Design and Implementation of a Campus Navigation Application with Augmented Reality for Smartphones

Benjamin Lautenschläger

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Matrikelnummer:	823577
Betreuer:	Prof. Dr. Miriam Föller-Nord
Zweitkorrektor:	Prof. Dr. Astrid Schmücker-Schend
Durchgeführt bei:	Prof. Dr. Frank Maurer Agile Software Engineering Group University of Calgary Department of Computer Science 2500 University Dr NW Calgary, Alberta Canada

Abstract

Mobile phones are nowadays far more than merely devices to communicate with. Especially, smartphones are products that help to make our work and everyday life easier. Along with the advance in technology and popularity of these devices, the use of mobile applications increased enormously in the last years. Based on new techniques like GPS and sensors, like compass and accelerometer, that can determine the orientation of the device, location-based applications coupled with augmented reality views are possible.

In the context of this work a mobile navigation application for the University of Calgary is developed. This thesis describes the initial thoughts on this application and the process that led to the final system environment. The approach on designing a graphical user interface for pedestrian use on mobile devices is described, as well as the actual implementation of it. To provide users with location based information a location tracking algorithm based on wireless network signals is created, which determines the geographical position inside buildings.

The resulting application enables the user finding paths to specific locations on campus and offers him the ability to explore the campus environment via augmented reality.

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Benjamin Lautenschläger

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List of Abbreviations

Symbol	**Definition**
AMF	Action Message Format
API	Application Programming Interface
AR	Augmented Reality
BSSID	Basic Service Set Identifier
CSS	Cascading Style Sheets
CSV	Comma-Separated Value
DAO	Data Access Object
DTO	Data Transfer Object
FSPL	Free Space Path Loss
GIS	Geographic Information Service
GPS	Global Positioning System
GUI	Graphical User Interface
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
JDBC	Java Database Connection
JNDI	Java Naming and Directory Interface
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
LDAP	Lightweight Directory Access Protocol
REST	Representational State Transfer
RF	Radio Frequency
RSSI	Received Signal Strength Indication
SDK	Software Development Kit
SOAP	Simple Object Access Protocol
SSID	Service Set Identifier
TDOA	Time Difference Of Arrival
UI	User Interface
URL	Uniform Resource Locator
Wi-Fi	Wireless Fidelity
WSDL	Web Services Description Language
XML	Extensible Markup Language

1 Introduction

This chapter introduces the reader to the topic of this thesis. The motivation for this work is explained as well as the goals which should be accomplished in this project. It also describes the structure of this thesis.

1.1 Motivation

A university campus is a complex infrastructure. Especially new students and people who are on it for the first time have a hard time to orientate themselves and find places.

The campus of the University of Calgary occupies more than two square kilometers and thus is even larger than Calgary's entire downtown. The campus has many different buildings with up to 15 floors. Most of the buildings are connected to each other, some of them even by underground walkways. Even if there are maps at some points on the campus, users do not have continuous help to get to their destination. They can try to figure out a way to get to their target on these static maps, but as soon as they start walking in the target direction they have no help any more.

Whereas it is very common to use navigation systems in cars to reach designated locations, systems for pedestrian navigation are quite hard to find.

So, how is it possible to help freshmen and other inexperienced people orientate themselves on the university campus and support them finding places on campus with the help of modern techniques?

1.2 Goal

As mobile devices like smartphones become ever more powerful and affordable for a majority of people, they are starting to access all different parts of life. The use of smartphones which comes along with the excessive use of mobile applications is becoming more and more common, especially in the university domain.

Besides the functionality of surfing the web, reading and writing emails, smartphones offer the ability of context aware applications. The majority of these mobile devices have built-in techniques to determine their geographical position. These techniques combined with the right software can provide the user with location-based information, which can help a user in different ways.

The goal of this thesis is to create an application prototype for a smartphone, which supports people on a university campus. Just like a car navigation system, a navigation system for pedestrians at the University of Calgary should be developed. Whereas paths computed by car navigation systems are just two dimensional, paths on campus can consist of segments on different building floors and so are in most cases three dimensional. Considering that, a new user interface which is suitable for 3D navigation has to be designed.

In addition to the navigation feature the user’s current location can be used to show him nearby points of interest and help him get to know the campus. To make the application more interesting and fun to use, social content like user posted comments or the position of friends will be part of the information that is displayed in the application. For displaying this information, an augmented reality view is integrated.

Given the fact that a high percentage of university life happens inside buildings, a suitable indoor location tracking method is part of the implementation, too.

To realize these features the existing information environment of the University of Calgary has to be investigated. A system architecture has to be designed, which handles different data sources and makes it simple to access them from client applications. There should be an easy way to exchange data sources or add new ones to the existing model. The main logic of the system has to be part of the server, so that it is easy to port the resulting application to other mobile platforms.

Although the prototype is focused on the campus of the University of Calgary, it should be easily portable to other areas.

1.3 Structure of Thesis

This thesis describes the entire process of developing a mobile application for pedestrian navigation purposes. It is divided into six parts.

After this introduction chapter, basic techniques and related work are briefly explained in chapter 2.

The third chapter is about the user interface. It describes the basic thoughts of adapting the user interface of car navigation systems and enhancing it with certain features that are helpful for pedestrian use. Different approaches are shown in sketches.

In chapter 4 the software concept is explained. Data sources that are useful for this application, as well as different methods to integrate them into the system, are evaluated. Technical decisions regarding the platform for the prototype are made along with others, which lead to the final system architecture.

After designing user interface and software architecture, chapter 5 describes the implementation process of server and client software. The management of data sources, as well as the interfaces of the server, are shown. Besides the integration of different information sources from the server, the main focus on the client side lies on the implementation of the graphical user interface.

Finally, Chapter 6 summarizes this work. It gives an overall conclusion, shows the problems that came up and the limitations of the resulting application. In the end of this chapter future tasks to enhance this application are listed.

2 Background

Before designing the application and the system environment, this chapter gives insight into techniques used in this project. Furthermore, a short overview of applications that are related to this project is given in the end of this chapter.

2.1 Geographic Information System

A geographic information system (GIS) is a system which is used to store, retrieve, map and analyze geographical data. These systems store any kind of information which is related to a geographical location. These spatial features are stored in a coordinate system which references a certain place on the surface of the earth.

The main use of geographic information systems is resource management, development planning and scientific research.

2.1.1 Describing Geographical Data

To describe a geographical position the terms latitude and longitude are used. They are measures of the angles from the center of the earth to a point on the surface.

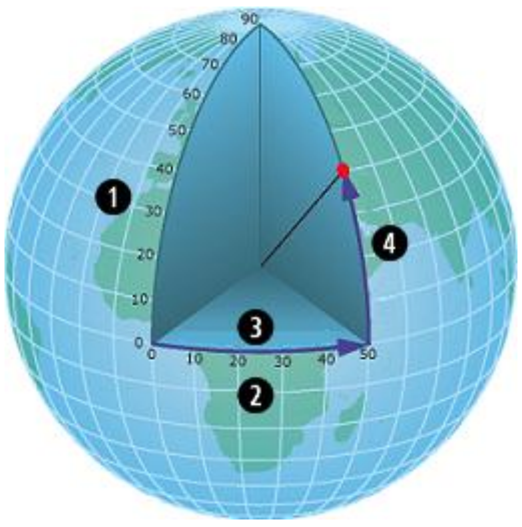


Figure 2-1 - GIS - Latitude and Longitude [1]

Figure 2-1 shows the sphere of the earth with lines that represent latitudes (1) and longitudes (2). The red dot in this figure is described by the coordinates 50 degrees east (3) and 40 degrees north (4).

To transform the surface of the earth onto a two dimensional plane, map projections are needed. Therefore, a projection surface, which is unfolded or unrolled in the end, has to be chosen. *Figure 2-2* shows three examples of projection surfaces.

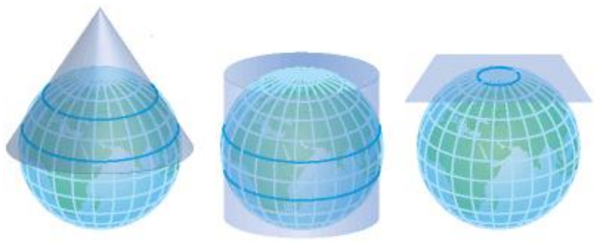


Figure 2-2 - GIS - Projection Surfaces [1]

No map projection is perfect. Parts of the map are always distorted when represented in a 2D plane. In *Figure 2-3* the distortion problem is illustrated. The projection surface (1), in this case a cylinder, is attached to the sphere of the earth at the secant lines (2). These lines are the only part of the projection without distortion. Inside these lines (4) features are smaller; outside (5) they are bigger.

