (Acc 2017-05-02)

Axis. (2017). *Identification and Recognition.* Retrieved from https://www.axis.com/cz/cs/learning/web-articles/identification-and-recognition/resolution (Acc 2017-05-08)

CBS Interactive Inc. (2017). *WikiLeaks says CIA hacked Samsung smart TVs.* Retrieved from http://www.cbsnews.com/news/cia-hacked-samsung-smart-tvs-wikileaks-vault-7/ (Acc 2017-05-02)

Cetas, T. C. (2008). *Practical thermometry with a thermographic camera—calibration, transmittance, and emittance measurements.* Retrieved from http://aip.scitation.org/doi/pdf/10.1063/1.1135377 (Acc 2017-05-09)

Chart.js. (2017). *Open source HTML5 Charts for your website.* Retrieved from http://www.chartjs.org/ (Acc 2017-05-02)

Chen, P. P.-S. (1976). *The entity-relationship model: Toward a unified view of data.* Retrieved from http://dl.acm.org/citation.cfm?id=320440 (Acc 2017-05-22)

Creative Commons. (2017). *Attribution 3.0 Unported (CC BY 3.0).* Retrieved from http://creativecommons.org/licenses/by/3.0/ (Acc 2017-05-10)

Dillon, C. (2015). *Sunder sandher's tech game changer.* Retrieved from http://www.betterretailing.com/sunder-sandhers-tech-game-changer/?utm_content=bufferdbcdd&utm_medium=social&utm_source=twitter_betterRetailing&utm_campaign=buffer (Acc 2017-02-10)

Eternicode. (2017). *Bootstrap-datepicker.* Retrieved from https://bootstrap-datepicker.readthedocs.io/en/latest/ (Acc 2017-05-02)

FLIR. (2015). *1974637.pdf.* Retrieved from http://www.farnell.com/datasheets/1974637.pdf?_ga=1.110030476.840432015.1490174485 (Acc 2017-04-29)

Foscam. (2017). *Foscam FI9900P.* Retrieved from http://www.foscam.com/FI9900P.html (Acc 2017-04-29)

Freepik. (2017). *Camera Icon, Dancing Person, Icon Image, Icon Man Watching Screen Icon.* Retrieved from http://www.freepik.com

Github, M. (2017). *Meteor.* Retrieved from https://github.com/meteor/meteor (Acc 2017-03-24)

Hamill, J. (2015). *Samsung spy telly scandal erupts after firm admits its television will RECORD your "personal and sensitive" conversations.* Retrieved from http://www.mirror.co.uk/news/technology-science/technology/samsung-spy-telly-scandal-erupts-5131842 (Acc 2017-05-02)

International Data Corporation. (2016). Smartphone OS Market Share, 2016 Q3. Retrieved from http://www.idc.com/promo/smartphone-market-share/os (Acc 2017-05-08)

Jansson, J. (2017). *Personal interview.* (Nightclub manager)

Jensen, O. H. (2008). *Implementing the Viola-Jones Face Detection Algorithm. (2008) .* Retrieved from http://etd.dtu.dk/thesis/223656/ep08_93.pdf (Acc 2017-05-10)

John Shackleton, J. H., Brian VanVoorst. (2010). Tracking People with a 360-Degree Lidar. Retrieved from http://www.velodynelidar.com/lidar/hdlpressroom/pdf/papers/journal_papers/TrackingPeoplewitha360-DegreeLidar.pdf (Acc 2017-03-24)

Kepler Analytics. (2016). *Why counting people is important in retail.* Retrieved from http://www.kepleranalytics.com.au/blog/the-evolution-of-people-counting (Acc 2017-02-10)

madebyoliver. (2017). *Database Icon.* Retrieved from http://www.flaticon.com/authors/madebyoliver (Acc 2017-05-10)

Mathworks. (2017). *Features.* Retrieved from https://se.mathworks.com/products/matlab/features.html (Acc 2017-05-09)

Maxim Basinski. (2017). *Cog Wheel Icon.* Retrieved from http://www.flaticon.com/authors/maxim-basinski (Acc 2017-03-24)

Meteor.com. (2017). *What is Meteor?* Retrieved from http://docs.meteor.com/#what-is-meteor (Acc 2017-03-24)

Microsoft. (2017). *SVG vs canvas: how to choose.* Retrieved from https://msdn.microsoft.com/en-us/library/gg193983(v=vs.85).aspx (Acc 2017-05-02)

MongoDB. (2017). *How does MongoDB work?* Retrieved from https://www.mongodb.com/what-is-mongodb (Acc 2017-03-24)

Node.js Foundation. (2017a). *Node.js Home.* Retrieved from https://nodejs.org/en/ (Acc 2017-05-03)

Node.js Foundation. (2017b). *Overview of Blocking vs Non-Blocking.* Retrieved from https://nodejs.org/en/docs/guides/blocking-vs-non-blocking/ (Acc 2017-05-03)

OpenCV Documentation. (2017a). Cascade Classification. Retrieved from http://docs.opencv.org/2.4/modules/objdetect/doc/cascade_classification.html (Acc 2017-05-10)

