

# Occupancy Analyzer

Global Software Development Project

Christoffer Wilken Pagaard

Jacob Romme Rasmussen

Theresa Brandt von Fackh

Tomas Miseikis

Report



**IT University**  
of Copenhagen

Denmark

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## Abstract

Write abstract text...

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# 1 | Introduction

## 1.1 Context

Smart use of energy resources is an ongoing topic these days. The reduction of expenses is mostly the biggest driving factor for companies. But also the debate around climate change brings new legislation to reduce the waste of energy resources, whose production is damaging to the environment and future generations. The IT University of Copenhagen (ITU) has an interest in producing an occupancy model for commercial buildings, like the ITU building, to detect where energy resources are needed and where they can be saved. Energy resources are needed for e.g. lighting and heat-regulating systems, which are relevant for occupants in a commercial building. With the detected occupancy data the ITU can predict occupancy and develop concepts for a smart use of energy resources in commercial buildings.

The Strathmore University in Kenya has also an interest in building up an occupancy model, but mainly for surveillance reasons. Surveillance can be used for several purposes like traffic monitoring, public safety and facilities surveillance. An IT-based surveillance system can automatically analyse the scene without the use of human resources. By analysing the scene the detection of occupancy is a major part. Moreover a real-time prediction model on top of the occupancy data can be used to prevent criminal activity by triggering alarms or other surveillance systems.

Currently there is no existing infrastructure to build up an occupancy model in the Strathmore University or the ITU building. Both universities want a solution for an occupancy analyzer based on Raspberry Pis due to the minimal consumption of computational and monetary resources. Furthermore, Strathmore University requests for an Android application, which represents a live-feed of the occupants in a monitored room.

A group of students from both universities have to collaborate to come up with a solution for an occupancy analyzer, which can satisfy the needs of both university interests. Ideally a product should be developed, which can be adapted to fit the needs of one or the other university. Furthermore, a collaboration project is mandatory for the student group from ITU, in which they have to face the challenges of global collaboration, navigate compromises and come up with a solution.

This report contains the product result, design of the product, details of the project work and the learning outcomes, which were achieved in the project with the globally distributed team from the perspective of the ITU students. The project team consists of international students located in Nairobi, Kenya (East African Time) and Copenhagen, Denmark (Central European Time).

## 1.2 Problem

The content of this project is to build an occupancy analyzer, which detects people in a room or corridor and predicts their movement. The occupancy analyzer has to be based on Raspberry Pis, which comes with computational restrictions, and webcams. A solution for the right architecture and programming languages has to be found, which can deal with those limited resources.

Due to the usage of webcams, a visual detection of people has to be made. Analyzing images by detecting people - which are moving objects and not part of the room - is one major challenge to face. Visual conditions of the image can change as a result of daylight. For example dynamic lighting and moving shadows should not influence the detection of people. To best capture occupants and the requirement to represent the occupants on an Android application, the webcam positions becomes important. The differentiation between multiple people, as well as between people and the setting of the room, is important for the quality of the detection. Only if reliable data about occupancy exists, can the data be used to construct a reliable prediction model usable for future concepts and projects.

The question of how the collected data can be used, has to be considered. Building prediction models, which relies on historical data and real-time data, is another requirement, which the project dealt with. Decisions on what kind of prediction for a meaningful application - like the one mentioned in paragraph 2 in section 1.1 - and how the data will be stored and processed have to be made.

Besides the design and implementation of an occupancy analyzer, another task is the collaboration of students from two different located universities. Cultural differences, difference in time, spatial distance and locally related influences have to be overcome. Different perspectives have to be combined and compromises have to be made.

## 1.3 Related Work

The concept of an occupancy analyzer, which uses visual recognition of occupants, is already handled in several papers and projects.

NREL IPOS Project:

## 1.4 Approach

## 1.5 Report Structure

## 2 | Analysis



## 3 | Design

### 3.1 Introduction

This section presents the high level overview of the Occupancy Analyzer system.