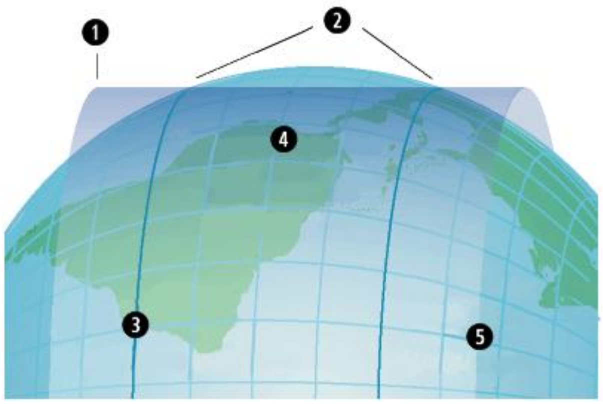


Figure 2-3 - GIS - Projection Problems [1]

To reduce distortion, different projections are used for different areas on the earth. A GIS is able to project geospatial features from one map projection to others.

2.1.2 Esri ArcGIS

At the University of Calgary the geographic information system of Esri is used. Esri ArcGIS is one of the biggest GIS on the market and has a share of over 30%. [2]

ArcGIS refers to an entire software suite around geographic information systems. It contains products for server and desktop use, as well as for mobile platforms. ArcGIS Server is used to deploy GIS functionality at a central point. It is used for creating and managing GIS data and applications. It also offers a variety of web services.

ArcGIS Desktop is a software suite which provides functionality to access GIS data stored locally on a PC or on a server. It offers methods to create cartography, edit them and do advanced analysis and geoprocessing. Furthermore, there are software products that enable 3D analyses and creation of network datasets to simulate real world networks, which can be used for routing.

Esri also offers a huge palette of developer tools for their system including mobile APIs[1] and APIs for web development.

2.2 Location Tracking of Mobile Devices

As location-based services have increased in popularity over the last years, the need for positioning of mobile devices becomes more and more important.

2.2.1 GPS-based Positioning

The Global Positioning System (GPS) is the leading technology to determine locations on mobile devices. Almost every smartphone on the market has the capability to receive GPS signals. GPS is a freely accessible system based on satellites. To determine a position the GPS receiver needs a line of sight to four or more satellites. Given this fact, GPS only works outdoors.

Each satellite is equipped with a highly accurate atomic clock and sends out this time along with position data of the satellites and error correction data. A GPS receiver compares the satellite time with its own clock and computes based on the difference the distance to the satellite. The distance to the satellite and its absolute position defines a sphere, centered at the satellite (see *Figure 2-4*). The position of the receiver has to be at one point on this surface. Adding data from a second satellite, another sphere can be drawn. Not considering the unlikely event they intersect in one point, both spheres intersect in a circle. A third sphere, computed by the data of the third satellite narrows the

[1] Application Programming Interface

position of the receiver down to two points on this circle. For position determination used by smartphones, the intersection point closest to the earth’s surface is the correct position of the receiver.

The fourth satellite is to correct the error which arises by the fact that the clock of the receiver is not as accurate as the atomic clocks of the satellites.

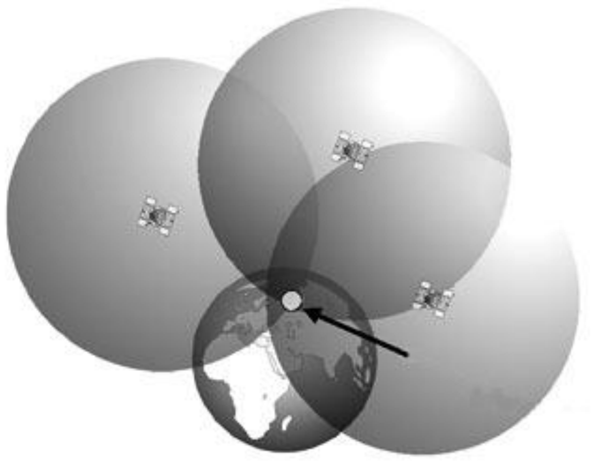


Figure 2-4 - GPS - Intersecting Spheres [3]

The accuracy of a position determined by GPS depends on the receiver. Most consumer receivers have an accuracy of 5 to 10 meters.

2.2.2 Wi-Fi-based Positioning

While the GPS method for positioning works great outdoors it is not usable indoors, due to the fact that it needs a line of sight to at least four satellites. With an accuracy of 50 - 300 meters, the location tracking method using the mobile phone network is also not suitable.

To determine a usable indoor location estimate, different approaches based on Wi-Fi technology can be used.

Nearest Sensor

The easiest way to get a location estimate based on wireless networks is to use the nearest access point. This system is integrated into most of the access point management systems. It determines the access point to which a client is connected. Under the assumption that this is the closest access point and based on the information of it, it computes how far the signal of this access point radiates. The client has to be in range of this area.

Received Signal Strength Indication (RSSI)

Similar to the computation of the GPS-based position, a location estimate can be calculated by the received signal strength of the nearby wireless networks.

Whereas the time difference of arrival (TDOA) was used to determine the distance to the satellite, the distance to Wi-Fi access points can be deduced from the RSSI. With the outgoing power level of the access point and signal strength received by the client, the absolute loss of the signal strength is calculated. With the free space path loss[2] equation this leads to the distance to a specific access point.

With the distance to three access points and their absolute position, the position of the client can be computed by using a trilateration algorithm. More precise information to this algorithm can be found in chapter 4.1.3.

Radio Frequency Fingerprinting

A relatively high effort is needed for the initial setup of this method. A physical walk around with special spectrum analysis units is needed to create radio frequency (RF) fingerprints for different points of the area where the location should be tracked. A fingerprint identifies locations by measures of the radio frequency setting, which is created by the wireless network access points.

Management systems from different vendors include functionality to manage these fingerprints. Based on the measured fingerprints these systems have the ability to compute fingerprints for every other point of the needed area with sophisticated interpolation algorithms.

To determine the position of a mobile device, the device sends the current RF fingerprint of its environment to a server. The server compares this real-time fingerprint with the ones in the database and computes a position based on the fingerprints which are similar to it.

The benefit of this system is that it also takes environmental effects like reflections on walls or other objects into account.

[2] relation of signal loss of an electromagnetic wave and the distance to the transmitter (described in chapter 4.1.2)

2.3 Augmented Reality

Augmented Reality (AR) is a type of virtual reality where a live view of a real-world environment is displayed on a device like a smartphone with a layer of additional data attached to it. This additional information (e.g. names and reviews of nearby restaurants as seen in *Figure 2-5*) augments the view of the real world by using the sensors of the device.

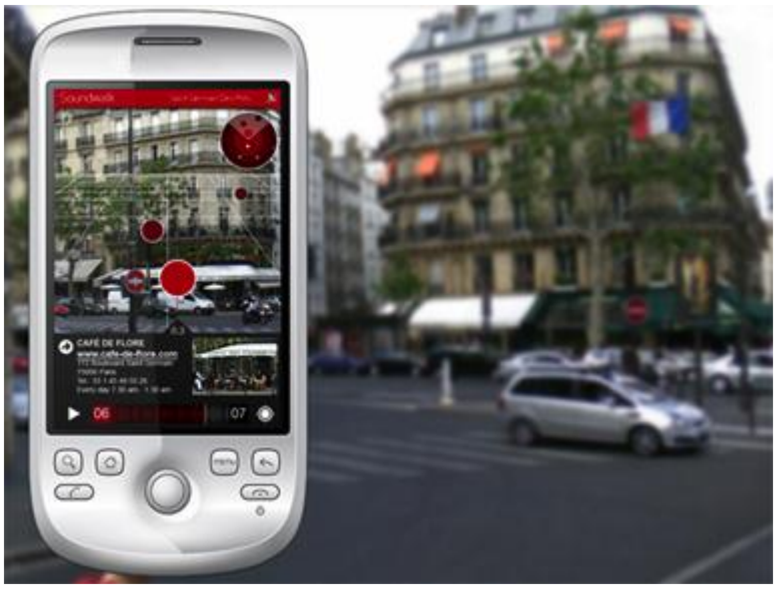


Figure 2-5 - Augmented Reality View on a Smartphone [4]

AR is a combination of different techniques. It requires a device with a camera to show the direct view of the environment. To determine the position and the orientation of the device several sensors are used. In most cases the GPS receiver of the smartphone is used for determining the current position. Compass and accelerometer help to determine the direction in which the device is facing. AR also needs an internet connection to receive data for the information layer.

In the end, everything is combined by software, e.g. an application on a smartphone.

There are not only augmented reality applications for mobile devices, AR also works on desktop computers with a camera attached to it. A user can hold objects (e.g. products from a specific company) in front of the camera and then see an information layer on the screen.

2.4 Related Work

In this part applications are described, which are related to the topic of this thesis.

