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# Generating Schematic Indoor Representation based on Context Monitoring Analysis of Mobile Users

Bachelor Thesis (6 EAP)

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## **Abstract**

Technology evolves with every day and life is getting easier because of with it. Navigation is part of it, when person goes from one location to another, then he is getting the path by heart or by getting help. It is common that for help they use positioning systems. Outdoor navigation has evolved a lot, while indoor navigation has not been researched that much. This creates a problem that user cannot get much help when they move indoors since usual systems might not work. Also carrying around extra devices can be quite annoying. To solve this problem, mobile application was created which gets input from user with the help of the accelerometer and orientation sensor. Besides that, room should have objects which have defined locations and can be identified with QR-codes. The sensor data should then be analysed and given results can be used for creating indoor schematic with knowing the object locations indoors.

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# 1

## Introduction

### 1.1 Introduction

Technological achievements in mobile technologies enable to extend the capabilities of the smartphones in order to recognize optical representation of data which are located in the environment (aka readable machine objects). For instance, Google has just released an API for the detection of QR-codes that can be deployed on an Android device (1). Moreover other open source projects like Zwing provides a large variety of barcode detection. It includes recognition of codification formats such as QR-code, MiniCode, Aztec Code, Code 93, etc.

On the other hand, mobile devices are equipped with multiple micromechanical sensors that can be used for sensing data from the user and his/her context. This sensors provide information about multiple activities depending on the orientation/position in which the device is held (e.g. reading, etc.) and about the changes in the environment in which the user is located (e.g. temperature).

Furthermore, lot of activity recognition research have been conducted and several algorithms and prototypes have been proposed for the detection of activities using the mobile phone. The most common sensor used in the recognition process is the accelerometer sensor due it is possible to detect activities such as walking, jumping or even crawling. Other sensors allows to detect other kind of user intent. For example, the compass sensor enables to understand the direction/orientation that the user is facing. Latest smartphones (e.g. Samsung Galaxy S2, iPhone 4, etc.) also include a new kind of sensors such as the gyroscope for navigation purposes. The main use of

the gyroscope is improving the accuracy on approaches such as video stabilization and face detection.

Other external sensor sources (e.g. GPS, etc) enriches the functionality of the smart-phones, in terms of environmental contextualization and positioning. However, this approaches target mainly outdoor locations.

In order to investigate the feasibility of contextualizing a mobile user in an indoor location using local sensor information and readable machine objects. The present work proposes the analysis of sensor data collected by the accelerometer and the compass sensor. This sensor information is combined with QR-code data collected by the user in order to improve the accuracy of the indoor navigation process. By analyzing this data, we aim to generate an schematic indoor representation that can be use for indoor positioning purposes.

### 1.1.1 Motivation

Currently we have a problem with tracking movement inside the buildings, because GPS navigation devices do not work well indoors. This happens because signal does not spread good enough without direct visibility to satellite grid. Even if one satellite can be reached, 4 is needed for correct positioning. Thus, solutions which would be accurate and works indoors are currently missing, there are some, but they get approximate user position.

On the other hand, user context monitoring approaches are used for anticipating and automating certain tasks according to the detection of the users intent. We aim to combine this approaches with latest trend for identifying object in the environment (barcode) in order to generate a schematic of an indoor location. In this work, we aim to prove the concept so that later, the approach can be used for analyzing huge amount of mobile user navigation data.

### 1.1.2 Contributions

Firstly there should be a smart phone application for solution, which would track users movement inside buildings, after that it is necessary to analyze the data and then generate a final report about user movement. One good solution for current problem is the usage of mobile sensors - digital compass which will help to determine the user movement direction. Second sensor is accelerometer which helps to determine the

acceleration in three dimensional space. Accelerometer is a device which measures acceleration and body vibration. It helps to find out how user is currently moving, like running or jumping with the use of patterns created before. Previous sensors only can determine the movement, but are unable to find out where this movement takes place, that is why it is needed to use some locations in room which have some known locations. QR-codes are used and are placed on defined objects to get the known position information to mobile. QR-code is a matrix type of barcode where its possible to save data - size is determined by the code size. Mobile phone camera is used for reading the code and translating it to data, after that it is matched with the location in room. Finally, the user moving pattern and QR-code will help to generate report which will show how and where the phone owner moved.

One practical usage of it would be museum - there are statues, paintings and other valuable stuff in certain positions. If we place QR-codes on them, then we have certain points in room which are known. Visitors who read the code near the valuable object, will be placed in certain position in room. After that we can determine the path with the mobile sensors. Result is input, which gives statistics on processing and it will give report where is seen what is visited more and where no one ever hardly has been. This gives possibility to reorganize rooms to raise number of visits of less visited objects. Other point of view is that you can close the walls and make rooms more comfortable for moving.

### 1.1.3 Outline

Chapter 1 will give the overview about mobile domain and about the current application which determines the movement indoors and the other application which generates a report about the movement.

Chapter 2 explains why and what is the current problem. Why is it important to us to resolve this problem.

Chapter 3 will give overview about ideas which author did come up during this thesis. Idea consists of the mobile application which will save the movement data and the analysis result of the given data.

Chapter 4 will give information about the current problem, its solution and why is it important. Also it will tell what needs to be done to get correct analysis result and indoor schematic.

## 2

# State of the Art

It is known that computing field is evolving fast, because we need to be able to use technology all the time, even while being on the move as well. This is why we need the mobile computing what generally will give a mobility to get the necessary information while being on the move. Usually mobile devices, devices which are mobile and can be carried in hand, have a lot of sensors then we can determine the environment changes which are required in computing data. For example when we move, we will get accelerometer data what will give us vital information how user moved. Since the data is taken from the current environment of the device, it will give opportunity to get fresh information, instead of using some old figures which have been measured from previous times. Also these figures are more close to the real than the ones taken in laboratory conditions. This will give advantage to get more exact results after analysis those numbers. For example more accurate results will give possibility to avoid catastrophes better, like earthquakes, tsunamis what have been causing a lot of damage in the past.

### 2.1 Mobile Devices

Like the word says, mobile devices are objects that are made or adapted for a particular purpose and can be moved really easily from one place to another. (2) They do not put limits on the user like usual devices do, for example you cannot carry your desktop computer around like you do that with your mobile phone or laptop. Usually they have less computing power and have less resources than the stationary devices. One example

is desktop computer, which needs power input, because it does not have battery for using it at any time and place. To use computer outdoors, laptop has been developed, which has less resources and computing power, but is capable of making the work while mobile and will gain time. Time can be used for doing something else important.

### 2.1.1 Smartphones

Smartphones are mobile phones which allow you to do several other things besides calling. For example you can play games, send emails, browse web, play games and so on. Basically smartphone is a small handheld computer which has been merged with phone functions. Smartphones usually have sensors attached to it which will help the phone to get information from the environment. (3) This has helped the developers a lot who create applications for smartphones. They create games, applications which use the sensors and makes it simpler for the user, they do not have to touch the screen to do something. Then they can perform some action with mobile. For example some smartphones have the ability to silence the phone when someone is calling by turning the phone that the screen is facing the ground.

#### 2.1.1.1 Accelerometer

Triaxial accelerometer sensor is used for finding acceleration of current device in three dimensional space. That means that there are three axes along which the acceleration is measured. Accelerometer will also measure the gravitational acceleration so the results are with it. Smartphone has acceleration sensor that measures the acceleration applied to the device, including force of gravity. Acceleration  $A$  which is applied to device is measured by following equation.

$$A = -g - F_{sum} / m$$

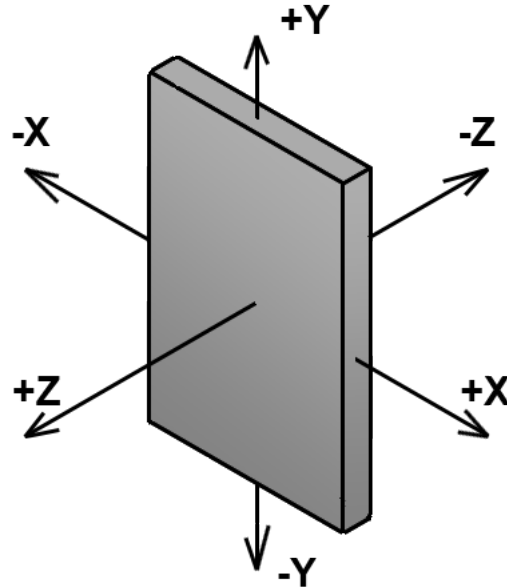
$g$  - gravitational acceleration

$F_{sum}$  - forces applied to the device

$m$  - device mass

Sensors use the standard sensor coordinate system.

Graph illustrates how 3 axes on phone are measured. The box is the device and there are angles represented. Phone screen is facing the  $Z+$  direction. When you hold



**Figure 2.1: Phone sensor axes. Phone screen is facing +Z direction**

phone like this then Y is showing the gravitational acceleration. To make it more clear when the phone is thrown in the air then acceleration will be gravitation minus the acceleration towards the sky. (4)

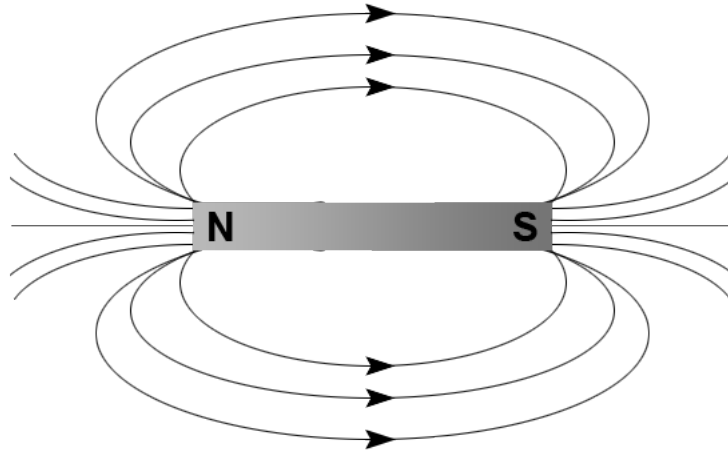
#### 2.1.1.2 Magnetic field

Magnets have influence to its surroundings. Region around the magnet and within the magnetic force influence area is called magnetic field. (5)

In the schematic the lines around the magnet are the force lines which affect environment with some force. The arrows on top of the lines are showing the direction of the force and they go from the north pole of the magnet to the south pole.

Earth has the magnetic field as well. It is called geomagnetic field and it has extremely small force which influences objects. It is strongest near the poles and several times weaker than that which is between the poles of a toy horseshoe magnet. (6) Toy horseshoe magnet is usual magnet, but it is bent so it looks like horseshoe and its poles are side by side. Earth magnetic field is used by compasses, birds to travel south and by phones which has digital compasses. They can determine which way is north.

Phone has magnetic field sensor as well, it measures ambient geomagnetic field for all



**Figure 2.2: Magnetic field visualization**

three axes which are described in accelerometer axes schematic in state of art part. It is measured in microteslas.

### 2.1.1.3 Orientation sensor

Orientation sensor is a sensor which will determine the azimuth, pitch and roll of a phone. It basically means that you can monitor the position of a device relative to earth. Orientation sensor derives its data by using device's geomagnetic field (magnetic field) sensor in combination with accelerometer.