OpenCV Documentation. (2017b). Face Detection using Haar Cascades. Retrieved from http://docs.opencv.org/trunk/d7/d8b/tutorial_py_face_detection.html (Acc 2017-05-10)

OpenCV-Team. (2017). *OpenCV Library.* Retrieved from http://opencv.org/ (Acc 2017-05-09)

Oracle Corporation. (2017). *About MySQL.* Retrieved from https://www.mysql.com/about/ (Acc 2017-05-03)

Runkel, J. (2014). *MongoDB for Time Series Data Part 1: Setting the Stage for Sensor Management.* Retrieved from https://www.mongodb.com/presentations/mongodb-time-series-data-part-1-setting-stage-sensor-management (Acc 2017-05-02)

Smith, W. E. (2014). Image Processing. *AccessScience.* Retrieved from https://doi.org/10.1036/1097-8542.337600 (Acc 2017-03-24)

Stubailo, A., Hwillson. (2017). *DDP.* Retrieved from https://github.com/meteor/meteor/blob/master/packages/ddp/DDP.md (Acc 2017-03-24)

Velodyne LiDAR. (2017). *VLP-16.* Retrieved from http://velodynelidar.com/vlp-16.html (Acc 2017-03-24)

Wheeler, B. (2016). *How Did MongoDB Get Its Name?* Retrieved from https://www.morpheusdata.com/blog/2016-03-15-how-did-mongodb-get-its-name- (Acc 2017-05-02)

Wood, L. (2017). *People counting system market - global forecast analysis to 2022 - propelled by the growing retail sector availability of economical and easy-to-install solutions - research and markets.* Retrieved from http://www.prnewswire.com/news-releases/people-counting-system-market---global-forecast--analysis-to-2022---propelled-by-the-growing-retail-sector--availability-of-economical-and-easy-to-install-solutions---research-and-markets-300398111.html (Acc 2017-02-10)

Yue M. Lu, M. V., Clement Fredembach, & Süsstrunk, S. (2009). *Designing Color Filter Arrays for the Joint Capture of Visible and Near-Infrared Images.* Retrieved from http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=5414324 (Acc 2017-05-09)

Appendix A

Pre-study

This pre-study has been divided into three major parts including what sensor technology that is available, what communication alternatives there are and conditions of the environment at the night clubs. The purpose of this study is to get a better understanding of the environment we will be working in, and the different technologies available to us to help solve our task. The different solutions vary in price and complexity. These factors have been taken into account to eliminate alternatives in an earlier stage without spending valuable time testing it and realizing it does not work out. The pre-study is wrapped up with a conclusion with regard to all the different parts and is ultimately the technology we decided to move forward with.

A.1 Sensors

There is a wide variety of sensors, all differing in complexity, price and what they are capable of. Below is a summary of different sensor technologies that can be used to track the flow of people.

A.1.1 Wi-Fi/Bluetooth

One of the possible ways to track people's movement is via their smart phones or tablets through Bluetooth or Wireless Fidelity (Wi-Fi). Every smart phone or smart device has a unique Media Access Control Address (MAC address), which makes it easy to identify. It can be detected by a central unit for Wi-Fi called Access Point (AP) or a central unit for Bluetooth called Master (Naeim Abedi, 2013). MAC addresses are assigned to a specific Network Interface Controller (NIC) and stored in the device's hardware (Luo, 2014). The MAC address could then be detected and used by IEEE 802 technologies (such as Wi-Fi and/or Bluetooth scanning, which is of our interest) (Naeim Abedi, 2014). When a device with a MAC address and Wi-Fi or Bluetooth connectivity enters the scanning field of a Wi-Fi or Bluetooth source the MAC address is collected along with the strength of the signal, thus giving an indication of the distance from the AP or Master (Naeim Abedi, 2015). The data collection and indication of distance provides an opportunity to track a single device, which presumably is carried by a person, movement closer or further from the Wi-Fi's AP or Bluetooth's Master, since the information is updated with every single field pulsation from the source (Naeim Abedi, 2015). Both Wi-Fi and Bluetooth tracking require that the devices that are to be tracked have enabled Wi-Fi/Bluetooth. Smart phones provide options to turn off Wi-Fi/Bluetooth, rendering them untraceable. This will ultimately result in a smaller number of traceable devices.