2.4.1 Oregon University App

In 2011 a team of graduate student developers and undergrad cartographers from the University of Oregon implemented a mapping application for the university's 20,000+ students and faculty members.

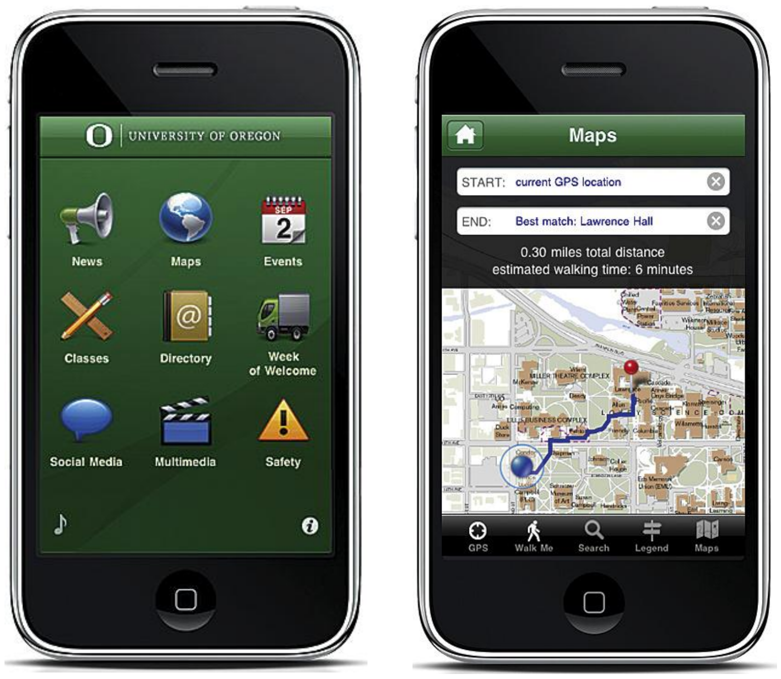


Figure 2-6 - Screenshots of Oregon University App [5]

Besides news and information about upcoming events of the university, the main features of the application are browsing maps and routing on campus. Connected to an ArcGIS server, the application offers users, after defining two places on campus, a route which leads to the destination point. Users of this software also have access to a campus tour, which is set up as a predefined route on the GIS. [5]

The downside of this application is that it only supports outdoor path finding. It is not possible to get a route to a specific room.

2.4.2 Project Glass

Project Glass is a program of Google for research and development of an augmented reality application using glasses as a head mounted display.

Basically this device enables a user to do things that are normally only possible with a smartphone. The user is, for example, able to look up context based information, take pictures and videos, get directions to stores or other locations or do video chats with this device. Information is displayed on a heads-up display as seen in *Figure 2-7*.

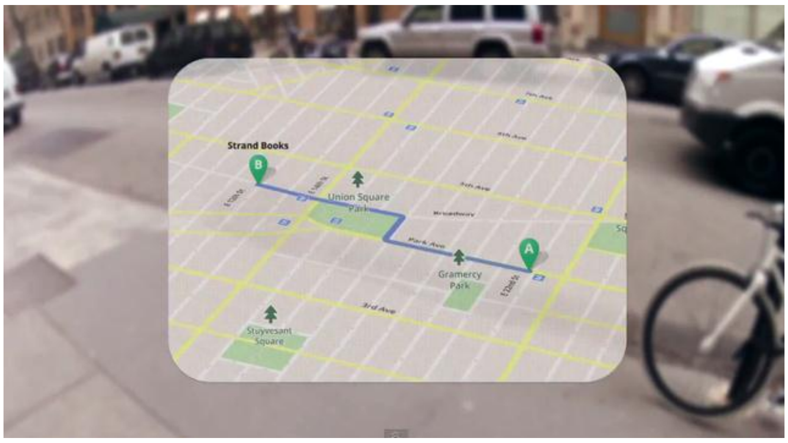


Figure 2-7 - HUD of Project Glass [6]

Different to augmented reality applications for mobile devices today, this project is based around a head mounted display in the form of glasses, shown in *Figure 2-8*. It is voice controlled and offers the user hands free interaction.

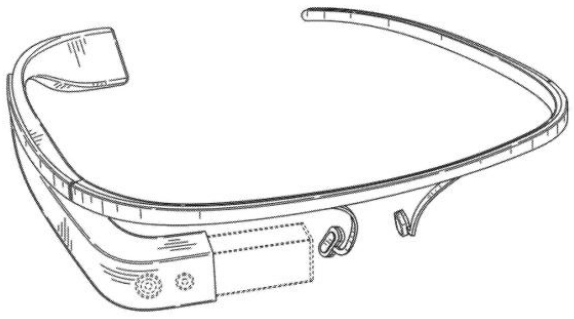


Figure 2-8 - Google Glass Explorer Edition [7]

At the opening keynote of Google's I/O conference, they announced that they will ship the device, named "Glass Explorer Edition", in early 2013 for the price of $1,500. [8]

2.4.3 Google Maps Indoor

In the end of 2011 Google started to integrate indoor maps into the Google Maps[3] application for Android. Instead of just showing the outdoor map with few details (see left screen of *Figure 2-9*), detailed floor plans are shown (see right screen of *Figure 2-9*). On the right side of this screen a floor selector is shown, which enables the user to switch between the different floor maps.

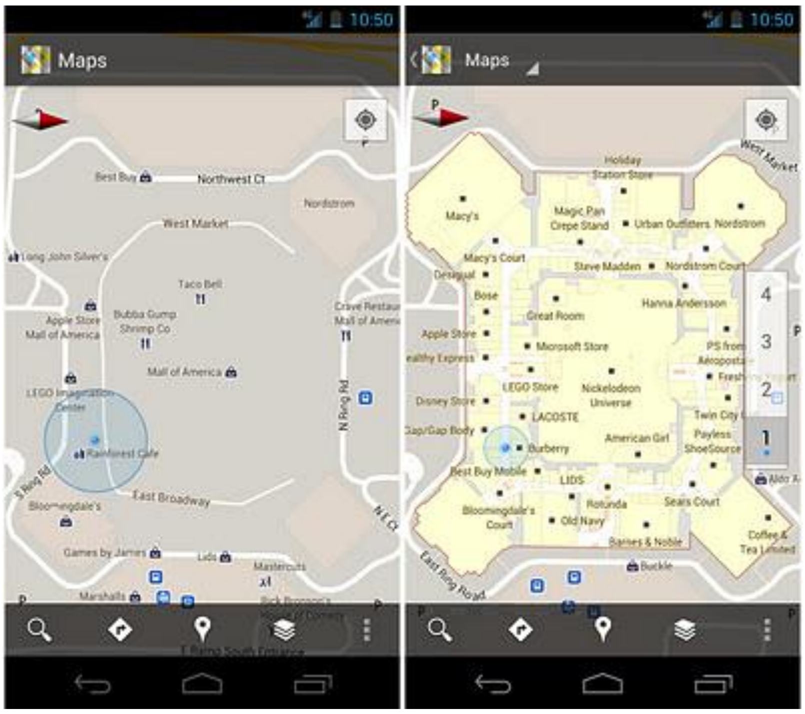


Figure 2-9 - Map of the “Mall of America” in Minneapolis with and without Indoor Maps [9]

By now, indoor maps are available for some of the biggest retailers in the United States (e.g. Mall of America, IKEA, The Home Depot), airports (e.g. Chicago O’Hare, San Francisco International Airport) and transit stations.

Indoor location tracking is also part of the application. Google claims 5 to 10 meters accuracy by using radio frequency fingerprinting technique.

[3] feature is available since version 6.0

3 Interaction Design

This chapter deals with different approaches on how to create an intuitive application for a mobile device to support a person on campus in different situations.

As described in the introduction chapter there are two main goals for this application prototype. The first goal is to provide the user with an on campus navigation system that helps him to get from his current position to a designated building or room. The second feature of this application focuses on presenting different kinds of useful information in an augmented reality view.

Different ideas to achieve these goals are discussed in this chapter. To better demonstrate the concepts and designs, low fidelity prototypes are created. These prototypes act as a model for the graphical user interface (GUI) of the application, which is created in the next chapter.

3.1 Navigation

Pedestrian navigation differs in many ways from the conventional navigation system used in a car. In this chapter main differences between these two systems are worked out and adapted for pedestrian use.

3.1.1 Basic Adjustments for Pedestrian Navigation

A route on campus of the University of Calgary can be very long and thus very confusing for a person who is not familiar with this area. To simplify the route, it has to be broken down into smaller segments that provide an easy overview. Regarding the low travel speed of a pedestrian, the route segments should not be longer than a few hundred meters. With those small segments the user can track his progress better and is more motivated to get to the next waypoint, because it is achievable in a shorter period of time.