Azimuth is angle between the magnetic north direction and the y-axis, around the z-axis (0 to 359). 0 = North, 90 = East, 180 = South, 270 = West.

Pitch is rotation around x-axis (-180 to 180), with positive values when the z-axis moves toward the y-axis.

Roll is rotation around y-axis (-90 to 90), with positive values when the x-axis moves toward the z-axis .

To make phone axes more clear, look at the accelerometer axes schematic in state of art part. (4)

#### 2.1.1.4 Gyroscope

Gyroscope is a device which measures the angular rate around a fixed axis with respect to an inertial space. Basic point of how it works is that gyroscope exploits the inertial properties of a wheel spinning at high speed, which tends to keep the direction of its spin axis by virtue of the tendency of a body to resist any change in the direction of its moment. (7) In simple words, gyroscope can take any orientation according to the acceleration given and it makes it possible to measure the orientation of the object. Schematic shows the basic gyroscope and how it looks like. In the middle is the spinning

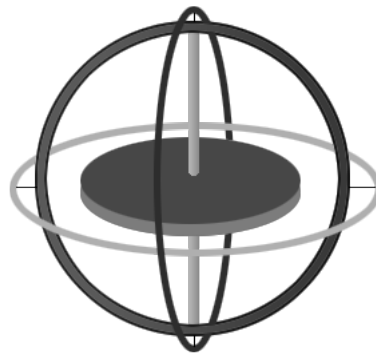


Figure 2.3: Gyroscope

wheel which takes the right position by the torque applied to it. Some mobile phones have gyroscope built in and it measures the rate or rotation in rad/s around the device's x, y and z axis. Rad is the short for radian, it is a measure unit which is the ratio between the length of an arc and its radius.

#### 2.1.1.5 GPS

GPS is Global Positioning System which provides the position, velocity and timing information. Satellite constellation nominally consists of 24 satellites arranged in 6

orbital planes with 4 satellites per plane. This system belongs to US and they have copyright on it so other countries have made their own systems for satellite navigation. For example Russians have created Global Navigation Satellite System (GLONASS). Because satellites only transmit data then this system can have unlimited number of users. GPS needs to make connection to satellites and then receive information from them. User position is found by calculating the information sent by 4 satellites. If info is acquired from less than 4 satellites then it is not possible to find out exact position. (8)

### 2.1.1.6 Another sensors

There are many more sensors on Android phones. They can be used for different purposes and help the developer to create applications and make user life much simpler. For example, light sensor can be used for determining if it is day or night and can make different color schemes for applications according to that. Only problem is that they might be missing for specific phone type.

Ambient temperature - sensor which measures the ambient room temperature in degrees Celsius (C).

Gravity - sensor for measuring the force of gravity in  $m/s^2$  that is applied to a device on all three physical axes (x, y, z)

Light - sensor for measuring the ambient light level (illumination) in lx. lx is the SI unit for measuring luminous flux per unit area.

Linear acceleration - sensor for measuring the acceleration force in  $m/s^2$  that is applied to a device on all three physical axes (x, y, z), but excluding the force of gravity.

Pressure - sensor for measuring the ambient air pressure in hPa or mbar. hPa is hectopascal and is equal to 100 pascals which is SI measuring unit for pressure. mbar is called millibar and is equal to 100 Pascals.

Proximity - sensor for measuring the proximity of an object in cm relative to the view screen of a device. This sensor is typically used to determine whether a handset is being held up to a person's ear. For example if phone is near the ear, the screen is turned off to save the battery. No point to waste energy on the screen while talking with the phone.

Relative humidity - sensor for measuring the relative ambient humidity in percent. (4)

### 2.1.1.7 SQLite

SQLite is an open source relational embedded database. Embedded means that rather than running independently as a standalone process, it symbiotically coexists inside the application it serves - within its process space. Basically the code is a part of the program that hosts it. It uses SQL which is Structured Query Language, basically it is used to communicate with relational databases. For example: `SELECT * FROM table;` will fetch all data from database where the table name is "table". This communication language for databases is most common and most spread. (9)

### 2.1.2 Mobile platforms

Mobile platforms are base for every mobile phone. They provide SDK, tools and the operating system what makes it possible to develop applications for that platform. SDK is source development kit, which consists of tools for making applications. Also for building application there are several APIs (Application Programming Interface) defined, which give the access to some defined system functionality. Basically sensors of Android phone can be accessed through API, because they usually have some work done with them and user can just use the end results what he needs. Usually mobile platform developers have their own distribution model which is supplied by the platform developer. For example iOS has apple market, google android has play store and windows phone has Windows Marketplace. The most popular platforms currently available are android and iOS.

#### 2.1.2.1 Android

Android is a software stack for mobile devices that includes an operating system, middleware and key applications. It is developed by Google and is really famous nowadays and is widest spread operating system. (4) Application for that platform is written in Java programming language. Java is a programming language and computing platform first released by Sun Microsystems. (10) Middleware is a software that acts as a bridge between an operating system or database and applications, especially on a network. (2)

### 2.1.2.2 iOS

iOS is a operating system (OS) what sits on top of a device hardware for Apple devices. For example Iphone 4. The newest version of OS is currently iOS 5. Operation system is really well known because it is really simple to use and can be learned fast. Applications which are created for this system needs to be in Objective C. To make development easier, there are several frameworks what can be used, for example UIKit framework which is most common framework for developing UI. (11)

### 2.1.2.3 Other mobile platforms

Besides iOS and Android, there are some other less known platforms for mobile. One other pretty famous platform is windows phone which is developed by Microsoft. Writing applications can be done in 2 ways, write them in XNA or in Silverlight. (12) XNA Game Studio is a programming environment that allows to use Visual Studio to create games. It includes XNA Framework which is based on Microsoft .NET Framework. (13) Silverlight is a cross-platform, cross-browser implementation of the .NET Framework for building media experiences and rich interactive applications. (14) NET Framework is an integral Windows component that supports building and running the next generation of applications and XML Web services. (15)

### 2.1.3 ZXing

ZXing is an open-source, multi-format 1D/2D barcode image processing library in Java which has been ported to other programming languages. It can translate several barcode types like QR-Codes etc. without communicating with servers. Firstly the image must be created from the barcode, after that Zxing will decode it and will give the decoded message. (16)

### 2.1.4 Object detection

Some applications will need to detect objects to link the work with something. For example, if person is stepping into the room from one entrance and there are more than one entrance, system does not know which entrance person used. This is where object detection is needed, system needs specific object for that location and needs to

detect it to be sure that it is the right spot. Usually objects are something that are easy to detect and does not take that much room, for example barcodes.

### 2.1.4.1 Bar codes

Barcode is a machine-readable representation of information that is formed by combinations of high and low reflectance regions of the surface of an object, which are converted to "1"s and "0"s. After the barcodes have been translated, they can be processed further to gain correct information for the end result. (17)

### 2.1.4.2 QR-Codes

QR-Code is short for quick response code. It is a matrix barcode readable by smartphones and mobile phones with camera. Most usual cases of QR codes appear as small white square with black geometric shapes, though coloured and branded QR codes are now being used as well. They can hold more information than usual barcodes. Most usual information is URL-s, but they can also hold other kind of data. The data size depends on the QR-Code size. (18) This is a QR-Code which holds the information



Figure 2.4: QR-Code

about something, for example text, number, web page urls and so on. This one on the image holds the text QR CODE.

### 2.1.4.3 Standardization

If object is different each time, it is almost impossible to know if it is the correct object or not. For that some standards has to be set, that define how the object looks like and what it has to have. The key elements what is defined by standards will help to match the required item and then it can be said that it is or is not the correct object.

### 2.1.5 Standardization

Navigating from one position to another will require some sort of path. Path must be correct to get to right position. This means that if person does not know the correct path, he needs some help, for example ask from somebody or use some device which can tell exact position and will help to get the person to end location.

#### 2.1.5.1 Approaches

Over time, several approaches for tracking have been thought of and built. The most famous one is GPS which helps us to navigate all over the world, but with one exception, the signal from all four satellites must reach the receiver. Indoor navigation is not that successful, because there is not a device which is as common as GPS. But several different solutions have been built.

**2.1.5.1.1 GPS** There have been pretty similar work, but it was made with GPS and accelerometer, it uses GPS to locate the starting point and accelerometer to find out how far user was moving inside buildings. It does show only the distance from the shop not how the user moved. This technology is called AAMPL.(19) Basically GPS is used to find out exact position outdoors, receiver will use the information from the satellites to find out the latitude and longitude and accelerometer data is sent to server over the network. The server will analyse the data and sends back correct position.

**2.1.5.1.2 Inertial Sensors** This solution is similar to the one used, it was created because GPS signals does not reach all locations. One big problem is in big cities where tall buildings obscure the signal. They used special sensor which has gyroscope, compass and accelerometer bundled together and placed on the person foot. They found out that compass has smaller error than the gyroscope and the error margin was not that big, it gives pretty exact results. So this work showed that tracking indoors is pretty viable and if the error margin can be reduced furthermore then basically they have a working solution. (20)

**2.1.5.1.3 WiFi** Wifi is used for tracking user movement indoors. Firstly there must be WiFi access points which devices connect to get access to network. Then signal strength is measured and the approximate position is calculated. More than

one access point is needed because one access point will only match position at certain distance from it. This means that position is on some radius. (21) There is also a company which created algorithm to find exact location of a user in WiFi area. It is calculated by nearby access points which location is known to system.(22)

## 2.2 Summary

Nowadays, most of the research is focused on contextualizing people not indoors, but outdoors. This generates a need for translating user path indoors and with pretty small error. Most viable device for it is mobile phone, because it is carried along all the time and extra devices take extra room and are uncomfortable. Use of mobile device sensors and some external elements will help the person to navigate. External elements should have fixed position at some point so it is possible to fixate location in room. Best solution is to use QR-Codes which are small and do not take much space.

# 3

## Problem Statement

Society needs the possibility to track everything and everyone at any given time and place. Navigation has been problem for everyone since the war, airplanes were shot down because they entered hostile airspace, soldiers did not find the fastest way from point A to point B. This was the one thing which generated the need for some positioning system and it should work everywhere and should be able to serve unlimited number of clients. Also the system should not disturb the actions of a user and should be really easy to use. That means that it should not take long time to set up and possibility to start it with few clicks and you know everything. In the end the GPS was developed, it did not stay only for military, it was shared with the civilians as well. Naturally systems are divided from each other, but it works for everyone. GPS has only a small setback, it requires that signal reaches a GPS receiver for it to calculate the correct position for the user. This strikes out the possibility to find out correct path indoors where the signal does not have a possibility to spread and reach the device.

### 3.1 Research Question

Since todays society has put a lot of effort into developing outdoor navigation then indoor navigation has not been evolving that much. If user goes indoors, they are completely blind and has to manage with his own skills to navigate from one position to another. Currently there is not many technologies to find the user path indoors and the ones that exist are not that accurate to pinpoint exact location somewhere inside the room.

Nowadays, there a lot of solutions that can be used for tracking mobile users. Some of the examples of this are Bing, Google. They have their own map system and the systems for mobile users are built on top of it with the use of API. For example Google gives API to create some application on top of the map functions. Android has maps application which uses google maps and its functions in it. It gives the possibility to do the same like on website. Get driving directions, search locations and so on. Since it only uses GPS then it does not know where exactly the user is inside building plus it has pretty big error span.