A.1.1.1 Using Wi-Fi to detect MAC addresses

Wi-Fi (or IEEE 802.11) has two different alternative modes where one is the infrastructure mode, where all devices talks through the AP, and the ad-hoc mode, where the devices talks directly to each other (Naeim Abedi, 2013). The scope of this will be restricted to the infrastructure mode. In the infrastructure mode a single Wi-Fi AP and one or more devices is called a Basic Service Set (BSS) (Naeim Abedi, 2013). When a device is within the range of a Wi-Fi's AP it goes through three procedures before it is a part of the BSS (Naeim Abedi, 2013). The first procedure is scanning, during which the device and the AP are trying to detect each other. The second and third one is authentication, followed by association, which establishes communication with the AP by transmitting the device's MAC address, Service Set Identifier (SSID) and other security settings (McQuerry, 2008). The time it takes to find a device within an AP's range is called the discovery time, which for Wi-Fi is estimated to be 1.365 seconds (Naeim Abedi, 2013). Wi-Fi-APs can be used to pin-point a single device's movement in an enclosed area by triangulating the signal strengths. One big problem with Wi-Fi tracking is that devices from big manufactures like Apple do not scan for Wi-Fi networks when they are not used (Apple Inc, 2017). This makes the Wi-Fi based solution with MAC-address tracking inadequate since the accuracy of the solution drops significantly. When the nightclub guests' devices are not in use they cannot be tracked. To verify this we did a small test with IOS 8, android 4, 5, 6 and 7 devices. When the screens were locked, no Wi-Fi packets were sent at all. Apple and Google also provide MAC adress randomization for their mobile operating systems to make devices harder to track via Wi-Fi. A recent study has broken this mechanism and the researchers claims that they managed to track 100% of tested devices despite MAC adress randomization (Jeremy Martin, 2017).

A.1.1.2 Using Bluetooth to detect MAC addresses

Bluetooth (IEEE 802.15.1) is a wireless technology that is generally used for a smaller range than Wi-Fi technology. A single network of Bluetooth devices is called a piconet and it can contain 8 devices,which consists of one master and 7 slaves (Naeim Abedi, 2013). The piconet share one physical channel and the slaves synchronizes in time to match the masters clock (Naeim Abedi, 2013).

To connect to a master, the device has to go through two phases. The first phase is the Inquiry, where the device searches for the master, which gives the master a chance to identify the device (Naeim Abedi, 2013). The next phase is named Page where the device transmits its identification status to the master and sets the masters clock as its own main clock (Naeim Abedi, 2013).

All the information needed to identify the device is given in the Inquiry state and a fully complete connection to the master is therefore not needed. One of the most important factors to take into account for the Bluetooth system is the discovery time, which tells us how often the system will update the position (signal strength of source) of a device. The discovery time of Bluetooth technology is estimated to be 10.577 seconds (Naeim Abedi, 2013).

A.1.2 Pressure

Tracking people using pressure is another interesting way to go (Candy Yiu, 2007). By placing thin pressure sensitive devices underneath floor tiles, a research team found that it is possible to track individuals moving within a store (Candy Yiu, 2007). The algorithm assumes an individual can only move in a straight direction or make a turn. When the individual has made a turn the algorithm makes a note and continues to track along the new axis. This method minimizes the number of sensors having to be placed, and therefore reduces the cost. However, as more individuals are within the grid of pressure sensors, the algorithms success rate deteriorates and with five people there is a 40 percent location error.

Another research team has investigated this further and analyzed whether it is possible to track individuals by their step pattern (Al-Naimi, 2011). As different people put pressure on different parts of their foot as they take a step. This pattern can then be used to identify a person's path more accurately.

Unfortunately there is one large problem with a pressure sensitive system; scalability. Depending on what accuracy is needed, whether it is okay to only track people walking in or out from a room or the path they choose within the room, the number of sensors needed quickly adds up. Therefore it might not be a suitable solution to use pressure sensors to track a lot of people in a large area. However, if the goal is only to know whether a person enters or leaves the room, this method might be a suitable option.

A.1.3 Active infrared

Another way to detect people is the so called AIR sensor or active infrared. They consists of two parts, the emitter and the receiver (Kanchann, 2014). The emitter is continuously emitting infrared radiation using an LED towards the receiver, and the receiver is checking whether or not the infrared beam has been altered in any way (Puschell, 2014). If the beam is interrupted completely or altered in any way, the sensor signals. Every human emits infrared radiation (Kanchann, 2014), this means that if a person moves between the receiver and the transmitter the infrared beam will be altered. The will result in a detection. Since you need to walk past the line between the emitter and the receiver this sensor could be used in door openings to determine when a person enters or leave.

To use an active infrared sensor you require electricity (Kanchann, 2014). Since the beam is supposed to be sent continuously, it will require a power source that is always connected which can last over a longer period of time. This in combination with the fact that the data need to be transferred using some sort of communication which also will require a power source, makes the solution very dependent on an effective power solution.

A second problem with the sensor is that it requires both the emitter and the receiver which makes positioning hard. You do not want to place them where people can easily get access to them or remove them, preferably they should be placed in the ceiling. This will not be the case if you use an active infrared, you would have to place them on the sides of a door, or at the floor, where people can easily step on them or bump in to them.

The main disadvantage with the active infrared are when there is a lot of people trying to enter a room at the same time. Since the sensor is binary and only provides information if the beam is altered it is hard to determine direction but also how many people have entered or left the room. A study using infrared binary sensor and an algorithm to count the amount of people passing by has already been done and yielded the following. The more people that is passing by the less likely it is to determine how many that passed by (Toshiaki Miyazaki, 2015). According to this study, even with a low amount of people such as four, the detection ratio started to become poor (45%).

Since the sensor is going to be used within the nightclub environment it should be able to handle the different possible environments there. However, this is not the case with the active infrared, it both has troubles when there is a lot of fog or when there is a lot of light (VSTAR, 2017).