### 3.2 System Overview

The Figure 3.1 (and 3.2) displays different components in the system and how they relate and communicate with each other.

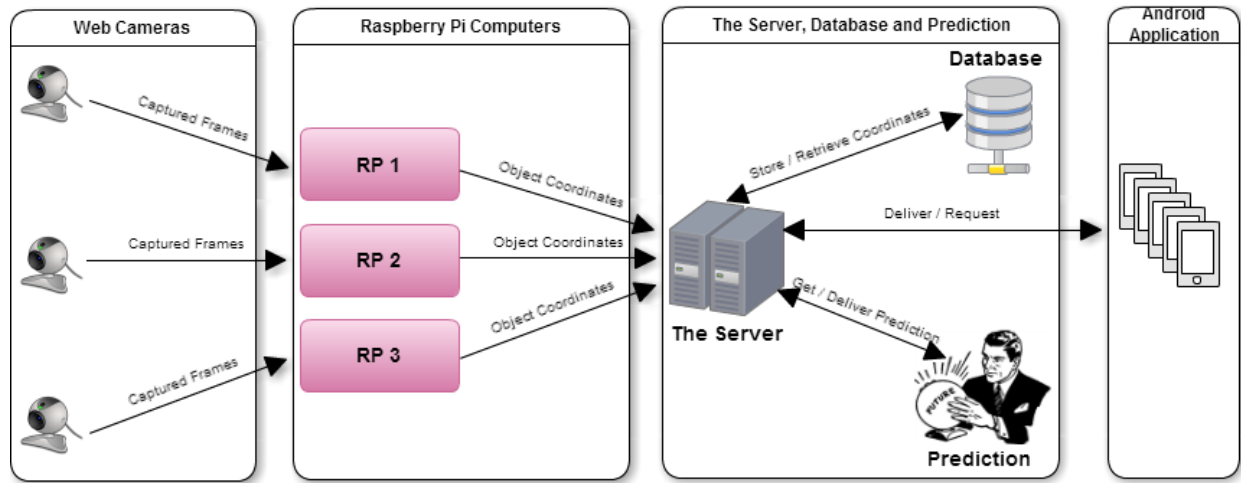


Figure 3.1: Occupancy Analyzer System Overview

As we can see, the system primarily consists of 4 components:

1. Web Cameras;

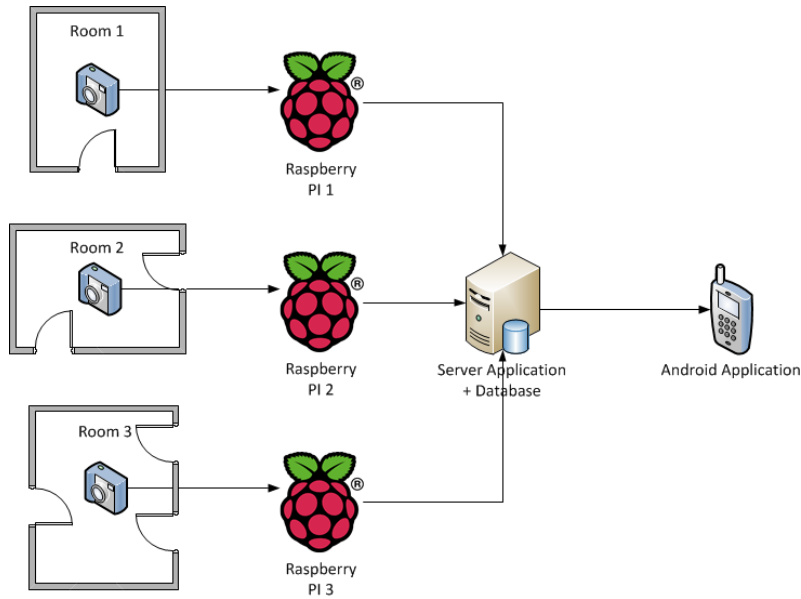


Figure 3.2: System overview of the occupancy analyzer

2. Raspberry Pi Computers;
3. The Server;
4. and The Android Application.

All of these components are discussed further on in the respected chapters.