There are three main criteria that define important waypoints on a campus route on which it would be useful to divide the route into different segments:

- *Entering or leaving a building*
  If a pedestrian enters a building his complete perception will change. To reflect the user's perception change the view on his mobile device should also change. For example, the map view should change from an outdoor map (only showing ground plans of buildings) to an indoor map (showing the map of the current floor).

- *On height change*
  If the path uses more than one floor it has to be split, because it is not possible to display more than one floor on a 2D map at the same time. Therefore, the route is segmented at every elevator or staircase.

- *Landmarks*
  such as sculptures, big signs

3.1.2 Navigation Views

For different situations while navigating on campus there have to be separate views.

The basic mode, which appears after defining the route, is called **map mode** and displays an overview of the entire route, the different segments and the user's progress on it. A screen is designed with a map that covers the route segment and displays basic information on it.

In case of car navigation, the navigation device is in the driver's field of view all the time. In case of pedestrian navigation it is different. While it is okay to hold the device vertical and look at the display for a short time to explore nearby points of interest, it is not possible to do so while walking. Beside the fact that there is a danger of colliding with other people due to a lack of attention, it would not be very comfortable for users to hold up their device and walk around on campus with it. The **walk mode** has to be designed in a way so that it can be used in a more natural way while walking.

In situations where it is very crowded, or when the user has to cover a large distance he does not want to look at the display of his mobile device all the time. A third mode which notifies the user in a non-visual way has to be created. This mode is named **invisible mode**.

Search View

Defining a route should be as easy as possible. It should only display one input field, where the user can insert free text. The underlying algorithm should be sophisticated enough to analyze different types of destination inputs such as:

- building and room (e.g. "Math Science 680")
- building abbreviation and room (e.g. "MS 680")
- university staff (e.g. "Vaughn Ravenscroft")
- points of interest (e.g. "Tim Hortons")

If the search returns more than one result a list with all results should be shown. Through a single tap on a list item the user can choose his destination.

Map Mode

This view is used for the route overview. It consists of three main components as shown in *Figure 3-1*.

The **map** shows a 2D drawing of the university campus. It displays the current route segment of the active navigation. The user can scroll the map, zoom in and out with multi touch gestures. His current position is marked on the map with a red dot. If the user is inside a building the displayed floor layer changes according to the user's location.

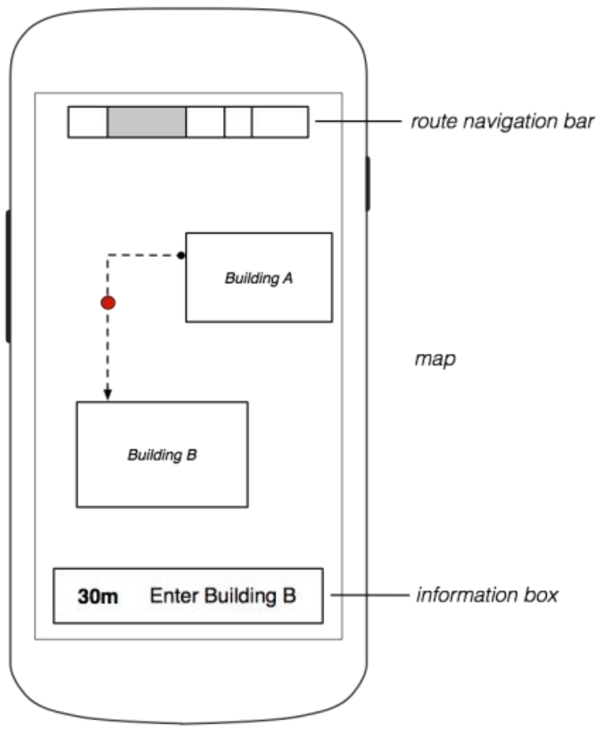


Figure 3-1 - Navigation - Map View

The **information box** gives the user hints to reach the next waypoint. It shows the distance to the next segment as well as the description of the waypoint. Like a car navigation device this description tells the user what to do next. Where a car navigation device would suggest that the user should, for example, "turn right onto University Drive NW" the mobile application tells the user that he should "enter building Math Science" or "take the elevator to the 6th floor".

The **route navigation bar** is an important part of this view. This bar represents the route segments and displays each one of them as a rectangle. The width of the rectangle reflects the length of the corresponding segment relative to the entire route length. The current segment is highlighted. A user can browse through the different segments by tapping on them.

There are a few enhancements which could improve the route navigation bar.

To enrich this bar with more information, the segments could get a background color which represents the type of segment. As it is shown on the left in *Figure 3-2,* the outdoor segment could be displayed with a grass texture whereas the indoor segment is displayed in cement gray. To highlight a segment it would simply get another shade of the segment texture.

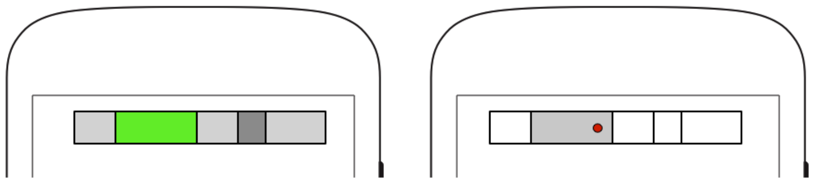


Figure 3-2 - Route Navigation Bar: a) with Textures, b) with accurate Position

Instead of only highlighting the segment in which the user currently is located, a symbol could be displayed at the exact point on the route to show the user his progress more accurately. In *Figure 3-2 (right)* you can see a red dot displaying the current location on the route.

The main difference to navigation systems used in cars is that pedestrian navigation on a campus can be three dimensional due to different building floors. The segments where the elevation gain occurs (elevators and staircases) could be displayed in another way than the flat segments of the route. The next sketches show different approaches to visualize elevation gain on a route.

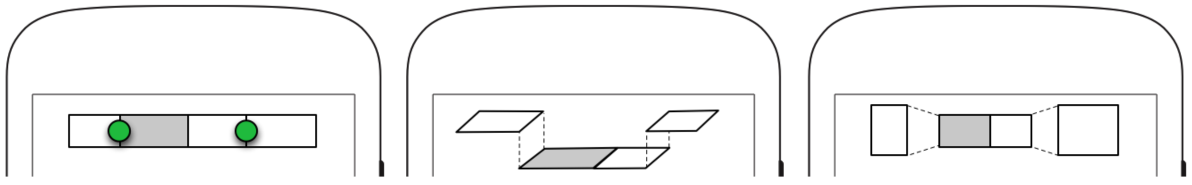


Figure 3-3 - Route Navigation Bar: a) Symbol, b) Cross Section, c) Top View

The first approach shown in *Figure 3-3 a)* suggests that the segment illustrating the elevation gain could be represented as a symbol on top of the route navigation bar. Instead of drawing the elevation gain segment as a normal rectangle this approach indicates in an intuitive way that something special is happening. The next two figures demonstrate other designs of the route navigation bar to illustrate 3D paths in a more intuitive way. *Figure 3-3 b)* shows a cross section of the route, which roughly displays the elevation profile. In *Figure 3-3 c)* the same data is shown in a top view.

Walk Mode

To give the user a more dynamic way of finding his route, views based on augmented reality could be offered to him. In this mode the user would see the camera feed of his smartphone. On top of it additional helpful information for his current routing segment would be displayed. He would see at least one next waypoint and his final target (see *Figure 3-4*).

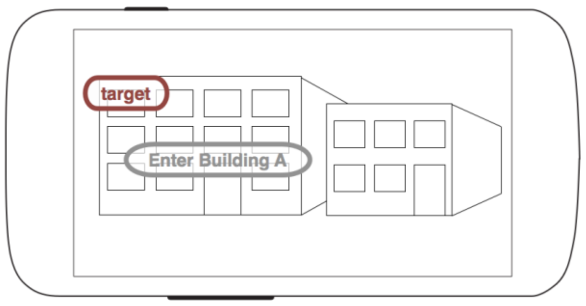


Figure 3-4 - Navigation - AR (Markers)

In addition to this view there could be another perspective, which is activated when pointing the camera of the smartphone to the ground.

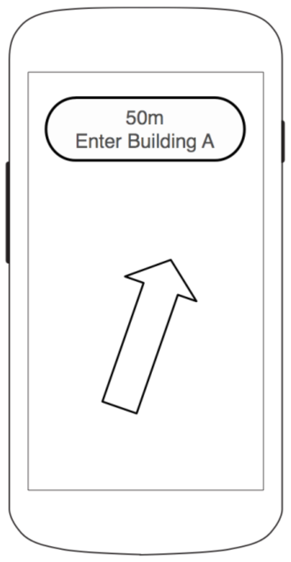


Figure 3-5 - Navigation AR (Arrow)

A compass-based arrow could be shown in this view. According to the device's orientation it always points to the next waypoint. A basic description of the next waypoint, as well as the distance to it, could be illustrated in a small box at the top of the display (see *Figure 3-5*). The user is able to get the most important information to reach the next waypoint with just a quick look.