Some apps allow to track the mobile users with higher accuracy, that is accomplished with multiple technologies working together for example AAMPL. This uses GPS, accelerometer and network connection. Data which comes from accelerometer is passed on to server what then analyzes it and will tell the user more or less exact location. Only problem is that it only says the distance travelled, it does not say how or what did the user do at given time.

Most of the existing solutions for navigation are targeted for outdoor usage. So there are not many for indoor usage. One possibility of indoor navigation is done with wireless networks, they are known positions and can give approximate location. With the network area increment, the accuracy increments as well. Cellphone masts are used also similarly, the more signals reach the phone, the more accurately the position can be matched. For example, Google asks to the shop owners to send the indoor schematics so it would be possible to navigate there. Google uses all the technologies out there to find out the location of the user on map. Currently indoor navigation is done by cell tower triangulation, WiFi positioning and GPS if available.

Since carrying around extra devices just for navigating is not comfortable, that is why the mobile devices have been equipped with variety of sensors, that will give information about environment and some will be monitoring the user activities. Some of sensors are for example accelerometer, GPS, compass.

Furthermore, some activities involve the identification of some objects. This identification can be performed with digital ids what has been assigned to each object. When objects are deployed to some particular indoor location, a lot of users who will walk in the room and identify the objects will help to create a the full estimated indoor schematic. It is created by the sensor readings and the object identification.

### 3.2 Summary

While being mobile, items which will take up extra capacity will slow the user down. Best case is when new technology can just be added to existing device. It means that person does not have to carry around items what actually are just for some specific case. For example, when user drives around in foreign country and does know the area well, he needs GPS to find out exactly where he is and where the target location is. If we have specific device, it takes up extra space plus it is only needed for driving, its useless when he goes to museum or some place. For that, smartphone can be used, GPS is built in and can be used for driving guidance. Besides that, it is carried around anyway, because calls need answering. That is why nowadays society gathers as much sensors and devices into one to limit the used space and make it easier for the user.

## 4

# User Context Monitoring with QR-codes

Indoor navigation is currently the one of the main bottlenecks for navigation, because we do not have a exact method to find out location indoors. For that application is needed what can determine how user is moving and how long distance and which way. Managing this solution, mobile sensors are required which help to determine how fast and what direction movement occurred.

### 4.1 General Approach and Implementation Details

Written Application consists of two parts, first part is smartphone application which will be responsible for data gathering and storing it to file what can be used for further processing. It takes all required information from the environment using sensors and mobile camera. Second part consists of analysis of the data data which will give information if the data can be used for navigation and getting correct path of user movement.

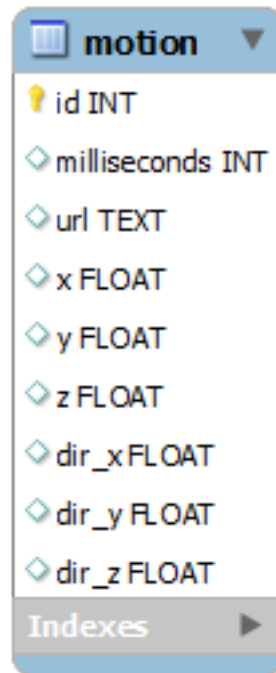
#### 4.1.1 Mobile application

For finding the patterns and getting the data about users movemenet, mobile application was created. It will read the data about the user movement and will save it to database. Program consists of 4 baseclasses and external libraries. For data saving, SQLite was used which stores data in database table. Table name is motion and has

## 4.1 General Approach and Implementation Details

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the following structure.



**Figure 4.1: Database structure visualization**

- \* id - each row will have its unique key which identifies the result of currently saved data row
- \* milliseconds - shows current time in milliseconds what have passed since 1. january 1970.
- \* url - holds the value of latest QR-Code. If no code has been read then Default is used.
- \* x - accelerometer x axis acceleration. See accelerometer under State of Art to find out about axis for mobile phone.
- \* y - accelerometer y axis acceleration. See accelerometer under State of Art to find out about axis for mobile phone.

## 4.1 General Approach and Implementation Details

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- \* z - accelerometer z axis acceleration. See accelerometer under State of Art to find out about axis for mobile phone.
- \* dir\_x - holds compass azimuth of mobile phone. See orientation sensor under State of Art for more information about azimuth.
- \* dir\_y - holds pitch rotation of mobile phone. See orientation sensor under State of Art for more information about pitch.
- \* dir\_z - holds roll rotation of mobile phone. See orientation sensor under State of Art for more information about roll.

System has following class diagram. This shows what variables and functions were used in the production of indoor tracking mobile application.

IndoorGpsActivity - this is the main class responsible for running the program. If user starts the application from the menu, then this will be run. Its responsible for showing messages on screen and passing data from sensors to database.

this is class for reading data from accelerometer. Data read from sensor is array with three values, where 0 value is x axis, 1 is y axis and 2 is z axis acceleration. This will read data each time it changes.

DirListener - this is class for reading data from orientation sensor. Sensor data is also as array with three values. 0 is azimuth, 1 is pitch and 2 is roll orientation. This one is also updated each time it changes.

IndoorDb - this class is responsible for creating database and saving data into it. On application creation the database will be created and on closing it will be shut down and copied to external memory card to be accessible later.

Firstly after the application has been run, it will start to store data right away. QR-Code value is Default and sensor data will be added to database with it.

This is the opening screen, data is already saved and the user interface has only one big button, which can be clicked for taking picture from QR-code. User interface