### 3.3 Web Cameras

The purpose of the web cameras is simply to surveillance the area they have been placed in and forward the captured frames to Raspberry Pi computers for further processing, as shown in Figure 3.1 (and 3.2). The cameras can be placed in a room, corridor, atrium or any other similar place in or outside the building, where people detection and their movement prediction is required. Camera can either be placed directly above the observed area or in the corner of it as illustrated in Figure 3.3. Naturally, a camera placed above the observed area would give better results, since this increases it's field of view, as well as makes it easier to correctly detect and distinguish between multiple people walking side by side. Furthermore, for the best results one must also take many different factors into account, such as the distance between the camera and monitored area, environmental conditions of the area the camera is placed in, lighting conditions, and many others.

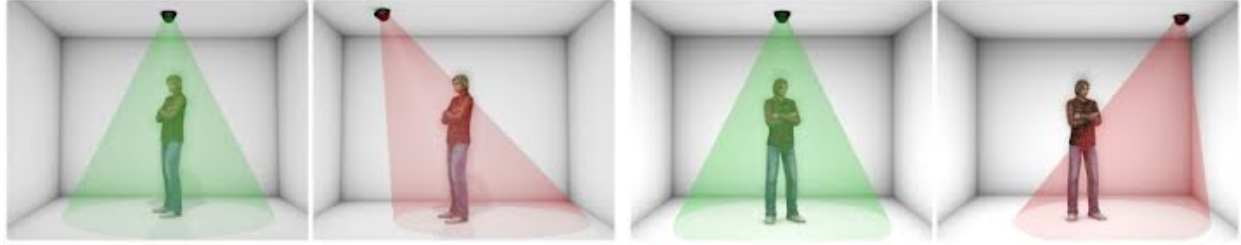


Figure 3.3: Camera placement in a room

## 3.4 Raspberry Pi Computers

The next component in the system architecture is Raspberry Pi computers. These computers have at least one web camera attached to them, and are responsible for processing the frames captured by that camera. The main goal of processing these frames is to try to detect people in the monitored area and determine their position in that area. There are many different challenges in object detection, as well as various concepts and techniques that can be used to achieve this, thus we discuss them in the next chapter.

### 3.4.1 Object Extraction

To detect and extract objects, or in our case, people and their movement, we need to apply several motion detection techniques on the frames we are receiving from the web camera. First of all, to detect changes in some monitored area, we naturally need to have at minimum two images, which we must compare to see what changes occurred. We will try to look into two different approaches in doing this, a simple one, but at the same time less flexible, and a bit more complicated and sophisticated approach, but much more adaptive and flexible.

#### 3.4.1.1 Background Subtraction Approach

To begin with, a simple approach, called Background Subtraction, would be to have a one static background image of observed area that was taken prior and did not have any people in it. Then, one can simply detect changes and movement in the area by subtracting the static background image from every newly taken image of the monitored area at some given rate, for example taking a new image of the area every 2 seconds. The difference between the two images would then allow us to see if any changes happened, since after subtraction the resulting image would either be totally black (Figure 3.4), meaning no one walked passed the observed area, or the image would have some resulting bright contours of detected object or objects (Figure 3.5).

After doing some research and experimenting with background subtraction technique, one



Figure 3.4: Background Subtraction with no background changes



Figure 3.5: Background Subtraction with background change

will quickly discover that there are multiple weaknesses to it. First of all, if the initial background image is always static and never changes, this technique will fail in environments where lighting is dynamic. This is perfectly illustrated in Figure 3.6. We can see that the lighting is much darker in the second image, possibly because the light was turned off in the monitored room, thus after subtracting our static background image from this image, the resulting image is simply a lighter version of the two images, and not the intended black image. This is a big problem, because now even if a person moves through the monitored area, he or she will not be easily extracted as in Figure 3.5, since the whole background of the newly taken image is interpreted as a totally different background than the original static background and will appear in the resulting image. This is illustrated in Figure 3.7.