As a slight modification of this view a map of the user's location could be displayed on top of the augmented reality view. This would combine both advantages of the map mode and the explore mode (see *Figure 3-6*). The downside of this approach is the limited space on a smartphone. To have an adequate area on the screen for the camera feed and the augmented reality layer, there is not much space left for the map view.

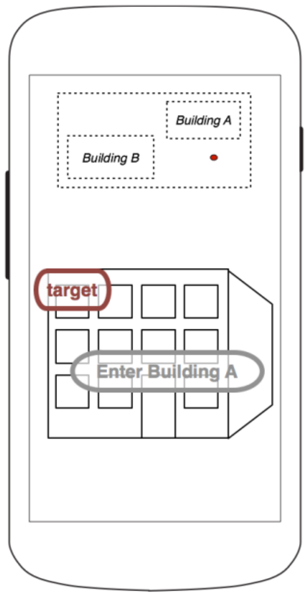


Figure 3-6 - Navigation - Rear Mirror Approach

Invisible Mode

On long walking parts of the route there is no need to look permanently on the device. Especially more experienced users do not need to look at the map and the navigation descriptions all the time. That is why there should be a third navigation mode which is more passive.

This mode – the invisible mode – is activated when the user turns off his display. He can put his mobile device in his pocket and still gets notifications. There are two types of notifications in this mode.

The first one uses the vibration motor in the smartphone. Whenever the user's location drifts too far away from the active route, the phone vibrates to attract the user's attention. The same happens if the user reaches a waypoint so that the application can give him new instructions. If the mobile device does not support vibration a short acoustic signal could be sent out.

Voice controls are the other type of notification. The user gets the navigation hints, normally displayed in the information box on the map view and via notes in the augmented reality view, through text-to-speech messages. These messages are only available when ear phones are plugged in, so that it does not disturb other people.

3.2 Explore

The Explore mode of the mobile App should help the user to obtain information of his close environment. Therefore, the augmented reality technique is used. As introduced in chapter 2.3, augmented reality adds additional location-based information to the camera feed of a mobile device.

3.2.1 Information Types in Augmented Reality View

There are different types of information which could be useful for a user to know about.

A big help for a user who walks on outdoor paths of the campus would be to show him which buildings are close to him. This would be the basic information everybody on campus needs to improve his orientation.

Inside of buildings this layer is not useful at all. It should be swapped for more detailed information about the specific building. The offices, lecture halls and nearby points of interest (e.g. stores, cafes or shops at the food court) could be displayed as well as details to these entities like:

- details of the person in a room like name, contact details (telephone number, email address) or a link to his page on the University of Calgary webpage
- next classes in lecture halls
- information provided by authorized university staff like the research field of a lab, the responsibilities of specific people in an office
- opening hours of shops
- special deals at the food court

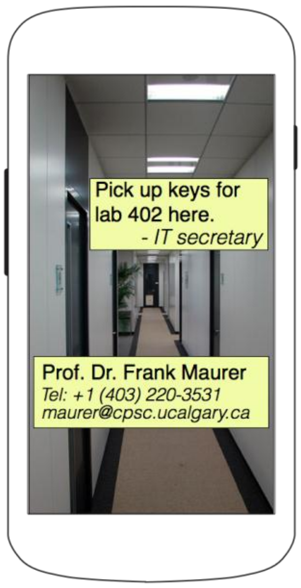


Figure 3-7 - Explore - Indoor Markers

Besides these static kinds of information (see *Figure 3-7*) several dynamic notes could be added to this mode. The application should offer users the ability to create location-based content. Each user should be able to add notes on walls of buildings or rooms like drawing graffiti on walls, but in a virtual way without the vandalistic aspect. Students could add comments to stores in the food court or upload geo-referenced pictures.

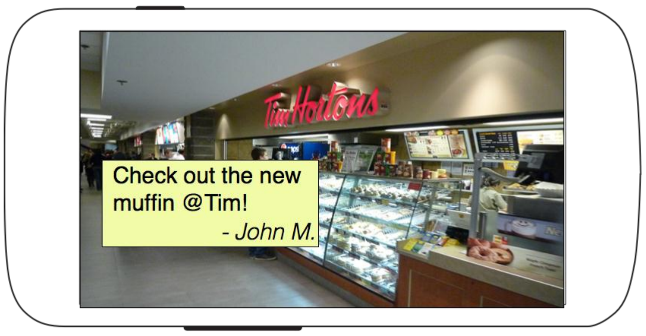


Figure 3-8 - Explore - Social Markers

In addition to these user-created notes, the current position of the user's friends on campus could be added to the augmented reality layer. Each user who wants to use this feature would submit his own coordinates in regular intervals to a central database. In return he would see the last known position of his friends on the map.

3.2.2 Displaying Information

Without limiting the displayed information in this view, the user would be overwhelmed and not be able to distinguish between essential and additional information.

To reduce the amount of notes in this view the user should be able to browse and limit those different kinds of data in an easy way.

Information Filtering

The different types of information suggested in chapter 3.2.1 could be arranged in layers. In a separate settings menu each layer could be turned on and off to reduce the overall amount of data displayed in the augmented reality view.

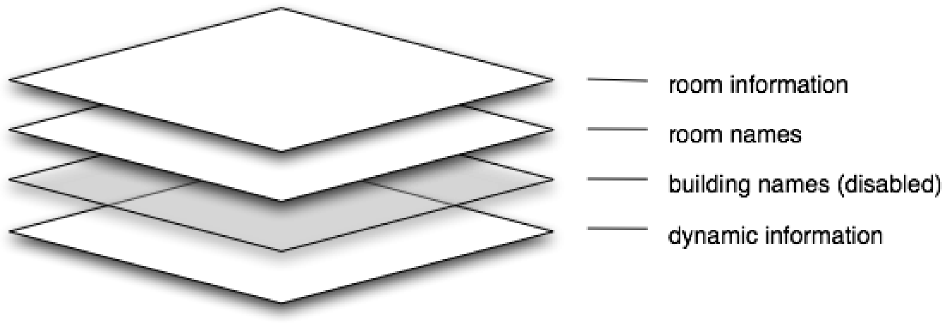


Figure 3-9 - Explore - Information Layers

In addition to disabling entire layers the radius of displayed notes could be used to limit data on the view. A user could set the desired radius of displayed information and thus hide data which is farther away and most likely not as important.

Intelligent Selecting

Even though the user has the ability to filter and reduce the displayed data, the amount of notes in the augmented reality can be confusing. An intelligent way has to be designed to display details to each augmented reality entity.

In case of five or more augmented reality notes on screen it is not possible to display a text box with details to each one of them.

To reduce the amount of notes on the screen, only details to the center note could be shown. The marker for the entity would be highlighted and a textbox is shown in the bottom center of the screen with details to it.

To get information on other augmented reality entities the user has to pan his mobile device to get those into the center of the screen. The text box changes its content accordingly to the selected marker (see difference from *Figure 3-10* to *Figure 3-11*).

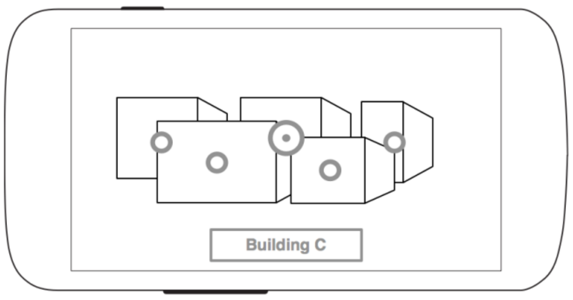


Figure 3-10 - Explore - Highlighted Center Marker

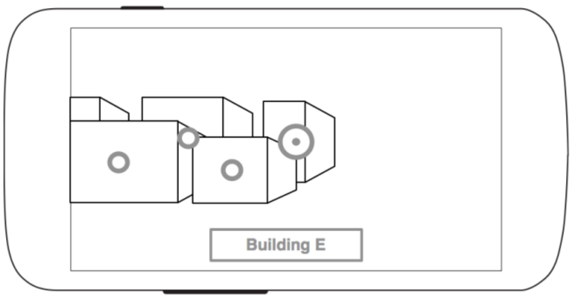


Figure 3-11- Explore - Highlighted Center Marker (moved)

Occlusion

Another method to separate more important augmented reality notes from less important ones, is to occlude the ones that are farther away from the user's current location. Buildings in the back get occluded behind buildings in the front, the shapes displaying the augmented reality information are illustrated in the same way. Given the fact that the more distant buildings are most likely less important than the closer ones, it is not a severe loss of information if a shape gets fully hidden by a closer one.