## 4.1 General Approach and Implementation Details

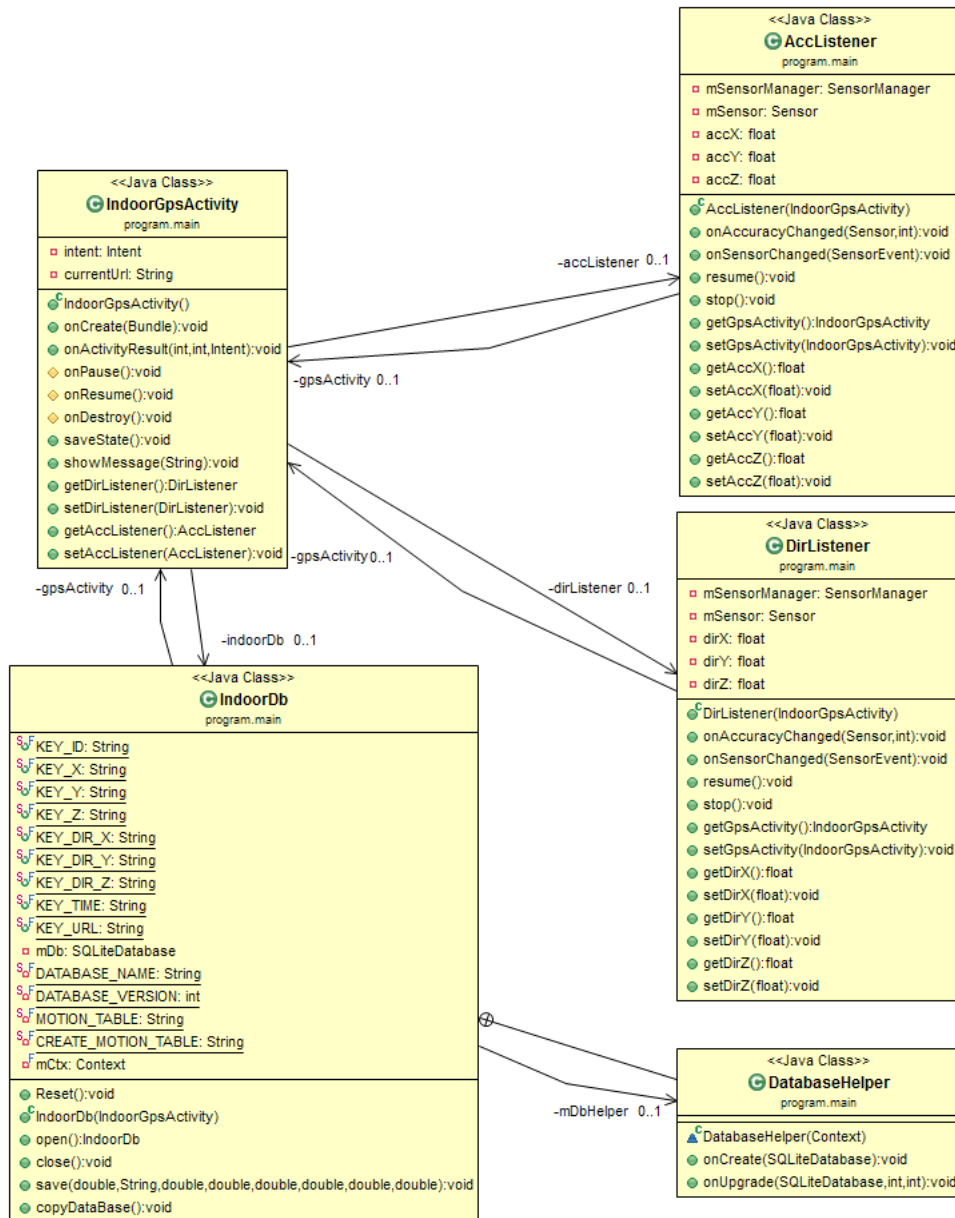


Figure 4.2: Program structure visualization with class diagram

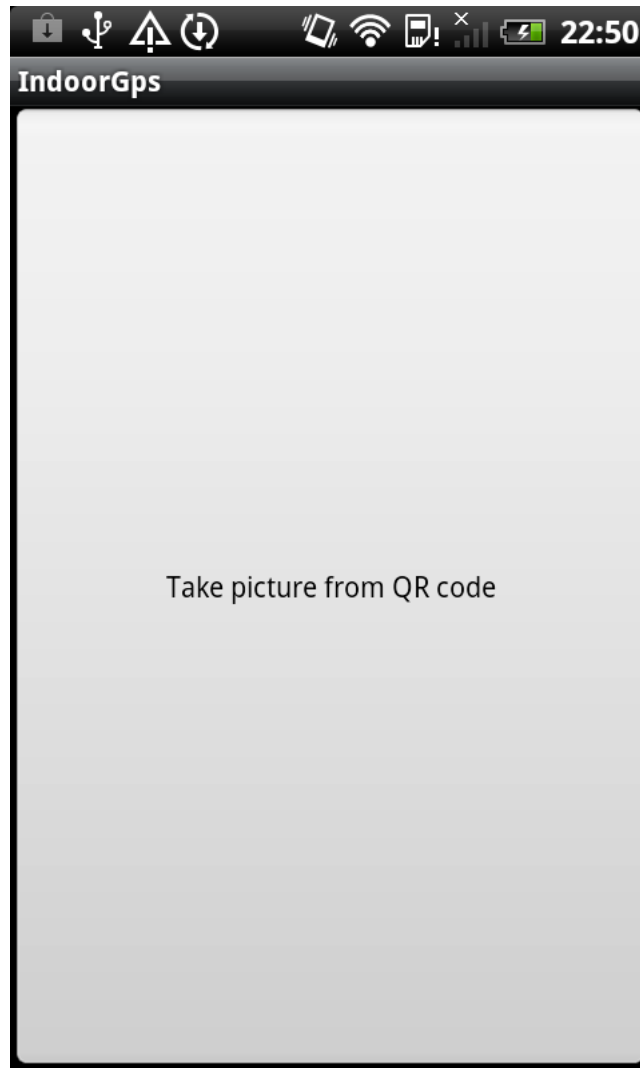
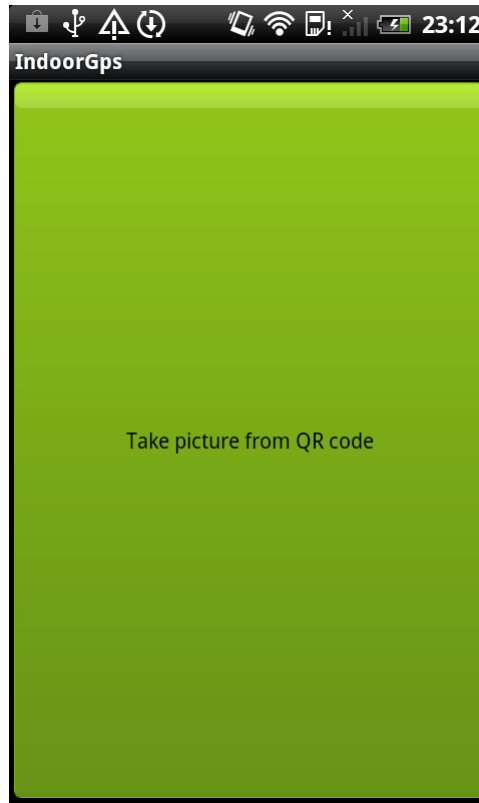


Figure 4.3: Application sensor saving screen with button to activate QR-Code reader

## 4.1 General Approach and Implementation Details

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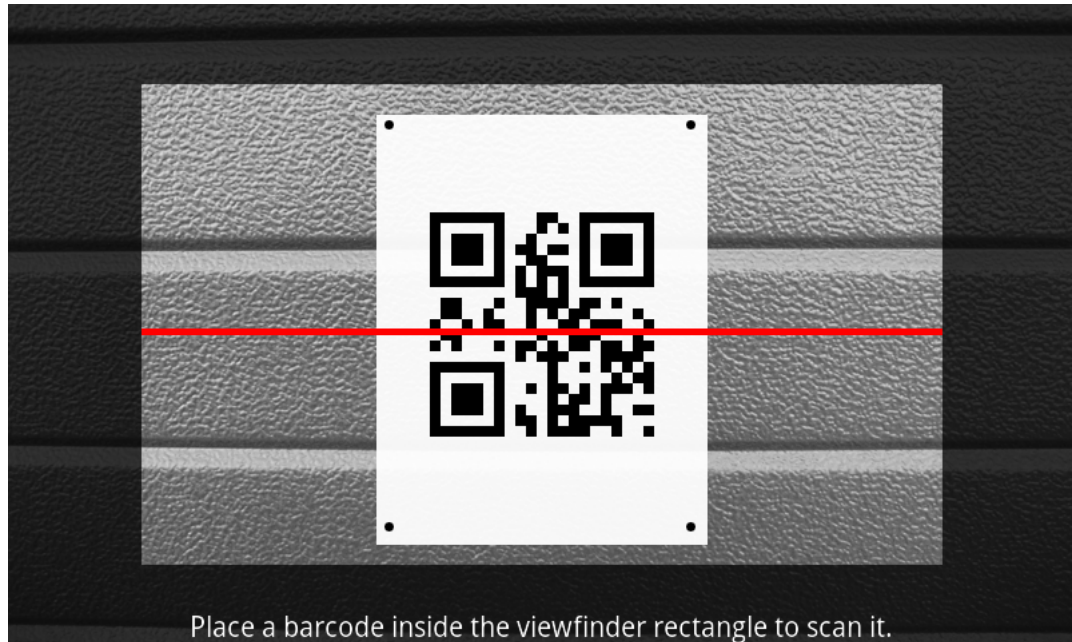
is the part of the system which user can see, hear and feel. Other parts of system are hidden from them, like database or sensor data. (23)



**Figure 4.4: Application sensor button to activate QR-Code reader was clicked**

This image shows case where the button on screen was pressed and now sensors will stop and camera will open up for barcode reading.

This image is taken with ZXing library. This image shows picture when camera is open and it starts to read barcode. Barcode must be in the center of the active area, this means inside the area which has red line struck through. Around it is area what has dark opaque background. On the current case there is a QR-code about to be read. If it is successfully scanned then the data stored in it will be retrieved by decoding image and it is passed on to the system.



**Figure 4.5: Application QR-Code reader with ZXing library**

After the camera closes, sensors start again. Here data has been retrieved, QR-code has been changed to QR-Code in system. Now following sensor states will be stored to database with this code. This will be repeated until the path data has been gathered and application is closed.

Now after the program closes, database file with gathered data will be closed and copied on external memory card just because it is unreachable in its default path. Database file name will consist of IndoorDb, after it is the time in milliseconds from first january 1970 till now and ends with file extension sql.

After program is finished, it is used for getting required patterns from people. These are needed to match the actions of users in future so it is possible to find out how he is moving. Patterns help to analyze the schematics of room, where user moved with certain actions. For example user crouched in order to take a picture from the QR-code. This will have a certain pattern and it can be matched, which will give information that the code was too low to take picture when standing. Other patterns will help to find out the user movement in room, for example when person runs, it is possible to match it with pattern and it gives information that between certain fixed points user

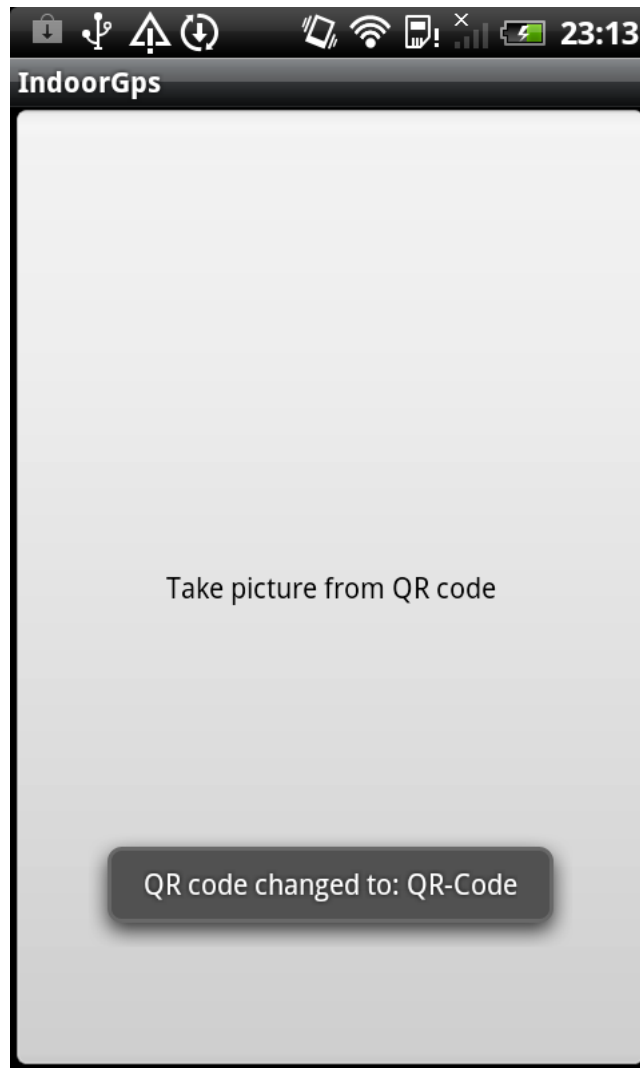


Figure 4.6: QR-Code reader information passed to application

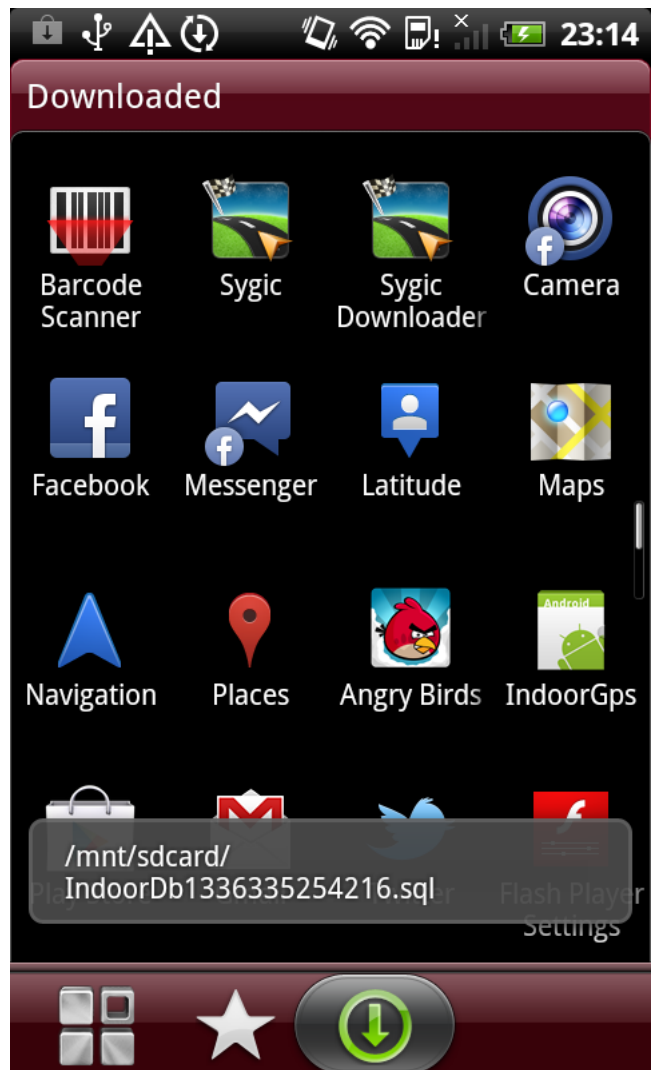


Figure 4.7: Application saved QR-Code to external memory card, popup in Android menu

## 4.1 General Approach and Implementation Details

ran. Then it can be used in order to get room schematic. Currently there are ten patterns created and are visible on following pages.

### 4.1.2 Accelerometer Activities Recognition Analysis

After getting the information about the user movement with sensors and QR-Codes, the data needs analysis. The data given has accelerometer and the direction data. Accelerometer data will give information about the user movement types and can be used for getting certain patterns, I.E. sitting, running and so on. For this thesis 10 patterns were created.