There are however some positive points that can be made about the sensor. First of all, the sensor is very cheap, you can get one for less than 5$ (eBay Inc, 2017a). This would give us an easy way to test without having to risk any major economic loss if the sensor would not fulfill our expectations. Using an active infrared sensor is also positive in the sense of integrity. Since you do not follow any human specifically, we do not invade any ones privacy.

A.1.4 Passive infrared

Another kind of infrared sensor is the passive one, often abbreviated as PIR. The PIR sensor consists of two slots that are made out of material sensitive to IR. When the sensor has not been active for a while both the slots sense the same amount of IR, thus they are in balance. As soon as an object radiating IR, i.e. a human body, passes by the first half of the sensor it generates a positive differential change between the two slots. When it later leaves the second half of the sensor there will be a negative differential (Colliard-Piraud, 2013).

The PIR sensor is only affected by objects passing by which radiates IR, which is great in a dark environment like that of night clubs. But it is not as simple as that since other variables can affect the temperature in the room. If for example the night club would be very crowded and it would not be cooled down properly the PIR sensor will have trouble distinguishing people passing by since the balanced temperature when the sensor is idle would be too close to that of the people passing by. Apart from this there are a lot of advantages with using PIR sensor. They are very cheap (eBay Inc, 2017b), small, easy to use, energy efficient flexible to install, can be mounted practically anywhere. When it comes to violations of integrity, the PIR sensor, like any other IR sensor, only sees the radiation of IR and therefore you can not distinguished a specific person from the data received from the sensor.

The common usage of the PIR sensor is for motion detection, usually when you want to activate the room's light depending if people are present. For our task, to count people, the PIR sensor will thus have a hard time to actually count the amount of people passing by. There have been more sophisticated solution presented where multiple sensors have been used, proved to have yield accurate results (Jaeseok Yun, 2014), (Kazuhiko Hashimotoa, 1997). The down side of these solutions are that in order to implement them one has to know more advanced programming styles, like machine learning. Since none in the group is familiar with subjects like these, it's likely that learning that would be a project of its own and thus out of context for our product.

For our task it is more likely that the PIR sensor could be used in combination with other sensors. For example you could use a PIR sensor that detect when there is motion and then trigger some other sensor to be activated, resulting in a more energy efficient product.

A.1.5 Camera

There is a big number of algorithms for people detection with the use of image analysis. These algorithms can extract interesting data from images that can be used to calculate and visualize the flow of for instance a crowd. Such solutions have already been implemented in some public environments across the world. Cameras/IR-cameras are relatively cheap to acquire and simple to install which makes them an attractive alternative when it comes to determining the flow of people. There are two viable alternatives related to the scope of this project. One of them require real-time video tracking of people passing by an entrance to an area and the other one relies on overview images of an area. This summary focuses on IR-cameras since dark night club conditions renders images taken with normal cameras useless.

A.1.5.1 Real-time video

By counting all people that pass by an entrance to an area, a good estimation of the number of people in the area can be made (Ariel Kapusta, 2016), (Adnan Ghazi Abuarafah, 2012). In order to do this the entrance to the area must be tracked in real time. There are many decent image processing tools for tracking people in real time with cameras that could be used for this purpose (e.g. MATLAB, OpenCV).

If all entrances are tracked the accuracy of the number of people in an area will be high. Facial recognition could be used to track which individuals move in and out of areas. Since images need to be taken with very short intervals a lot of computing power will be required to process all these images.

A.1.5.2 Overview images

The number of people can be estimated from overview images of areas (Adnan Ghazi Abuarafah, 2012). Images from different cameras could be merged to provide greater overviews, thus creating a heat map of larger areas that ca not be covered by just one camera. People detection algorithms could also be used to count the number of people in an image. With a heat map you could visualize where in a room someone is and without real-time tracking large computing resources would not be needed.

People counting based on overview images could be applicable to many different sorts of environments since no specific type of entrance would be required. Achieving high accuracy when counting people with image analysis on still images, can be difficult. Real-time video sequences provide more information and makes it easier to distinguish people from the background in the images.

A.1.6 Laser Radar

A technology that is already widely used in scanning and measuring scenarios is the laser radar (also known as "Light detection and ranging", LIDAR or LADAR). LIDAR works much like a RADAR but with laser signals instead of radio signals (P. S. Argall, 2007). Laser pulses are sent out and reflected on the environment. The laser radar then collects the reflected data and calculates the distance to the objects. In recent years advancements in LIDAR technology allows for creating a 3D-map of the environment and the people in it with precision of a few centimeters (John Shackleton, 2010).

For the tracking purposes of our application however LIDAR has a few problems mainly because of the crowded area that would be scanned. Despite using advanced algorithms for the purpose of carefully detecting each person it seems according to research to be very hard to separate people for example shaking hands or standing shoulder to shoulder (John Shackleton, 2010). This is problematic in our application for two reasons. First and foremost the application is meant for a very crowded area where people move in ways that are very hard to predict, for example dancing, hugging, holding hands and bumping into each other. Secondly this uncertainty also means that tracking of a person for longer amounts of time will be incredibly hard since it is very easy to swap two or more people while tracking.