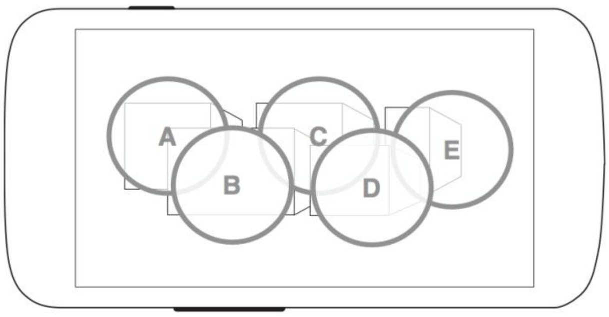


Figure 3-12 - Explore - Occluded Markers

The shapes should be transparent so that the camera feed underneath is not completely covered (see *Figure 3-12*).

4 Software Design and Concept

In the software design chapter different decisions regarding used techniques and the software structure are made. The available data sources are analyzed. It is evaluated whether they offer the information that is needed and how they can be integrated into the application environment.

Furthermore, the challenge of determining a usable indoor position will be discussed. With the received signal strength of the wireless network and the help of the FSPL[4] equation the distance to a Wi-Fi access point is estimated. This information is then converted to an approximation of the indoor coordinate with the method of trilateration. Aberrations and measurement errors are identified and tried to reduce. In the end the result of this technique is compared to the location information based on GPS and cell tower triangulation provided natively by the Android operating system.

4.1 Indoor Location Tracking

For an application which is mainly used inside of buildings, indoor location tracking is very important. Section 2.2.1 describes why GPS is not able to provide an accurate position indoors. Therefore, Wi-Fi location tracking is used in this project.

For Wi-Fi based indoor location tracking there are different methods, as described in section 2.2.2. In this thesis the device location will be estimated on the basis of nearby wireless networks and their received signal strength. The distance from the Wi-Fi receiver to at least three transmitters has to be determined. With these distances and the geographical position of the access points, the location of the smartphone can be estimated with a trilateration algorithm.

A complicating factor of this method is that the known coordinates of the Wi-Fi access points and the computed distance from the smartphone to them includes measurement errors.

This procedure and an approach to handle those measurement errors are described in the next subchapters.

[4] Free Space Path Loss (see chapter 4.1.2)

4.1.1 Collecting Wi-Fi Information

The first step to determine the geographical position of the mobile device is to gather the relevant Wi-Fi information. The smartphone scans the Wi-Fi environment for all accessible wireless network signals. For the RSSI approach the BSSID, the received signal strength and the frequency of the signal is needed (example data is shown in *Table 4-1*).

ID	BSSID	RSSI in dBm	frequency in MHz
AP1	00:0b:86:d6:ab:a0	-63	2437
AP2	00:0b:86:d6:ab:d0	-72	5220
AP3	00:0b:86:dc:de:40	-91	2437

Table 4-1 - Raw Wi-Fi Data

For trilateration of the smartphone position this data has to be enriched with geospatial data. The absolute position of the Wi-Fi access point has to be added to each dataset. In addition to that, the outgoing power level is needed to determine the absolute signal loss, which is used for estimating the distance to the transmitter (see *Table 4-2*).

ID	BSSID	outgoing signal strength in dBm	longitude	latitude	altitude
AP1	00:0b:86:d6:ab:a0	15	-114.1303676	51.08024832	12
AP2	00:0b:86:d6:ab:d0	40	-114.1301293	51.08028129	16
AP3	00:0b:86:dc:de:40	15	-114.130464	51.08041162	16

Table 4-2 - Wi-Fi Data from Database

To achieve this, the BSSIDs of *Table 4-1* are joined with the database containing the Wi-Fi access point data.

4.1.2 Free Space Path Loss

Before the trilateration algorithm can be used, the distances to three access points is needed. One method to determine this distance is to use the relation between signal loss and distance to the transmitter as shown in equation (1). [10]

$$P_r = P_t + 20 \log\left(\frac{\lambda}{4\pi}\right) + 10n \log\left(\frac{1}{d}\right) \tag{1}$$

where:

- P_r is the power level of the receiver (in dBm)
- P_t is the power level of the transmitter (in dBm)
- $\boldsymbol{\lambda}$ is the wavelength
- n is the pass loss exponent (n=2 in free space)
- d is the distance between receiver and transmitter

Given the fact that the signal frequency differs for multiple access points the wavelength has to be calculated for each one with formula (2).

$$\lambda = \frac{\mathrm{c}}{\mathrm{f}} \tag{2}$$

The wavelength λ is the result of the velocity of propagation of the wave (in case of electromagnetic waves: the speed of light *c*[5]) divided by the frequency of the signal f.

With equation (1) and the three datasets out of table *Table 4-2*, we get the following distances as a result:

d_1	77.76m
d_2	1819.50m
d_3	1953.29m

Table 4-3 - Results for Distances with FSPL Equation using n=2

Since the value 2 for the pass loss exponent *n* is the value for free space it is not surprising that the results are much too high. A more accurate value for *n* has to be approximated.

[5] c = 299,792,458 m/s

The real distance from the receiver to the access points is measured with a floor plan (see *Table 4-3*).

d_1	10m
d_2	18.5m
d_3	9.5m

Table 4-4 - Measured Distances to Access Points Based on Floor Plan

This experiment is repeated for different locations. For each location the value of *n* is approximated. In the end the average indoor value for the ICT building of the University of Calgary was determined to be $n = 5.3$.

With this value the distances of *Table 4-1* are corrected to be:

d_1	5.09m
d_2	16.54m
d_3	16.99m

Table 4-5 - Results for Distances with FSPL Equation using n=5.3

The values for the computed distances still differ from the correct ones, but due to measurement errors based on the nature of electromagnetic wave propagation inside of buildings, these results cannot be completely accurate.

4.1.3 Trilateration

The distance calculated with equation (1) in section 4.1.2 can be used to draw circles around the known position of the access points.

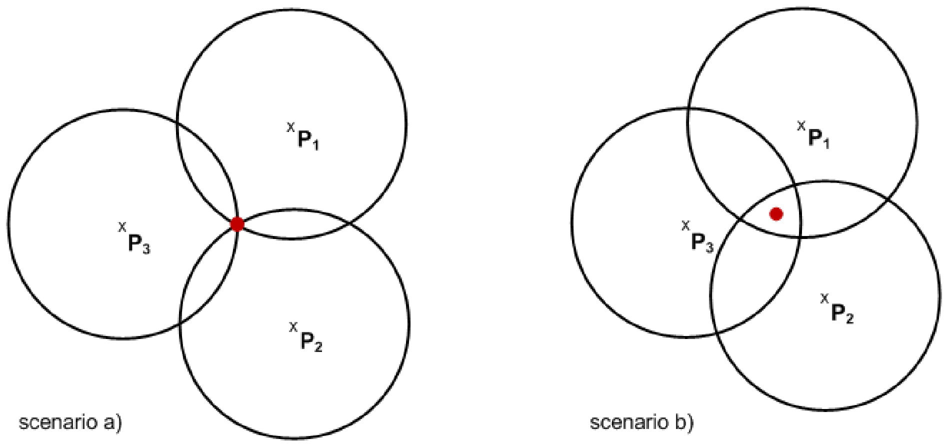


Figure 4-1 - Trilateration: a) Perfect Signals, b) Imperfect Signals

With perfect information the three circles overlap in one single point as shown in *Figure 4-1 a)*. Due to measurement errors the circles will not intersect in a single point.

For this situation an algorithm is needed that determines the position which minimizes the distance to all circles. With the computed distances out of *Table 4-5* and the position of the access points out of *Table 4-2* the x- and y-coordinate can be computed. ([11], page 97ff)

The z-coordinate of the estimated position is the median of the altitude values. In this example the three altitude values are 12, 16, and 16, which implies that the z-coordinate is 16.

4.1.4 Evaluation of the Results

Wireless network signals are very variable, especially indoors where they are reflected on obstacles and weakened through walls. The received Wi-Fi signal strength differs from scan to scan even though the position of the receiving device stays the same. Small variations in the RSSI value result in distance discrepancies of several meters.

Another error source is the absolute position of the Wi-Fi access points which is part of the basic computing data. As described in section 4.2.3 the position in the database is anything but exact. It depends on the center of the room which is closest to this device, which can differ from the correct position by less than one meter in the best, up to 20 meters in the worst case.

Given these two facts it is not surprising that the result is not completely accurate. A couple of tests in different locations resulted in an accuracy of 10 to 20 meters. The average GPS accuracy that can be achieved with consumer GPS receiver is 5 to 10 meters.

The big advantage of this technique over the location provided by GPS is that the z-coordinate is much more accurate. Especially indoors where the z-coordinate represents the floor on which the user is located, this information is very important to display the correct floor plan. With the correct floor plan and a position with an accuracy in the range 10 to 20 meters the user should be able to orientate himself.