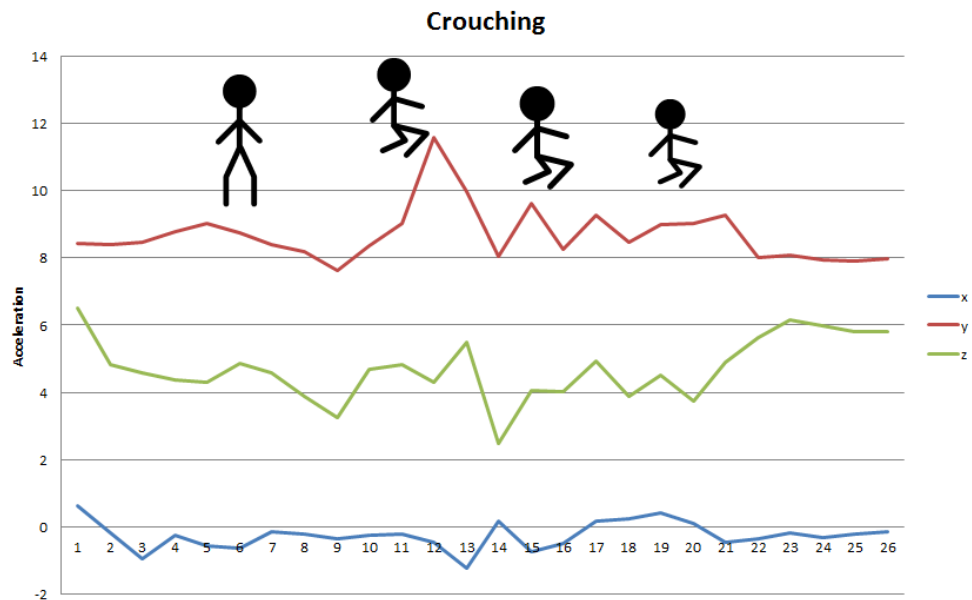


Figure 4.8: Crouching pattern graph

This pattern shows that entropy of signal starts fluctuating a bit when user crouches. Pattern data saving took 15.34 seconds.

4.1 General Approach and Implementation Details

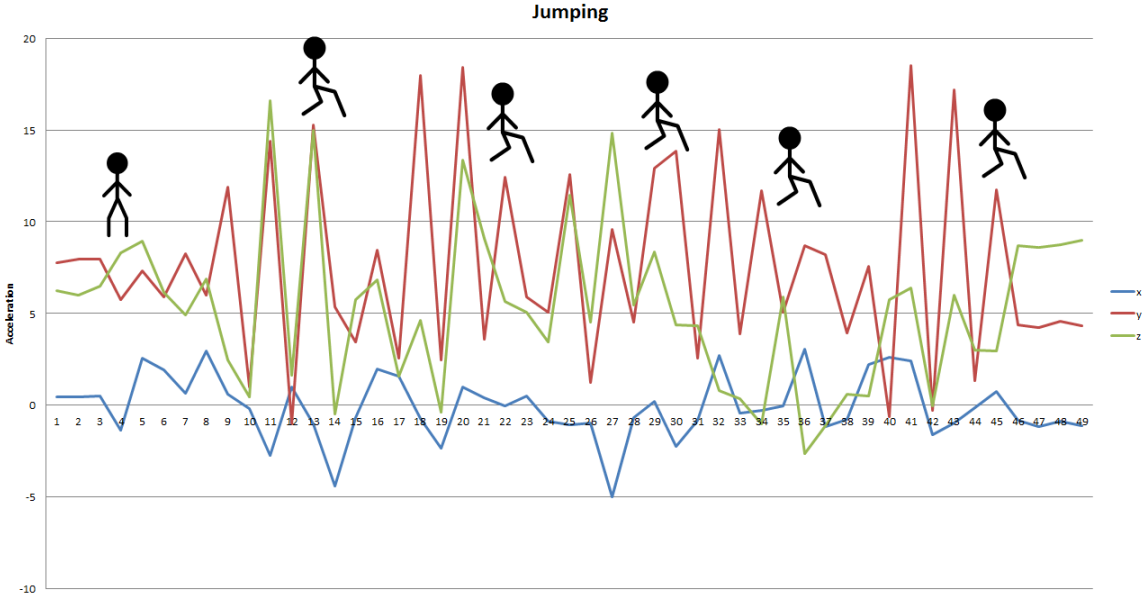


Figure 4.9: Jumping pattern graph

This pattern shows that entropy of signal starts fluctuating a lot when user starts jumping. Pattern data saving took 17.87 seconds.

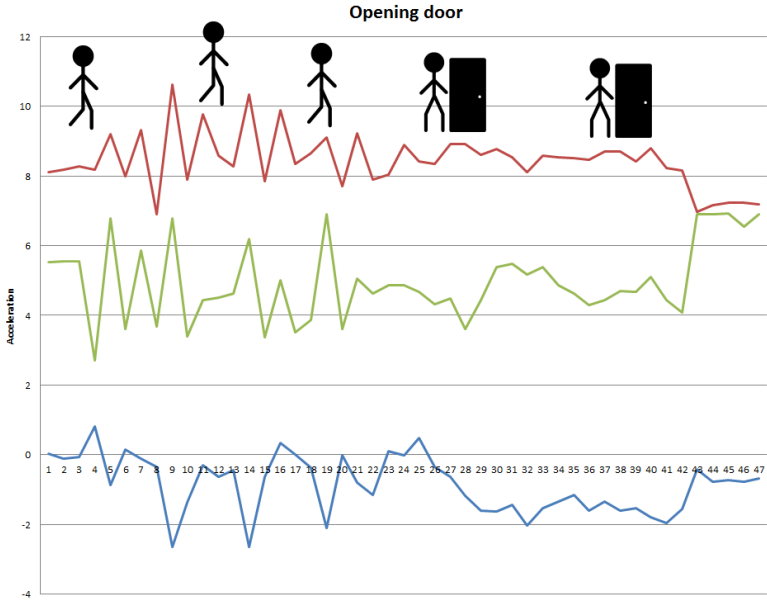


Figure 4.10: Opening door pattern graph

This pattern shows that entropy of signal starts fluctuating bit less when user starts opening the door. Before it he was walking. Pattern data saving took 13.3 seconds.

## 4.1 General Approach and Implementation Details



**Figure 4.11: Running pattern graph**

This pattern shows that entropy of signal fluctuates a lot when user runs. Before it he was walking. Pattern data saving took 14.18 seconds.



**Figure 4.12: Sitting pattern graph**

This pattern shows that entropy of signal starts fluctuating a bit when user sits, as seen on x and z graph lines. Pattern data saving took 15.06 seconds.



4.1 General Approach and Implementation Details

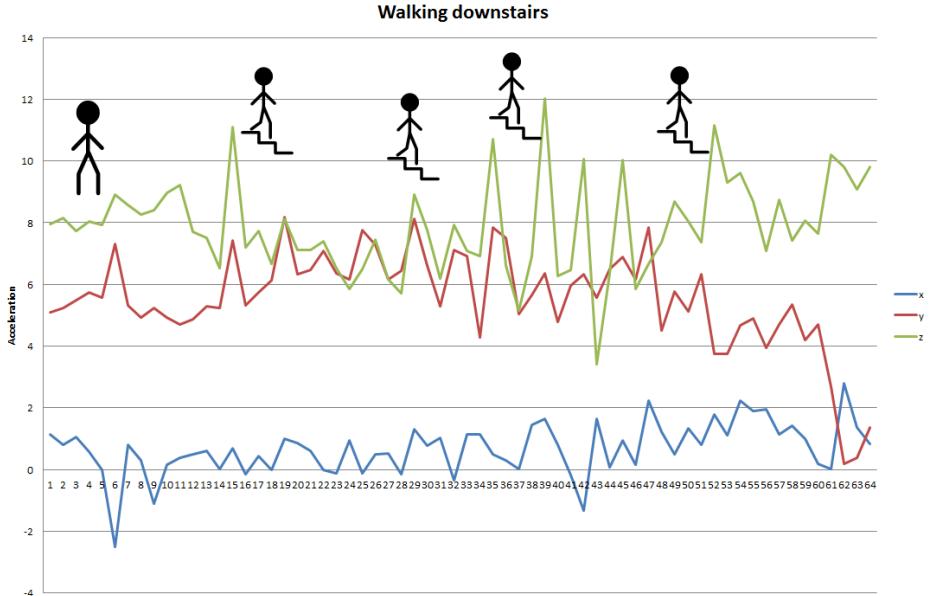


Figure 4.15: Walking downstairs pattern graph

This pattern shows that entropy of signal fluctuates a lot when user moves down the stairs. Pattern data saving took 13.57 seconds.

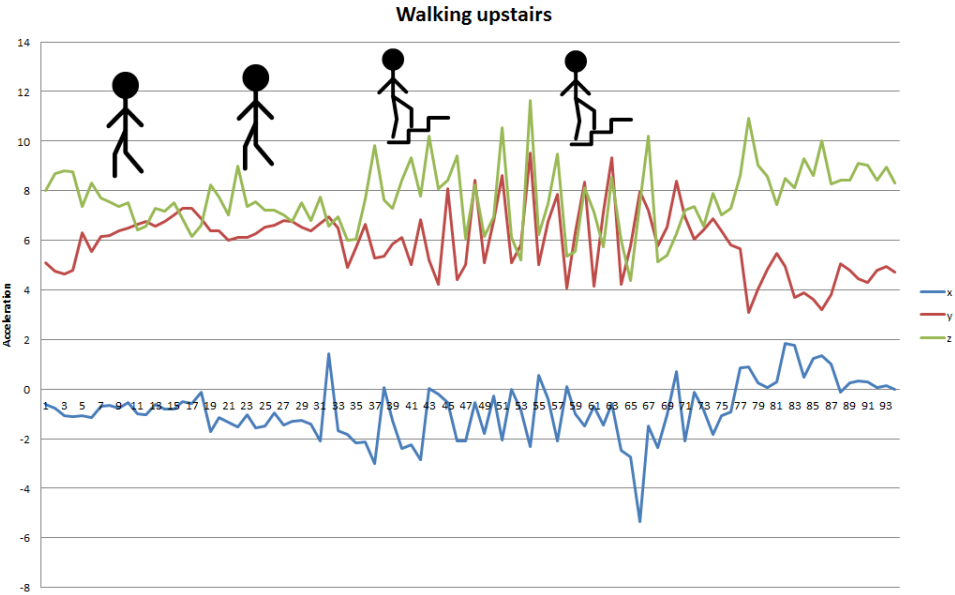
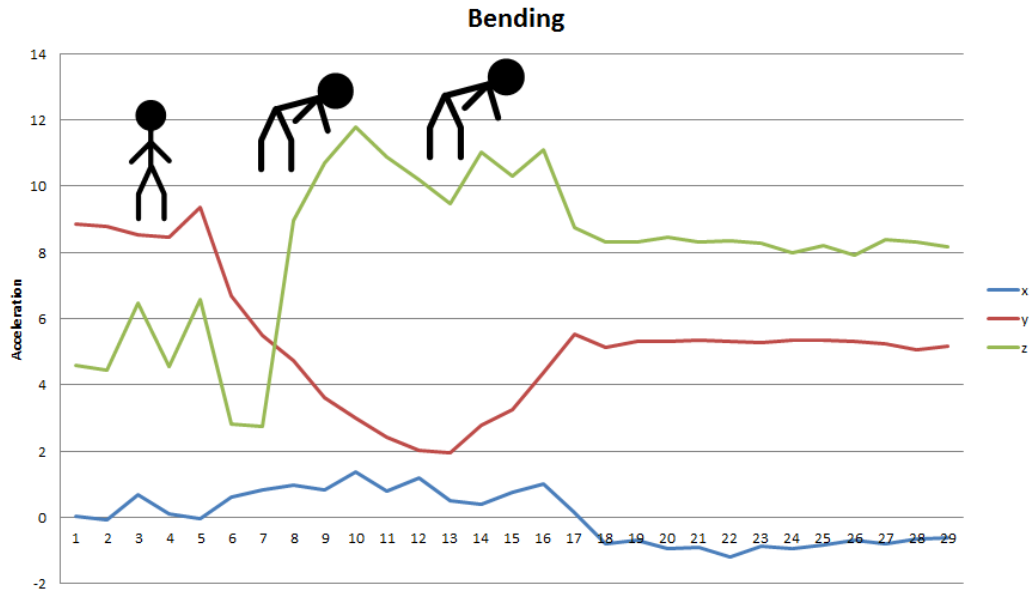


Figure 4.16: Walking upstairs pattern graph

This pattern shows that entropy of signal starts fluctuating a lot when user starts walking up the stairs, before it user was walking. Pattern data saving took 19.88 seconds.