While LIDAR might be a very good tool for tracking people in some scenarios the price point for these LIDAR devices is still very high. Velodyne is one of the most established brands of professional LIDAR equipment and the cheapest alternative they provide costs almost 8000 USD (Velodyne LiDAR, 2017). Considering the problems mentioned earlier using LIDAR these cheap solutions would likely provide even worse results.

In conclusion LIDAR shows potential for this application in the long run but shows a few major flaws in its current state. Mainly that it seems highly unlikely to accurately be able to track someone with high accuracy in a crowded and unpredictable environment. Even if this would not have been a problem the extremely steep price point would make a solution using LIDAR unsustainable for our application at this time and point.

A.2 Connectivity

There are multiple ways to connect the sensor from the night club to a server where we can perform our calculations. These connections can be split up into wired and wireless.

A.2.1 Wireless

The two main interfaces used today for wireless connectivity is Wi-Fi and Bluetooth. The following sections will delve into the possibilities of them.

A.2.1.1 Bluetooth

Bluetooth provides a low energy wireless solution for transmitting data in short ranges although amplifiers should in theory support up to 100 meters range (McDermott-Wells, 2004). While it is theoretically possible to extend this range this is strictly prohibited in many countries due to laws regarding signal strength (McDermott-Wells, 2004). Bluetooth provides the possibility to encrypt data which makes for secure communication, but just like most wireless technologies also suffer from security problems (John Padgette, 2012). If high bandwidth and range is needed Bluetooth is a bad choice as competing solutions such as Wi-Fi are better at this.

A.2.1.2 Wi-Fi

Wi-Fi provides better range and bandwidth than Bluetooth does. However Wi-Fi is also more power consuming which could be a problem in a battery driven solution (Roy Friedman, 2013). Nowadays, based on experience most restaurants, night clubs and stores already have a Wi-Fi network that our product would be able to access making for an easier and quicker deployment than using a wireless Bluetooth solution.

In conclusion Wi-Fi should be the better choice over Bluetooth for means of communication as long as there is no need for low power consumption. Bluetooth presents no pros other than power consumption that favors it over Wi-Fi in the wireless communication category.

A.2.2 Wired connection

The alternative to the wireless solutions would be using a wired connection such as Ethernet. This would ensure very good stability almost no matter what interferences present themselves in the environment. On the other hand there would possibly be a need for time consuming wiring in what might be a challenging environment. If cables are already appropriately placed however a wired solution would be the most stable and provide the highest bandwidth (IEEE, 2015).

A.3 Nightclub environment

The nightclub is not an ordinary place to track people flow. Usually, the sensors described earlier are located in closed environments where it's free from disturbance. This is not the case for night clubs, there are several physical constraints that has to be taken in to account when making a decision about what sensor is the most suitable one.

A.3.1 Physical

One of the main constraints being in a night club is the amount of people that the sensor needs to be able to handle. There's always a chance for the place to be very crowded and that people is almost standing on top of each other. This could possibly interfere and make it harder for some sensors to determine the flow. This is something that must be taken in to account when the sensor is chosen.

The night club could possibly have certain effects which the sensor also should be able to handle. Among these we have fog, light, temperature shifting and sound (Rolén, 2017).

No night club is the other one alike, because of this the sensor that is chosen needs to be able to work at any type of night club. No matter if there are small rooms, big rooms or just one room.

A.3.2 Others

According to (Jansson, 2017) the detection rate needs to be around 50-60%, otherwise the data won't be sufficient enough to make any value for the customer.

A.4 Conclusion

When making the final decision regarding what sensor to choose, there are several aspect to take into account. The main focus will be to find a sensor and connection suitable for the nightclub environment.

A.4.1 Sensors

Passive and active infrared sensors are great sensors when it comes to detecting motion but for our application, to track number of persons and direction, the solutions tends to become quite advanced. To implement these solutions specific knowledge in fields like machine learning is required which none in the group is familiar with, thus not a viable options for our time frame.

Laser sensors is a useful and established way of scanning environments but due to its expensive price it is not a solution that would be beneficial to our cause. The LIDAR is thereby not a candidate to be implemented in our final solution.

Furthermore pressure sensors is a good alternative but lacks in accuracy, especially in a night club when people tend to move in groups and in different directions. This combined with its somewhat problematic installation guidelines made us neglect this option.

Bluetooth would not be reliable since it would require people to have Bluetooth activated, which is not something we can expect. Wi-Fi was the alternative with most promise but the tests we conducted proved us wrong. Therefore neither Bluetooth nor Wi-Fi was pursued.

The last alternative is a camera solution, but due to the limitations of calculation power a real-time solution won't be possible. Instead we will take pictures periodically of the entire venture from multiple cameras and count the number of people present.

A.4.2 Connectivity

When it comes to connectivity we will use Wi-Fi due to the fact that we cannot expect there to be wired connections available at every night club. Furthermore everyone in the groups is more familiar with Wi-Fi than Bluetooth and there are camera devices with built in Wi-Fi interface that can be utilized.