4.2 Data Sources

Every data source which is used in this project is listed in this section. The level of information and the method how it can be accessed is described.

4.2.1 University of Calgary LDAP directory

The Information Technologies department of the University of Calgary is running a general purpose LDAP service. Data in this directory is obtained from a variety of different data sources as shown in *Figure 4-2*.

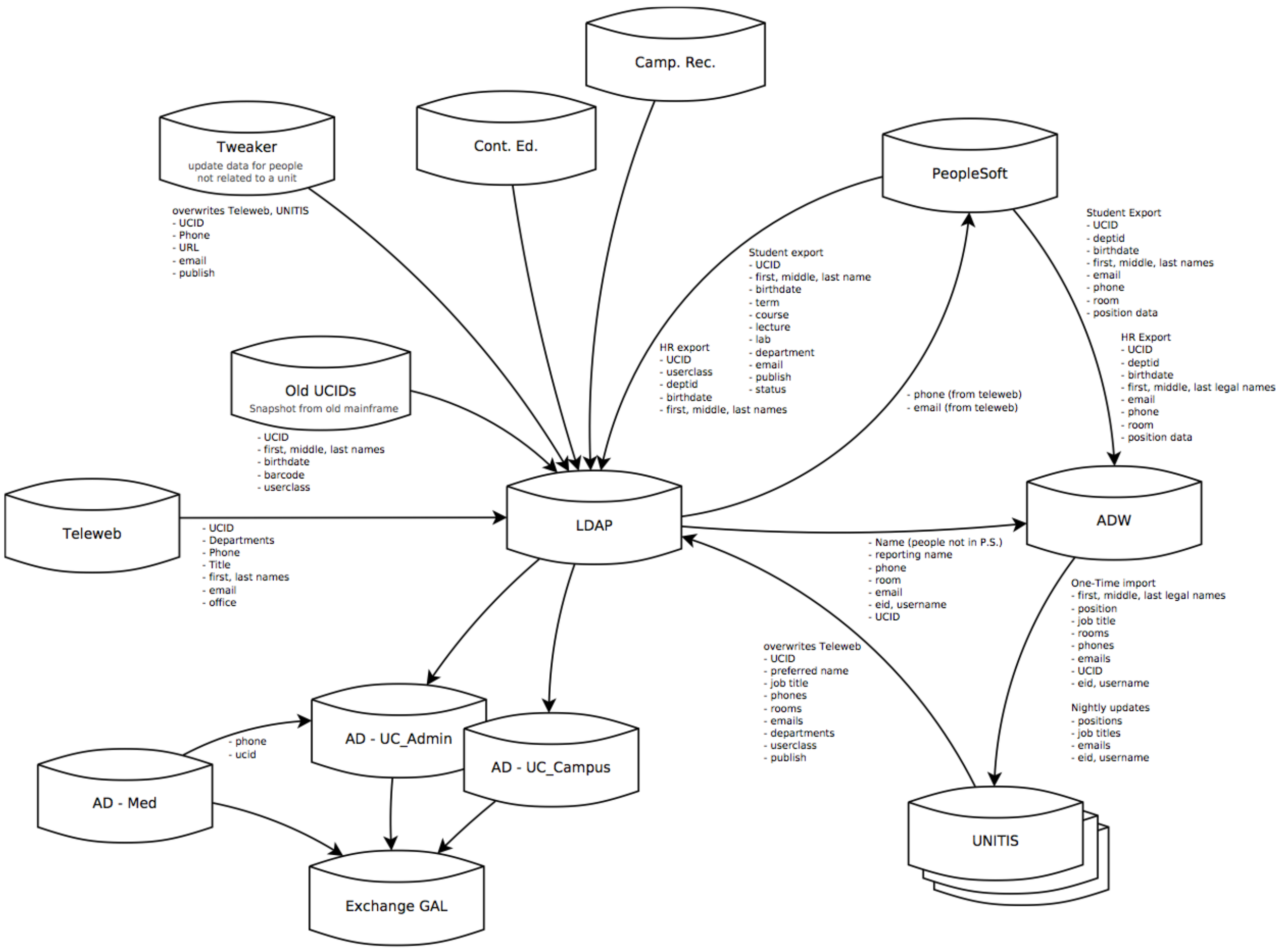


Figure 4-2 - Data Flow Diagram v0.3 by Marc Wrubelewski

The service consists of two distinct LDAP directories.

The “master” directory contains 3 main trees:

- "people", containing one entry per issued UCID[6] (about 600,000 entries)
- "uidauthent", containing one entry per valid IT user account (about 35,000 entries)
- "eid", containing one entry per valid myUofC Portal[7] ID

[10]

This directory is password protected and is not open to the public. The other directory - the “public” directory – can be accessed by anyone. It contains a subset of the “master” directory and has a limit of 100 result sets per search. This LDAP directory contains the following information of staff and students marked as world publishable[8]:

- sn (surname)
- givenname (preferred given name)
- cn (common name, i.e. givenname + sn)
- telephoneNumber
- facsimileTelephoneNumber
- roomNumber
- department (department or faculty name according to TeleWeb or SIS)
- labeledURI (URL of homepage)
- mail (preferred e-mail address)
- userclass (staff, student)

Since these data elements include everything that is needed for the application and 100 results per search is enough, it is not required to access the “master” directory.

LDAP is a widely supported protocol and APIs for almost every programming language are available. In the case of this project the directory will be accessed through the JNDI[9].

[6] University of Calgary Identification number
[7] central web service of the University of Calgary to provide information and manage personal data
[8] based on internal guide-lines
[9] Java Naming and Directory Interface

The long term goal of the IT department is to rearrange the entire database architecture so that everything can be accessed via the data warehouse ADW. The application should be able to exchange the current LDAP data source for this new data source easily.

4.2.2 Esri ArcGIS Server

As described in section 2.1.2 the Esri ArcGIS server handles everything that has to do with maps and geospatial data. Furthermore, it is the source of the paths on campus and used for routing. The GIS server hosted by the IT department of the University of Calgary offers a couple of different services.

The main service that is used in this project is the map server. It provides any client that can access this data with different maps. Besides a building map (see *Figure 4-3*) where only the ground plan of each building is available, there are also maps for each floor of on-campus buildings (see *Figure 4-4*). On these maps each room with its doors and its basic equipment, the elevators, the staircases and the hallways can be seen. As a third map there is an aerial image (see *Figure 4-5*) which can be used to provide the user with a more detailed view of the campus.