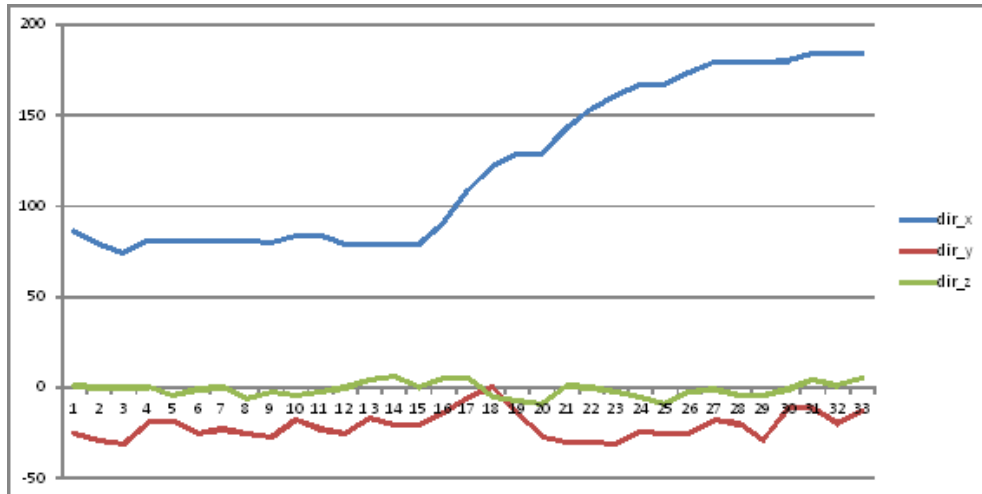
**Figure 4.17: Bending pattern graph**

This pattern shows that entropy of two signals fluctuated a lot when user bent. Third one practically remained the same. Pattern data saving took 13.47 seconds.

### 4.1.3 User Orientation detection using Orientation sensor

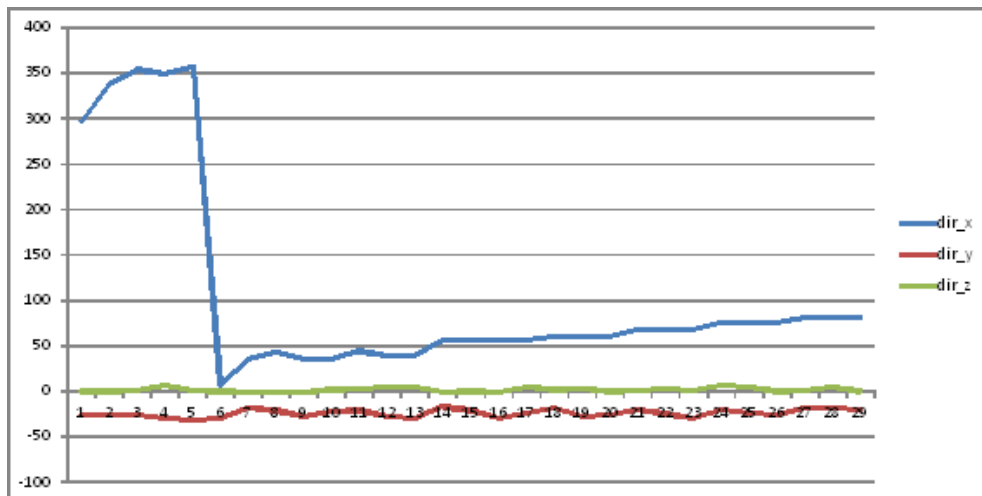
Accelerometer is not enough alone for identifying the user path, direction is also necessary. Then we can put together the path of user. Orientation is saved as data which consists 3 elements, which are azimuth, pitch and roll. All it is needed is azimuth, basically it shows the direction of the user. Four patterns were identified for user direction.

## 4.1 General Approach and Implementation Details



**Figure 4.18: Turning left pattern**

This pattern shows that when user turns left, his azimuth is changing according to the direction he is facing.



**Figure 4.19: Turning right pattern**

This pattern shows that when user turns right, his azimuth is changing according to the direction he is facing. Since the direction goes till it gets to 360 degrees, then it goes back to 0 and starts from there.

## 4.1 General Approach and Implementation Details

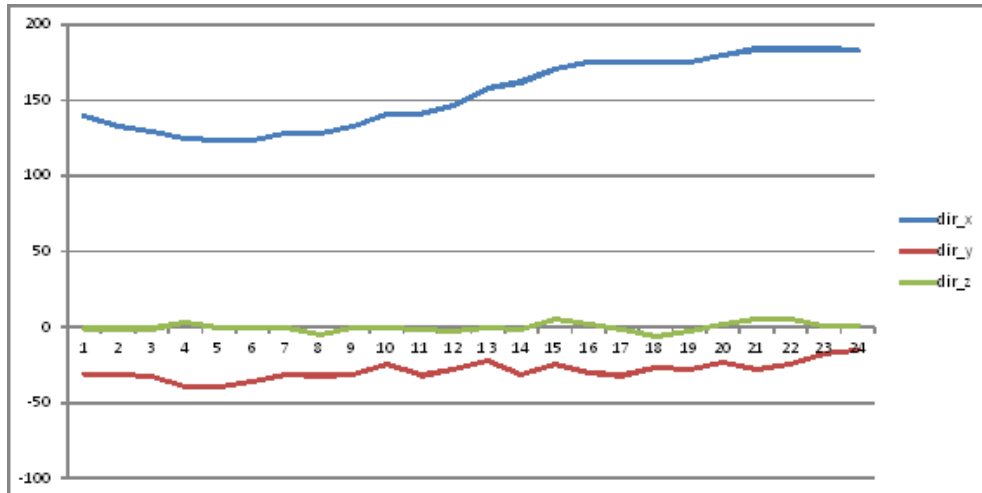


Figure 4.20: S-curve pattern

This pattern shows that user moves with S-curve. He is firstly moving right and after that back to left.

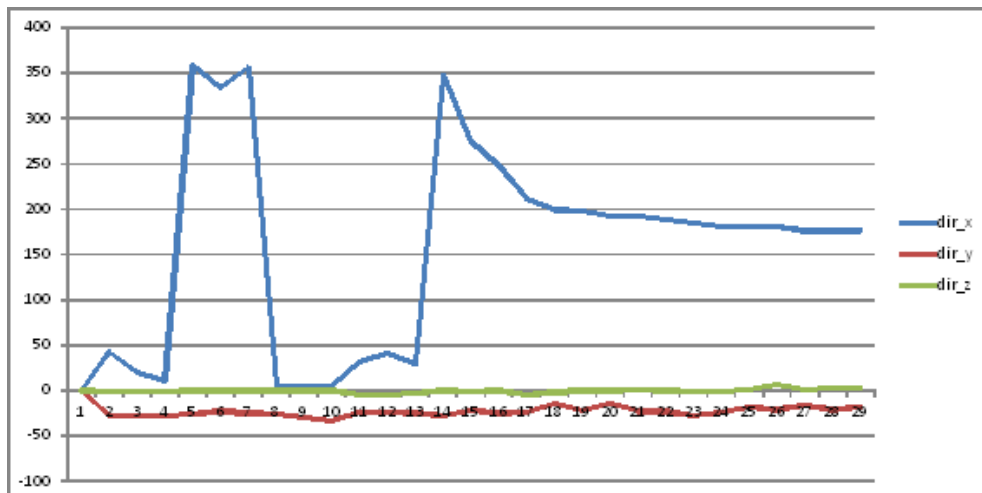


Figure 4.21: 180 degree turn pattern

This pattern shows if user makes 180 degree turn. First he is facing south and later he is facing south.

## 4.2 Summary

Main idea is to find out user's movement indoors where GPS signal does not reach or is not good enough for path finding. Full user movement will consist of two parts, first there is user path saving and second part will calculate it. Mobile sensors will do initial processing of the movement data and will save the given data for further processing. Second part of the program will take the data and will match the exact locations of QR-codes. Then the data will be processed, accelerometer data will give the pattern for given movement and user direction will be taken from orientation data. When the calculations are finished then resulting report will have information if the user movement can be tracked with mobile sensors or not.

## 5

# Case Studies

Main idea of current topic is to find out the path of the user indoors. For starting it is necessary to read the QR-code to match the location in room with some point to start calculating the proceeding movement. Then the code will be read by built-in mobile camera which pass the data to the current program. Then its possible to save accelerometer data and user direction found out by digital compass and it is saved within SQLite.

Now that everything necessary is included, the data is passed on to second program which will calculate users path. It knows the locations of the QR-codes, with the given locations it processes users movement data. It will match the patterns of the movements which is taken from the accelerometer data, so if the user jumps all the way, then we will have some pattern for jumping, if they walk, then we have some pattern for walking. Basically it will give us idea how user moved and we will try to match some kind of movement for it. After that movement type will be used and put into the report, for example, when user is running, we will determine more or less how fast the movement takes place and put it into the report. Finished report will show the movement path indoors.

### 5.1 Full pattern of movement

Now that patterns have been found and the accelerometer actions are known for each actions, it is possible to create a full pattern which consists of all the patterns above

## 5.1 Full pattern of movement

to test if it is possible to find out the user movement path. For this test case is created and put in use to find out generated report.