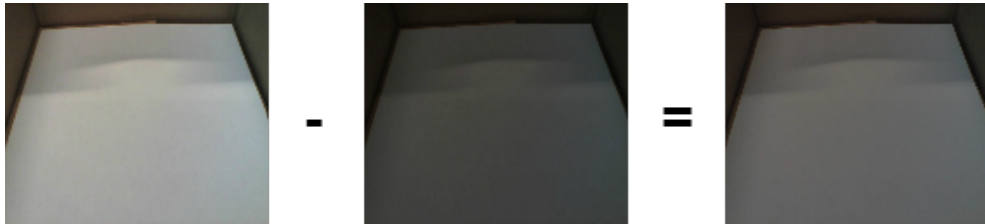


Figure 3.6: Background Subtraction with background lighting change

Another problem with background subtraction approach is that if a camera is placed inside an area which has objects that constantly change their original position (chairs, tables, appliances, etc.) by being moved, even small changes in object's location will spoil the resulting image after subtraction. As we can see in Figure 3.8, the object is displayed twice in the



Figure 3.7: Background Subtraction with background lighting change and lego figure appearing

resulting image, even though we were not even interested in it, making it much harder to detect actual people moving in the area. From now on, the resulting image after subtraction will always be corrupt unless the object is placed back to its original position.

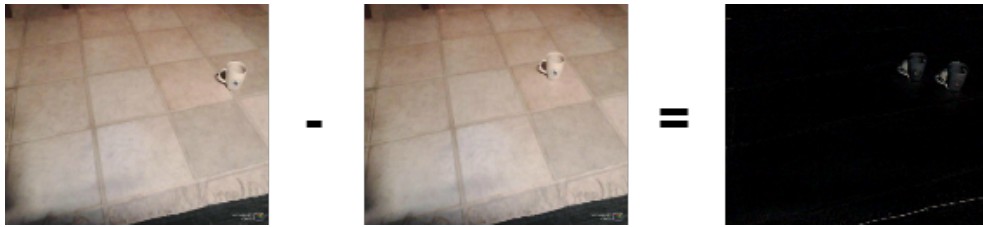


Figure 3.8: Background Subtraction with object changing its location

In conclusion, we can see that background subtraction approach can work well in static environments, however it falls short in dynamic spaces. Naturally, these mentioned drawbacks of background subtraction approach need to be handled for object detection to work well, which unnecessarily creates additional challenges when implementing the system.

#### 3.4.1.2 Moving Average Approach

A much better and preferred approach for movement detection is using moving average method. In this technique we do not need to rely on a static background image of the monitored area taken prior. Instead, we try to find a new "approximate" background image by interpreting any changes in the background as noise and blurring them out. This exact approach is illustrated in figures 3.9 and 3.10. As we can see, hand motion moving up and down gets blurred out when applying moving average method, thus producing an approximate background image that can be used for subtraction of the original frame from it. After subtraction, the motion areas will simply stand out against a black background of non-motion, as it was similarly shown in Figure 3.5. This method of object extraction works very well and has a lot of flexibility, since it can adapt to environmental changes in monitored area, thus eliminating most of the weaknesses that background subtraction approach has.

For these reasons, moving average approach was chosen for our design.



Figure 3.9: Original frame

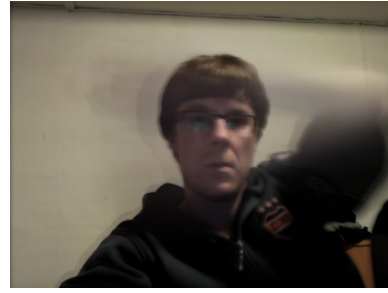


Figure 3.10: Moving average frame

### 3.4.2 Object Detection

Now that we can extract objects using moving average technique, we need to be able to actually find them in the resulting image we get after we perform subtraction. For this, we need to apply several key techniques in image processing.

If we start at the beginning, after we capture the initial frame of the monitored area, it will often contain noise and small details that we are not interested in. To deal with this, we must first apply blur or smoothing filter, which helps to reduce image noise and detail, as shown in figures 3.10 and 3.11.