Bibliography

Adnan Ghazi Abuarafah, E. A., Mohamed Osama Khozium. (2012). *Real-time Crowd Monitoring using Infrared Thermal Video Sequences.* Retrieved from `http://free-journal.umm.ac.id/files/file/015_8123am0803_133_140.pdf` (Acc 2017-03-24)

Al-Naimi, I. (2011). *Advanced Multimodal Approach for Non-Tagged Indoor Human Identification and Tracking Using Smart Floor and Pyroelectric Infrared Sensors.* Retrieved from `https://www.researchgate.net/publication/268420758_Advanced_Multimodal_Approach_for_Non-Tagged_Indoor_Human_Identification_and_Tracking_Using_Smart_Floor_and_Pyroelectric_Infrared_Sensors` (Acc 2017-03-24)

Apple Inc. (2017). *iOS Security.* Retrieved from `https://www.apple.com/business/docs/iOS_Security_Guide.pdf` (Acc 2017-03-24)

Ariel Kapusta, P. B. (2016). *Person Tracking and Gesture Recognition in Challenging Visibility Conditions Using 3D Thermal Sensing.* Retrieved from `http://ieeexplore.ieee.org/document/7745247/` (Acc 2017-03-24)

Candy Yiu, S. S. (2007). *Tracking People In Indoor Environments.* Retrieved from `http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.65.9054&rep=rep1&type=pdf` (Acc 2017-03-24)

Colliard-Piraud, S. (2013). *Signal conditioning for pyroelectric passive infrared (PIR) sensors.* Retrieved from `http://www.st.com/content/ccc/resource/technical/document/application_note/b8/84/29/41/21/00/44/41/DM00096551.pdf/files/DM00096551.pdf/jcr:content/translations/en.DM00096551.pdf` (Acc 2017-03-23)

eBay Inc. (2017a). *IR sensor.* Retrieved from `http://www.ebay.com/bhp/ir-sensor` (Acc 2017-02-10)

eBay Inc. (2017b). *PIR sensor.* Retrieved from `http://www.ebay.com/bhp/pir-sensor` (Acc 2017-02-10)

IEEE. (2015). *IEEE 802.3.* Retrieved from `http://standards.ieee.org/getieee802/download/802.3-2015.zip` (Acc 2017-02-14)

Jaeseok Yun, S.-S. L. (2014). Human Movement Detection and Idengification Using

Pyroelectric Infrared Sensors. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4063065/ (Acc 2017-03-23)

Jansson, J. (2017). *Personal interview.* (Nightclub manager)

Jeremy Martin, C. D. L. F. L. B. C. R. E. C. R. D. B., Travis Mayberry. (2017). *A Study of MAC Address Randomization in Mobile Devices and When it Fails.* Retrieved from https://arxiv.org/pdf/1703.02874v1.pdf (Acc 2017-03-24)

John Padgette, L. C., Karen Scarfone. (2012). Guide to Bluetooth Security. Retrieved from http://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-121r1.pdf (Acc 2017-02-14)

John Shackleton, J. H., Brian VanVoorst. (2010). Tracking People with a 360-Degree Lidar. Retrieved from http://www.velodynelidar.com/lidar/hdlpressroom/pdf/papers/journal_papers/TrackingPeoplewitha360-DegreeLidar.pdf (Acc 2017-03-24)

Kanchann. (2014). *Infrared sensors.* Retrieved from https://wiki.metropolia.fi/display/sensor/Infrared+sensors (Acc 2017-02-10)

Kazuhiko Hashimotoa, S. M. K. M. N. Y., Makoto Yoshinomotob. (1997). Development of people-counting system with human-information sensor using multi-element pyroelectric infrared array detector. Retrieved from http://www.sciencedirect.com/science/article/pii/S0924424796014008 (Acc 2017-03-23)

Luo, H. (2014). Wireless fidelity (Wi-Fi). *AccessScience.* Retrieved from https://doi.org/10.1036/1097-8542.802040 (Acc 2017-05-10)

McDermott-Wells, P. (2004). What is Bluetooth? Retrieved from http://ieeexplore.ieee.org/document/1368913/ (Acc 2017-02-10)

McQuerry, S. (2008). *Wireless LANs: Extending the Reach of a LAN.* Retrieved from http://www.ciscopress.com/articles/article.asp?p=1156068&seqNum=3 (Acc 2017-03-24)

Naeim Abedi, E. C., Ashish Bhaskar. (2013). Bluetooth and Wi-Fi MAC Address Based Crowd Data Collection and Monitoring: Benefits, Challenges and Enhancement. *AccessScience.* Retrieved from http://eprints.qut.edu.au/71808/1/2013_abedi_bhaskar_chung.pdf (Acc 2017-05-12)

Naeim Abedi, E. C., Ashish Bhaskar. (2014). Tracking spatio-temporal movement of human in terms of space utilization using Media-Access-Control address data. *Applied Geography*, 72–81. Retrieved from http://www.sciencedirect.com/science/article/pii/S0143622814000629 (Acc 2017-02-10)