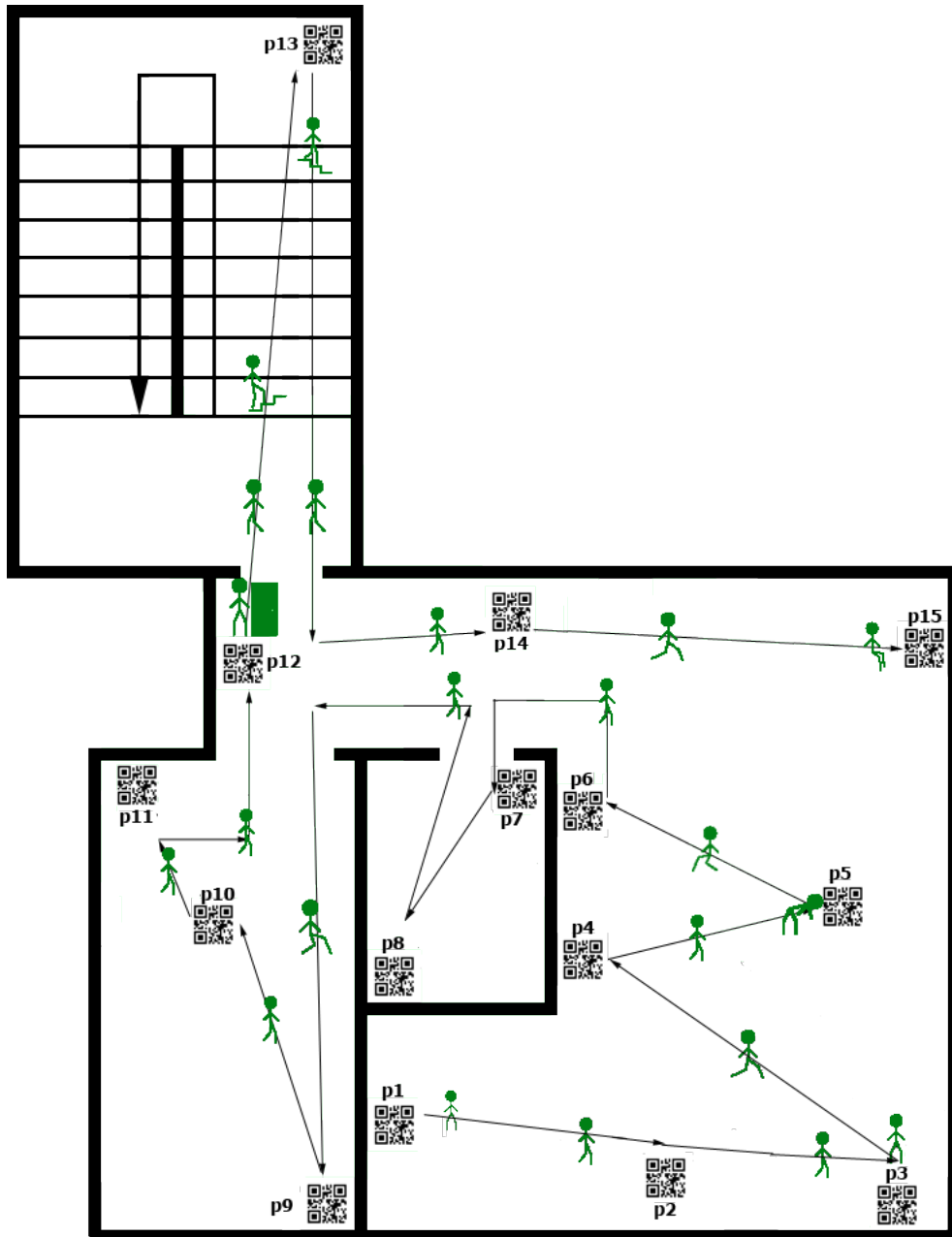
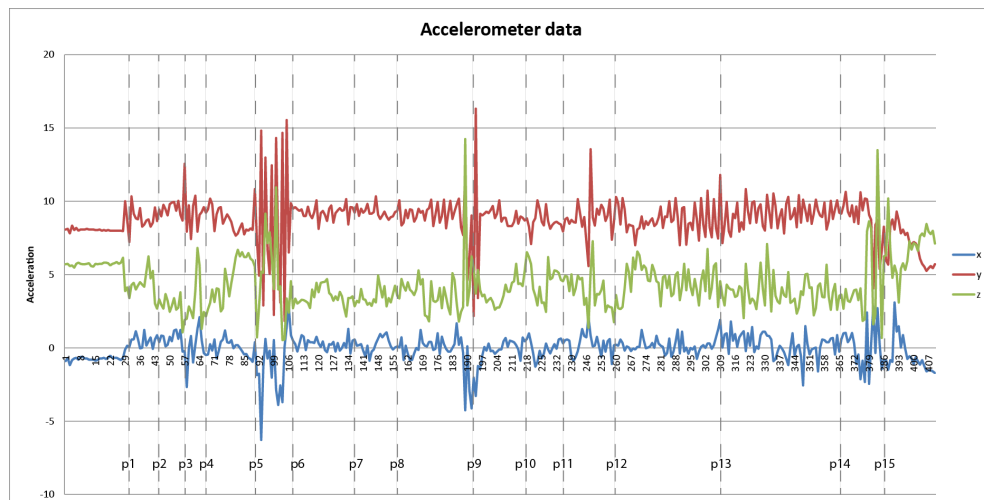


Figure 5.1: Indoor movement pattern for patterns

## 5.1 Full pattern of movement

This is the case where user starts from the bottom center of schematic from the point 1. He stands there for a while and then takes picture of QR-code in the beginning and then walks towards second point. Takes a picture and walks to p3 where he stands again. Then he runs from point 3 to point 4 and again picture will be taken. Pictures will be taken in each point, but user walks to point 5 where he bends down to take picture, because code is near the ground. From there he jumps to point 6 and after that walks to point 7, then 8 and then walks to the corner of hallway. From there he jumps to the bottom corner of the leftmost room down from the door. After point 9 it is necessary to walk to point 10 where crouching is needed because the code is near the ground, point 11 is on some height and one step has to be made to take a picture. Near the door is point 12 after which door has to be opened and he must walk up the stairs. Then again, down the stairs and inside the room, since door was open, door did not have to be opened again. To reach the last point which is fifteenth will be reached by running and sitting down. Overall this pattern took 199,612 seconds to perform. Example file is named full\_pattern.3.xls

User will get the data from the session given on the above image. Now accelerometer and orientation sensor data can be analysed and movement info can be extracted. Following will show the accelerometer graph and orientation sensor data graph which are necessary to analyse user movement.



**Figure 5.2: Accelerometer data from the session**

This pattern shows graph about the previous session accelerometer results. From this result it is possible to get movement patterns.

## 5.2 User movements for room schematic

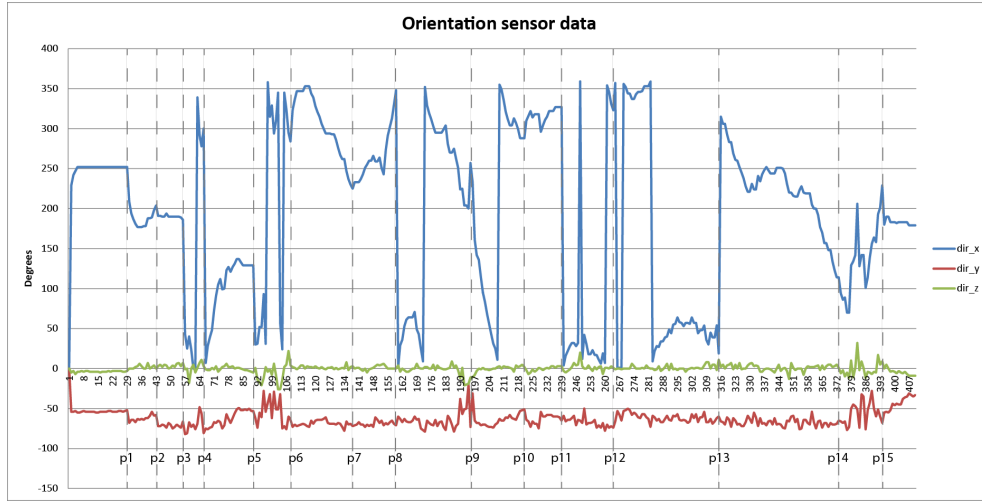


Figure 5.3: Orientation sensor data from the session

This pattern shows graph about the previous session orientation sensor data. From this result it is possible to get movement direction.

## 5.2 User movements for room schematic

For the experiment, 15 different object were needed in indoor environment. Then QR-codes were put near them to have some kind of identification for objects for users. QR-codes were placed near or on those objects on different heights to match the real object position. For example flower pot which was on the ground got code on its pot near the ground. Codes had text written in them, for example object 1 had p1, object 2 had p2 and so on. After the room was prepared, users were asked to move around in the room and identify objects they liked. They had to locate code and scan it with the phone. Since users had their own free will to visit the locations they liked, not all codes were scanned during each person's session. In the end, 10 patterns of the movement was saved on the phone and then the analysis were made. The ending result is indoor schematic about different user movements and table with data how and what user did between 2 objects. Table has the following data, first column describes that which user has which data. Second column shows the object where the user came from, if it is named "Default" then it means that application was turned on and no object code has been scanned. Third column shows what user scanned for next object. Fourth column

## 5.2 User movements for room schematic

is showing the time between the points and sixth the actions made during that time.