Figure 3.11: Original frame

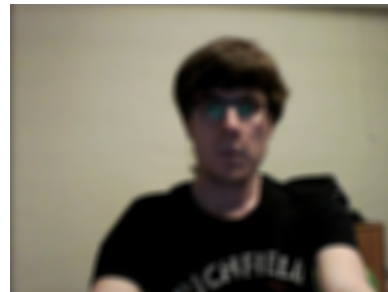


Figure 3.12: Frame after blur is applied

After we remove the initial noise, we can perform subtraction using moving average approach (described in section 3.4.1.2). After subtraction we will either get a totally black image, meaning no motion occurred, or an image where some colors stand out, meaning some motion has occurred. In either case, for further processing of the taken frame, we need to convert it to a grayscale image. The reason for this is that the original RGB image we get has three channels, while grayscale image has only one, thus it is easier to work with. This procedure is illustrated in figures 3.13, 3.14 and 3.15.

For further processing of the image, we apply threshold technique, which converts the image to black and white and removes some more unwanted details and noise. After threshold is

applied we get the image shown in Figure 3.16.

Moreover we want to expand the interesting parts of the image and contract smaller pieces, which can be consider noise and managed to slip through, even after we performed thresholding. To do so, we use two fundamental operations in morphological image processing, that is, dilation and erosion. Dilation allows us to probe and expand the shapes contained in the image, whereas erosion simply shrinks shapes, so that bright regions surrounded by dark regions shrink in size, and dark regions surrounded by bright regions grow in size. When we apply dilation and erosion we get the image shown in Figure 3.17.

Now, to project the detected area onto the original frame, we simply use bounding box technique, which gives us the coordinates of the rectangular border that fully covers the extracted white silhouette that we got in Figure 3.17. Then we use these coordinates to draw a simple rectangular, as well as mark it's middle position by a red circle, as illustrated in Figure 3.18.



Figure 3.13: Original frame



Figure 3.14: After subtraction



Figure 3.15: After grayscale filter is applied



Figure 3.16: After threshold is applied



Figure 3.17: After dilation and erosion

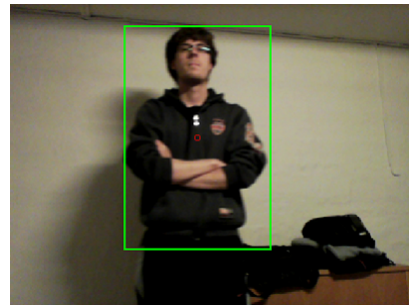


Figure 3.18: After bounding box is drawn

In conclusion, by applying the steps discussed in this section, we can fairly accurately detect people and their movement in the monitored area.

### 3.4.3 Object Differentiation

There will naturally be cases when multiple people will walk through monitored area and will be captured by the cameras, therefore we must have a way to differentiate between them. This task becomes rather difficult if people are very close to each other, since they will simply be interpreted as one person. However, as long as people are far enough from each other, the task becomes significantly easier. There are multiple ways of differentiating between objects.

One of them is simply looking at object's histogram, which gives a graphical representation of it's pixel intensity distribution. Since people are usually dressed in different color clothes, we can simply calculate a histogram for every detected person and remember it. Now, every time we receive a new frame and detect a person in it, we go through our previously saved histograms and check whether any of them are the same or similar to our newly detect person's histogram. If there is such histogram, we interpret the person we detected in our new frame as the same person we detected a second or few seconds ago, otherwise, we conclude that we have not detected this person before, thus save his histogram for future reference. The biggest weakness of this approach is that person's clothes might have different colors from the front and back. Therefore, his histogram calculated while he is facing the camera might be rather different than the histogram of when his back was towards the camera. For this reason, if the person decides to turn around midway, he might be interpreted as a new person, never seen before by the camera, when in fact his frontal or back histogram was already saved.