Naeim Abedi, E. C. M. M., Ashish Bhaskar. (2015). Assessment of antenna characteristic effects on pedestrian and cyclists travel-time estimation based on Bluetooth and WiFi MAC addresses. *Transportation Research Part C: Emerging Technologies*, *60*, 124–141. (Acc 2017-02-10)

P. S. Argall, R. J. S. (2007). Lidar (Laser Radar). Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/9783527600441.oe044/abstract (Acc 2017-02-10)

Puschell, J. J. (2014). Infrared radiation. Retrieved from https://www.accessscience.com/content/infrared-radiation/344500 (Acc 2017-02-10)

Rolén, A. (2017). *Personal interview.* (CEO VNU)

Roy Friedman, A. K., Yevgeny Krivolapov. (2013). On Power and Throughput Trade-offs of WiFi and Bluetooth in Smartphones. Retrieved from http://ai2-s2-pdfs.s3.amazonaws.com/b454/a3a1e56994df96161c040b7c0ac9d767f835.pdf (Acc 2017-02-14)

Toshiaki Miyazaki, Y. K. (2015). Multiple Human Tracking Using Binary Infrared Sensors. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4507662/ (Acc 2017-02-10)

Velodyne LiDAR. (2017). *VLP-16.* Retrieved from http://velodynelidar.com/vlp-16.html (Acc 2017-03-24)

VSTAR, H. (2017). *Difference between PIR motion sensor and infrared beam motion sensor.* Retrieved from http://www.hkvstar.com/technology-news/difference-between-pir-motion-sensor-and-infrared-beam-motion-sensor.html (Acc 2017-02-10)

Appendix B

User Manual for the Web Interface

Before describing the process of interacting with the system and what goes on under the hood, the current state for the user needs to be presented. Assume the following:

1. The user has created an account at VNU.
2. The user has logged in and has a nightclub assigned on his or her profile.
3. The user has navigated to the page.
4. No data is to be found for the current date.

Initially the user is presented with the following view of the date-picker, see figure B.1.

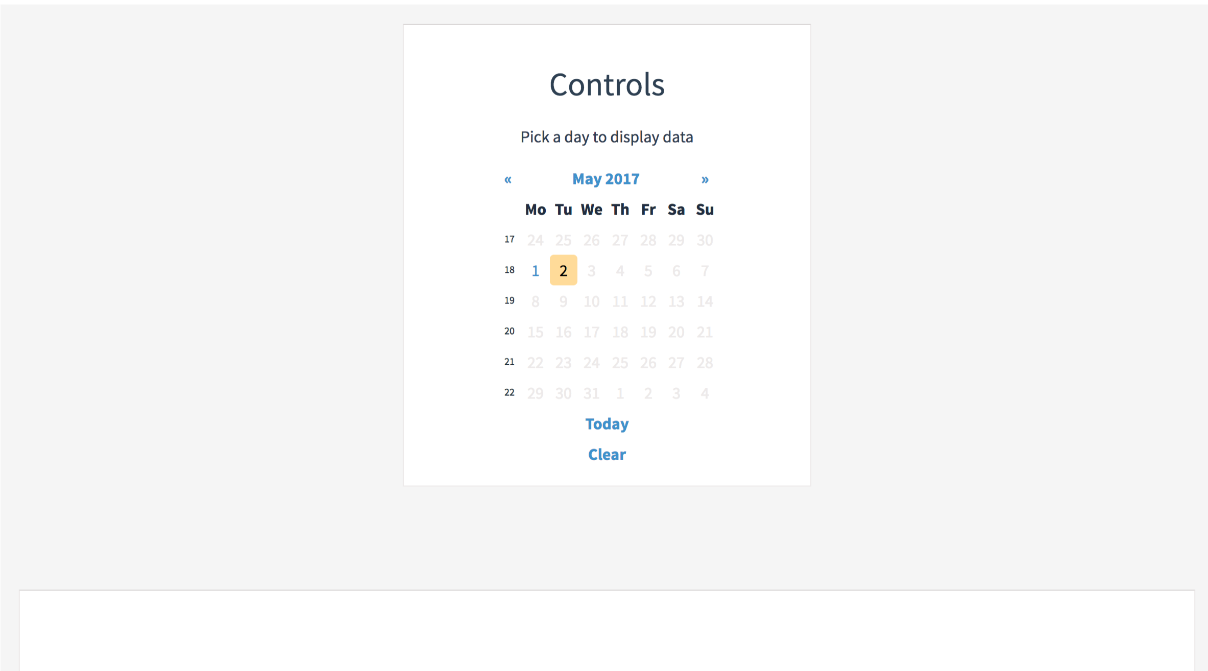


Figure B.1: The date-picker without a visible graph.

The date-picker defaults to the current date, which in case of data will render the graph. Otherwise the user have the possibility to pick a date where data is available. The implementation of the graph only displays the dates containing data. The graph does so by graying out the dates containing no data as in figure B.1. The reason for doing this is to give the user a hint that no information is there to be found.

Technically this is done by requesting the dates that actually contains data from the database on load. When the date-picker is about to be rendered, each date is checked against the available dates in the database matching the correct nightclub. If the date is not found in the available dates object, the date will be grayed out.