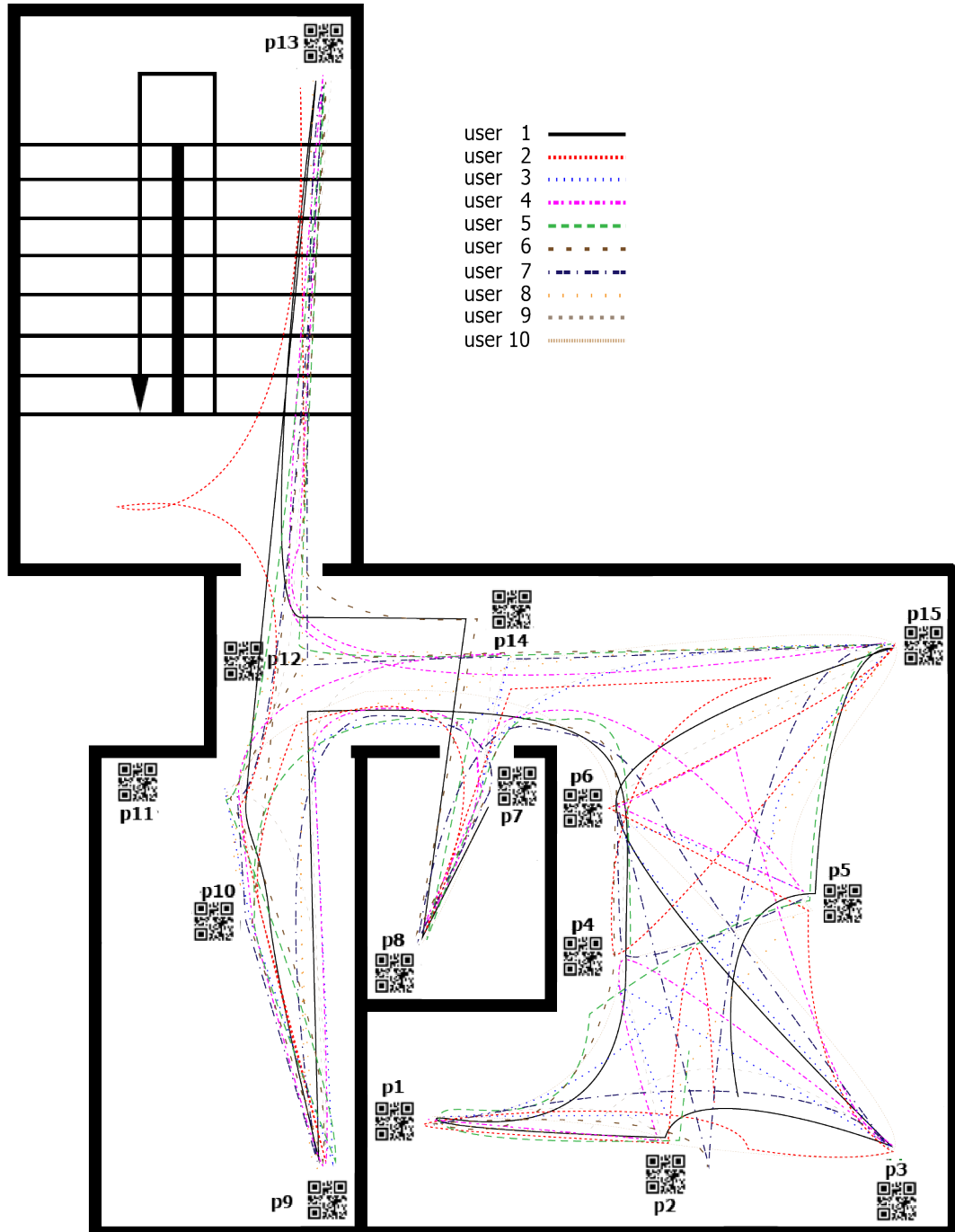


Figure 5.4: Indoor movement schematic of users

## 5.2 User movements for room schematic

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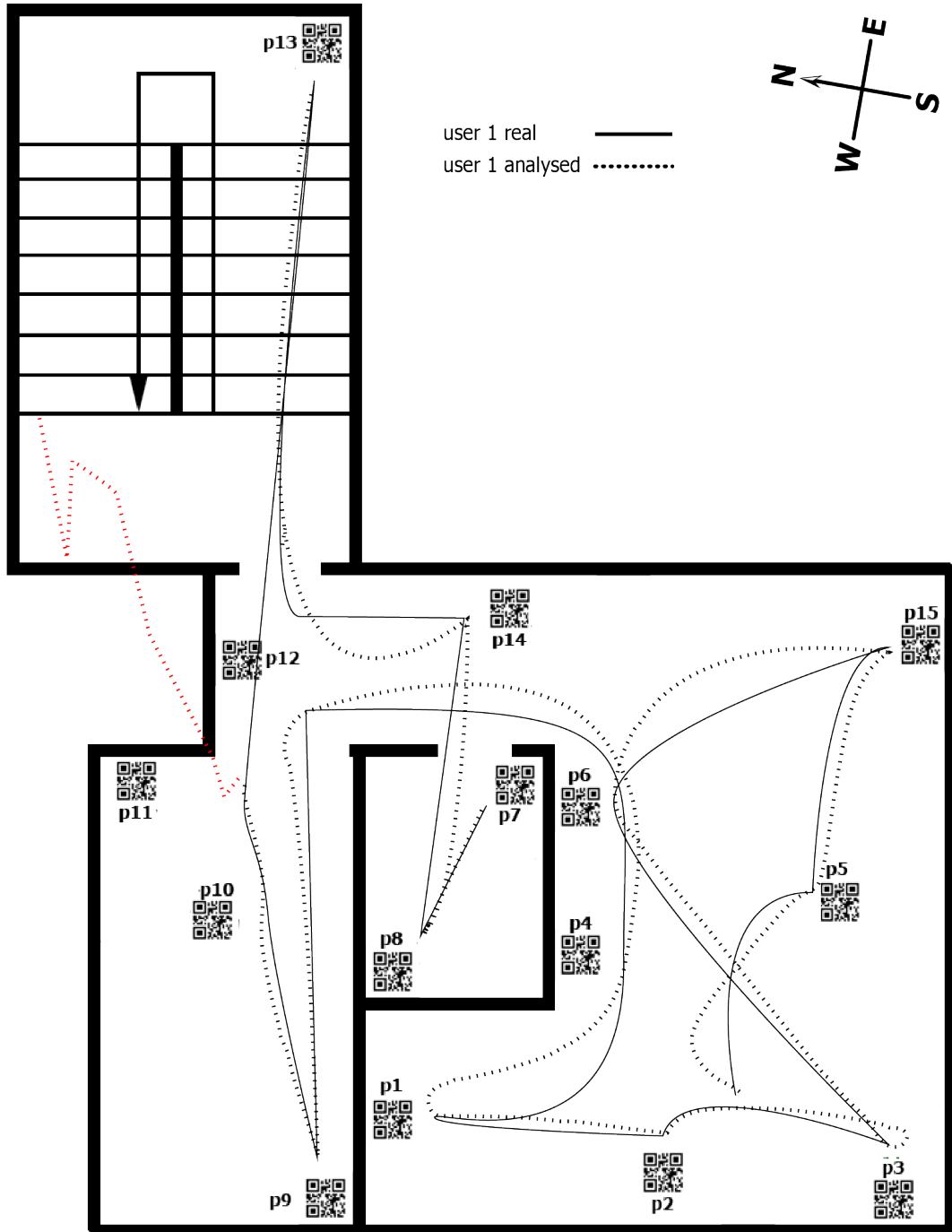
Following table illustrates the data about User 1 movement throughout the session. The actions made during the process were identified and added to the table. First column shows the user who made the action, second shows from which point the user came, third shows where he was heading. Fourth shows the duration in milliseconds for actions between given two points. Final column will show the activities identifies with the help of patterns. For the rest of the user information, see the file attached to the cd which is along with the thesis.

User	From	To	Duration in milliseconds	Activities
User 1	Default	p5	6228	Walking
	p5	p15	7598	Walking
	p15	p6	4956	Walking
	p6	p3	8380	Walking
	p3	p2	6039	Walking
	p2	p1	4508	Walking
	p1	p4	6684	Walking
	p4	p12	12694	Walking
				Crouching
	p12	p9	8388	Walking
	p9	p10	4733	Walking
	p10	p11	4278	Standing up
				Walking
	p11	p13	29962	Walking
				Walking upstairs
	p13	p14	14972	Walking downstairs
				Walking
	p14	p8	7131	Walking
	p8	p7	4529	Walking
	p7		5348	Walking
		Total time	136428	

One really big problem is that if phone is held that y axis is more towards the ground than z axis then the patterns will change. The gravity has effect on the accelerometer and will have more effect on the axis which is more towards the ground.

Following image will show the real and analyse result for user 1 movement. Other users path can be analysed as well with the data given in the files.

## 5.2 User movements for room schematic



**Figure 5.5: Indoor movement schematic of user 1, consists of analysed and real results**

This pattern shows that user's paths are more or less the same. Between points p11 and p13 something happened with sensor. Either the user held the phone in hand that it faced north or there was some stronger magnetic field which ruined the data. Other data was really good and gave correct results.

### 5.3 Summary

According to the last section, the accelerometer pattern analysis and compass, it is possible to track the user indoors. To prove the concept, experiment with ten users were made. First they moved between objects they liked the most and author tracked them for real path. They had to use mobile phone with sensors which data was saved to database. Later the necessary sensor data was analysed to see if problem can be solved. Patterns were searched and found in accelerometer data which could be used for getting movement type and compass gave the user direction. This data was used for getting similar path to the real one, which was pretty close match with only minor errors.

## 6

# Conclusions

Smartphone is extremely good device in nowadays society, it will help a lot because it has functions what will make everyday life much simpler. Also there are sensors which will give user info about the surroundings, also they can be used to make interesting apps, for example games that will use environment data to make it more interesting and help the user to blend into the game. It is always good if more items are in one, so it is more comfortable to live everyday life. Some problem rise with current solution. For example smartphone must support that several tasks can be done simultaneously, otherwise it is useless.

Smartphone sensors are good for positioning, patterns can be made from person actions and can be matched in real life. For example if action matched is running, pattern will help to find out the current movement and this can be used for schematic which shows which way and how far the user moves. In the end full movement path has been generated, it will show the information of indoor location, where are the walls and objects and so on. Since outdoor navigation is part of our everyday lives and indoor has not had that much research, then researching it more and finally creating an indoor navigation application, will make the life easier. For example if the child gets lost, user can get the path how she walked and that will eventually give the final position of her. That is usual when info desks in malls yell that somebody's child is lost and they are looking for her parents.

Tracking is part of our society, because people want information and a lot of it. They want to know everything, because it is in human nature that they are curious. This makes it important that indoor navigation should get some research as well. People

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will get to know their surroundings in buildings like they do that outside. They will get a chance to find out where is some certain statue in museum and do not have to find it and it comes out that it is the last one they have not seen yet.

## 7

# Related Work

Since indoor navigation is still in relatively new state, it is investigated and new solutions are being researched. Couple of solutions for tracking user in locations where GPS signal does reach have been developed, but they are not that good to be in mass production and used by everyone. One possibility is to find user location by the WiFi area location, but it is pretty wide area since network signal reaches up to 300 m away. The most famous company who developed algorithm for it, is SkyHook. It uses every possible way to determine location, Wifi signals, cellular towers and GPS. It sends the data to server and it will return the data with user location in it. There is also one application created for finding the user movement types by defining them by some patterns which has some accuracy for matching. To math them, accelerometer was used. This gives basic idea about user current action and what user is currently doing. (24). Secondly there is program which uses GPS and sensors for user position. Because GPS only works outdoors then Google maps showed it in wrong location on map. That is why this solution was created, server is used to analyse the accelerometer and GPS data and it will send position back to user. This will only show the distance travelled inside the building because it does not know the objects or direction user is travelling. (19) Also there is a work done where patterns have been searched for user movement types with accelerometer. Each pattern has also matched accuracy of determining the user movement type. (24). Besides all the previous, there is also a work with gyroscope, compass and accelerometer. It was a research for finding if it is possible to find a position from A to point B, when GPS is not available. It found the error margin for both compass and gyroscope to determine which one is better for navigating.

## 8

# Future Research Directions

Since the concept was proved, then the next logical step would be desktop application. Application should be able to simulate huge amount of users for further analysis which gives possibility to speed up the research because real users are not that necessary anymore. Other possibility is to find an approach that can be used for processing all the data, both accelerometer and orientation sensor data. This means that application should be able to determine the user movement type and after that, direction which comes from orientation sensor can be used and correct path can be generated.

## 9

# Sisukokkuvõte

### **Mobiiliseadme kasutajate konteksti jälgimise analüüsil põhinev siseruumide skeemi genereerimine**

Tehnoloogia areneb iga päevaga ja meie elu muutub selle tõttu lihtsamaks. Navigatsioon on tehnoloogia üks osa, kui üks inimene liigub ühest kohast teise, siis ta teeb seda kas teed teades või abi küsides. Abi saamiseks kasutatakse ka positsioneerimissüsteeme. Välistingimustes navigeerimine on arenenud väga palju, samas kui sisetüingimustes on ta jäänud pisut tagaplaanile. Sellest tuleneb probleem et kasutajad ei saa majas sees liikudes oma asukohta nii kergelt teada kuna tavapärased süsteemid ei pruugi töötada. Samuti eraldi seadmete kaasaskandmine on küllaltki tüütu. Probleemi lahendamiseks, tuleks luua mobiilirakendus mis saab infot väliskeskkonnast sensorite ja kaamera abil. Peale selle peavad olema ruumis objektid, mis on kindlatel kohtadel ja QR-koodiga identifitseeritud. Sensorit andmeid tuleb töödelda ja seejärel saab tulemusi koos objekti asukohtadega kasutada siseruumide kaardistamiseks.

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