Another approach of differentiating between multiple people, and in fact the approach we used in our design, is to simply use the whole frame as a coordinate system and remember the last coordinate of every single detected person. Now, similarly to histogram approach, whenever we detect a new person in the frame, we simply look throughout previously saved coordinates, and if we find that this new person's coordinates is relatively close to some previously saved person's coordinates, we simply interpret him as the same person we detected a second or or few seconds ago, otherwise we see him as a new person. Naturally, we must regularly clear our previously saved coordinates, so that newly detected person would not be interpreted as a person who is no longer in the monitored area only because he took the same path. **TODO: add some figures?**

## 3.5 The Server

**TODO**



## 3.6 Prediction

**TODO**

## 3.7 Android Application

**TODO**

## 4 | Implementation

## 5 | Evaluation

### 5.1 Verification

### 5.2 Benchmarks

## 6 | Collaboration

This chapter deals with the collaboration and process in the project. We introduce the project team, the initial situation and present the chosen project management concept. The procedures and tools, which were used in the project, are declared and evaluated. We also list the difficulties, which occurred during the project and within the global collaboration. Furthermore we reflect the process and collaboration and explain our learning outcomes.

### 6.1 Introduction of the Project team

The project team consists of two groups of students. One group is from the Strathmore University located in Nairobi (Kenya). The other group is from the IT University (ITU) in Copenhagen (Denmark). The project team agreed on to name the two groups "Team Kenya" for the student group from Strathmore University and "Team ITU" for the student group from ITU. This helped to address each group in meeting reports, emails and conversations.

In the beginning Team Kenya consists of three members, which are all in the Masters programme "Telecommunication and Innovation" of the Strathmore University. The members are all from Kenya. The official languages in Kenya are English and Swahili. The members of Team Kenya met each other the first time on the 1.10.2013 (-> Global Meeting Report 1.10.2013). One member had to leave the project in the last third of the project due to workload of other projects and obligations (-> Global Meeting Report 26.11.2013).

Team ITU started with four members, which are all in the Masters programme "Software Development and Technology (Software Engineering)" of the ITU. The members are from three different countries: Lithuania, Germany and Denmark. Although there are minor differences between the nationalities, which could have an influence on the team work, we will not go into this, because it is out of scope for this report. The communication language within Team ITU is English, which is not the mother tongue of any of the members. The members of Team ITU met each other the first time on the 27.8.2013. One member left the project after two weeks, because he changed to another project and project team. Each member of the project team created a member profile to introduce themselves, which are attached in the -> Appendix xx.

## 6.2 Initial situation

The students of Team ITU have to complete the project under the course "Global Software Development Project", which is mandatory for their masters programme. The requirements and deadlines for the project are given in the course base from ITU (-> Link to the course base) and by the advisor of the project. The course is rated with 15 ECTS points, which corresponds to approximately 20 hours per week per student. The students of Team ITU have to hand in this report as a mandatory requirement.

There are no mandatory requirements or deadlines, which the Kenyan students have to achieve, except that they have to create a documentation for their advisor to prove the progress of the project. Team Kenya agreed on to go with the deadlines from Team ITU (-> Global Meeting Report 24.11.2013).

## 6.3 Projectmanagement Method

- Classic approach
- SCRUM method
- Our method (Structure)
- Weekly meetings internal, global, with advisor
- Time recording
- Splitting up assignments
- Plans

## 6.4 Collaboration tools

- Communication
- File sharing tools
- Time recording

## 6.5 Project Team and Organisation

- Project team members
- Skills
- Preferences
- Roles
- Splitting of the technical parts

## 6.6 Timeline

- Overview of the phases, milestones, deadlines, other exams/hand-ins
- Ressource planning
- Time-Recording (Toggl)

## 6.7 Collaboration Issues

- Illusion of the project work and project team
- Failure to comply with the assignments
- Communication
- Lack of skills
- Other exams/hand-ins
- Differing requirements
- Attendance of meetings
- Equipment

## 6.8 Hypothetical Scenarios

- Assignments
- Communication
- Requirements
- Organisation by the universities (Requirements, clarification, )

## 7 | Discussion



## 8 | Conclusion

## 9 | References