The user then either have the possibility to pick a day in the current month, or use the "«" to look further back in history for data. After picking a date, the graph will render the graph with all available zones for the chosen date. An example can be seen below in figure B.2, where the zones in the figure are named "1" and "2".

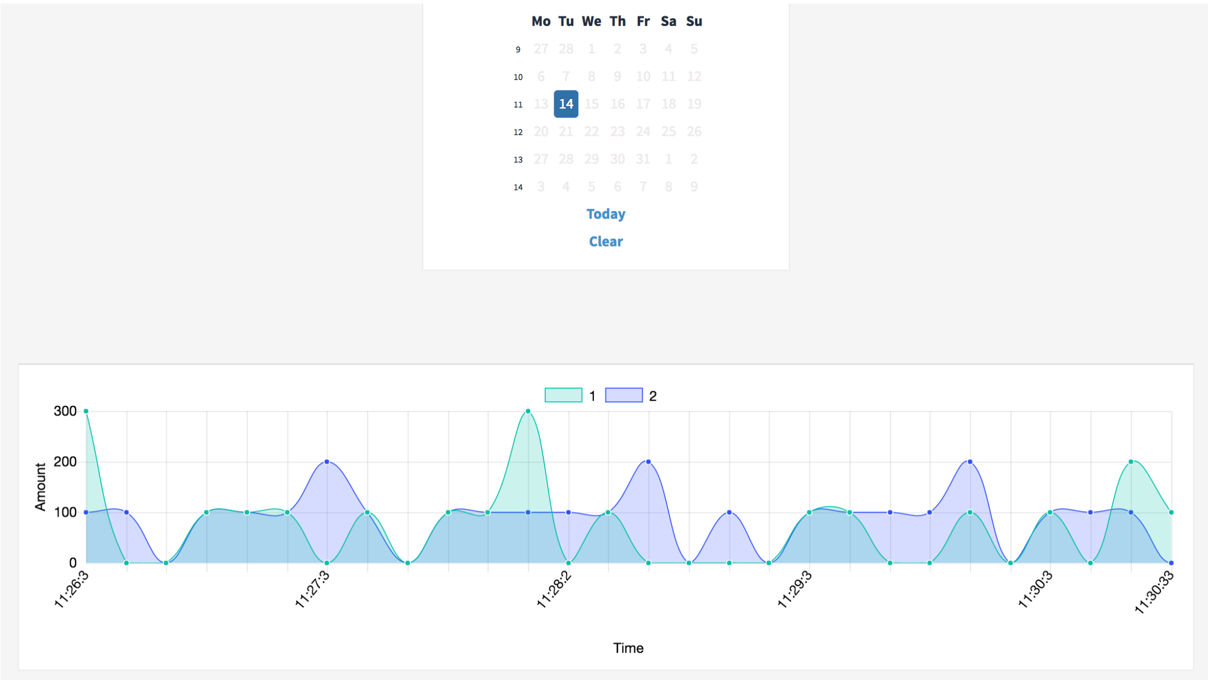


Figure B.2: Graph is presented after picking an available date.

When picking a date, the Meteor framework queries the database for the chosen date and since all data are within the object with the chosen date, the look-up time is fast. Another option could have been to have the data points spread out and find all the data points with the chosen date.

The user now have the option to either pick another date where the same rendering process will be performed again, or disabling a certain zone. Disabling a certain zone is something that is supported by the library on default and results in a smooth transition where a rescaling is done to fit the remaining zones. An example of this is show in figure B.3. In this figure it is visible that zone "1" is disabled by crossing out the zone name.

To make the zone "1" visible in the graph again, the user simply has to press zone "1" a second time.

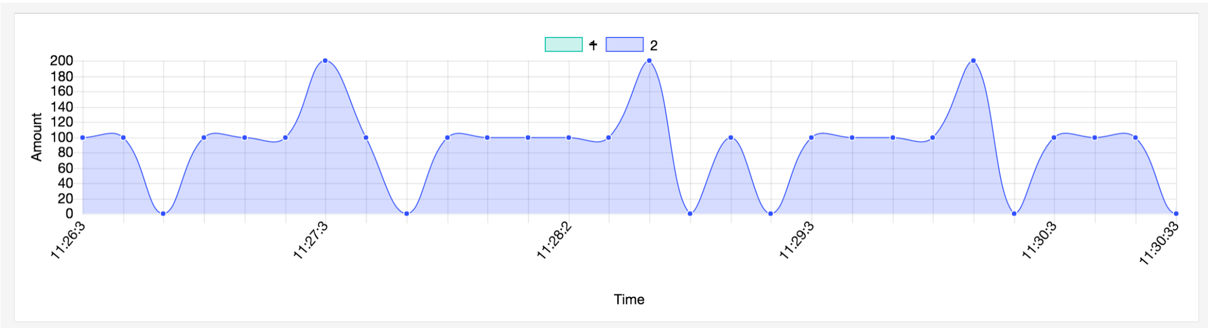


Figure B.3: The graph with two zones and one disabled.