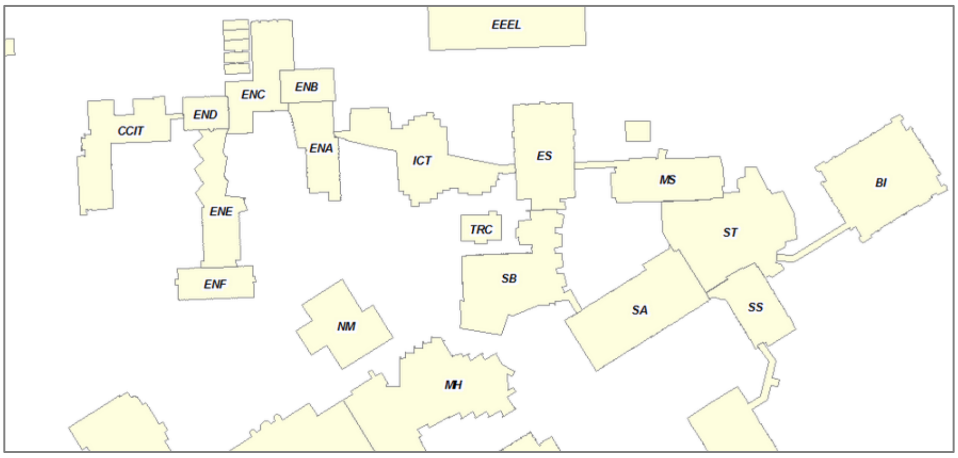


Figure 4-3 - Building Map

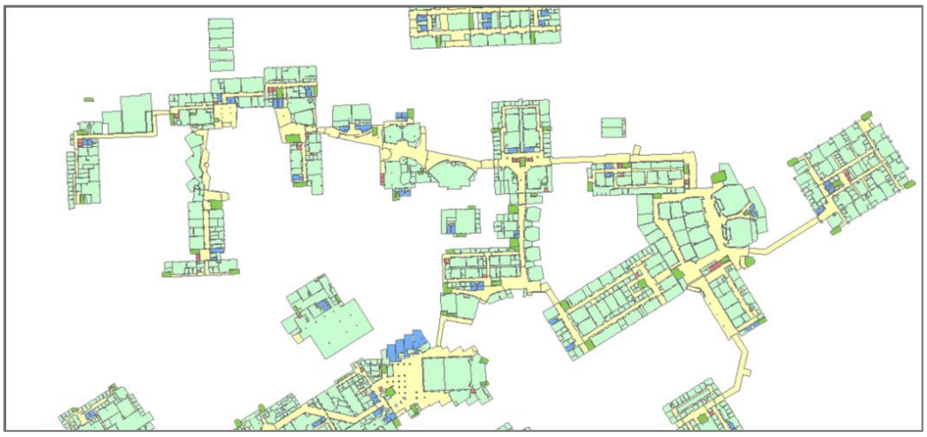


Figure 4-4 - Floor Map

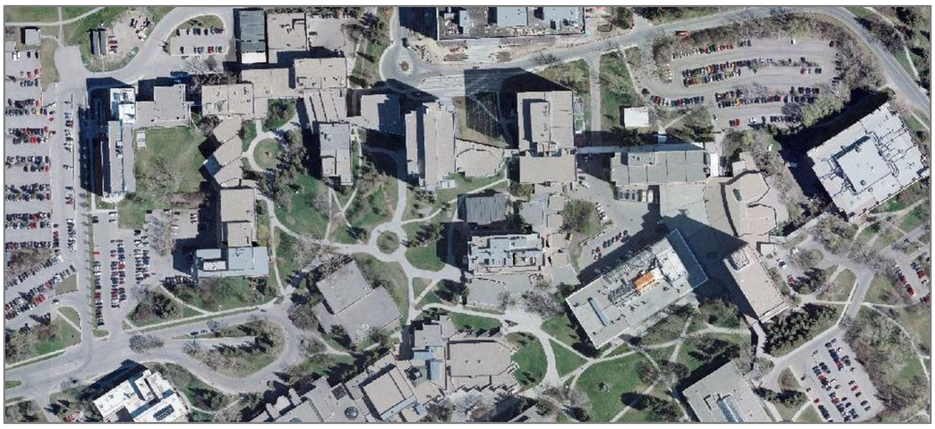


Figure 4-5 - Aerial Image

The other important part handled by the ArcGIS server is the path finding. For that purpose, there is the ArcGIS Network Analyst module. It is used for modeling real world networks and is able to compute the shortest route from one location to another one.

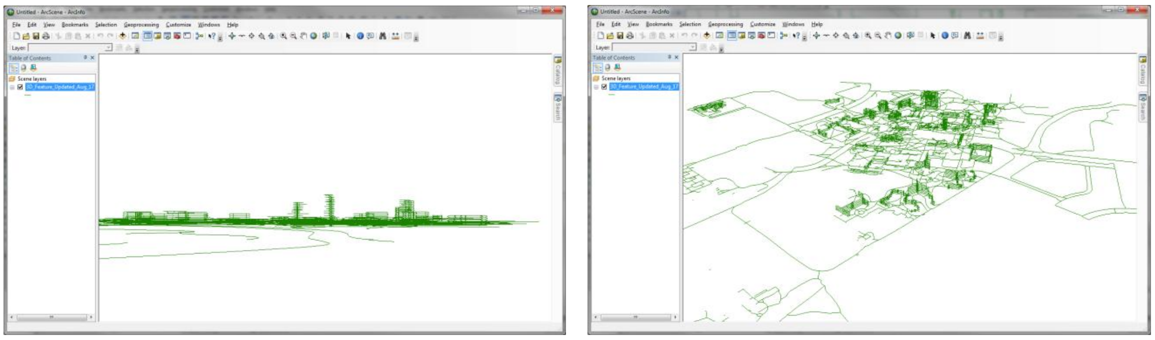


Figure 4-6 - Screenshots of 3D Network Dataset

The server can be accessed through many different interfaces. There are native and web APIs which can be used on almost every mobile device:

- ArcGIS for iOS
- ArcGIS for Android
- ArcGIS for Windows Phone
- ArcGIS for Silverlight/WPF
- ArcGIS for Flex
- ArcGIS for JavaScript

[11]

Furthermore, there are REST and SOAP web services provided by the server which can be integrated in every application system independently. The Roomfinder server will mainly focus on these web service interfaces. For querying geospatial data stored on the ArcGIS server the REST interface is used. It is very easy to handle and the queries via the REST URL can be tested directly in a browser.

For computing the shortest path between two locations, there is currently only one way which returns 3D coordinates as a result. Neither the native Android API nor the JavaScript API service returns a z-coordinate, which is required for displaying the route on the correct floor layer. The REST web service is also unable to process 3D routing information. Only the SOAP web provides x-, y- and z-coordinates in the resulting route.

4.2.3 Airuba AirWave Wireless Management Suite

Everything that has to do with the wireless network infrastructure is managed in the Airuba AirWave Wireless Management Suite. Each Wi-Fi access point on campus with its specific data is stored in this system.

An excerpt of the data stored in this system:

- name of the access point (e.g. ICT_524[10])
- SSID[11]
- BSSID[12]
- outgoing signal strength
- channel
- frequency
- history of connected clients
- (x- and y-coordinate)

As shown in chapter for trilateration purposes the following information of the wireless network infrastructure is needed:

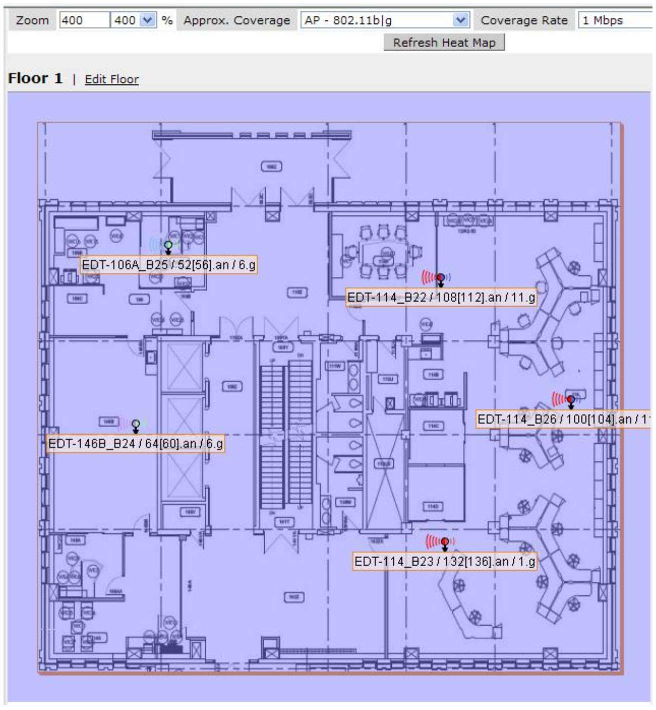
- frequency of the signal to determine wavelength
- outgoing signal level of the Wi-Fi transmitter to determine the FSPL value
- mac address of the access point to join the received signal information on the mobile device with the datasets out of this system
- absolute position of Wi-Fi access points

The first three bullet points are exactly in the AirWave Management Platform. The problem is the absolute position of the access point. The x- and y- coordinate stored in this system represents the pixel position of an access point on a floor plan. This floor plan is stored as a small image[13] which does not even have to be in a correct scale. Each access point is placed on this picture manually by a

[10] references the building and the room number in which the access point is installed
[11] Service set identifier, it names and identifies a wireless network
[12] Basic service set identification, the mac address of the Wi-Fi access point
[13] width and height are maximum 200px

person of the information technology department based on the information they got from the person who installed the device.

An example of such a floor plan is shown in *Figure 4-7*. The red and green symbols in this picture represent the access points. The text box under them displays the name, the power levels, the channel and the Wi-Fi standard.


Zoom 400 400 % Approx. Coverage AP - 802.11b|g Coverage Rate 1 Mbps

Floor 1 | Edit Floor

Refresh Heat Map
EDT-106A_B25 / 52[56].an / 6.g
EDT-114_B22 / 108[112].an / 11.g
EDT-114_B26 / 100[104].an / 1
EDT-146B_B24 / 64[60].an / 6.g
EDT-114_B23 / 132[136].an / 1.g

Figure 4-7 - Screenshot of a Floor Plan in the AirWave Management Platform

The picture has no reference points so that the x- and y-coordinates of the access points cannot be translated to an absolute geographical location. That is why the only geospatial information that can be used in this system is the name of the access points which refers to the building and the room in which it is installed.

The next problem with this system is that there is no way to access this database directly. Currently there is no web service interface and direct database connection is not possible due to security restrictions. The most up-to-date data that is accessible is a CSV[14] export on a daily basis (see *Appendix: Example CSV Data for Wi-Fi Access Points*).

The problem that emerges out of the daily export is that there is no access to the live power levels of the access points. The outgoing power level of them is not constant at all. It changes according to the amount of the connected clients and the power levels of the nearby access points. With this out of date

[14] Comma-separated values, a file format

data the FSPL value cannot be determined accurately, which results in an even more inaccurate distance from the signal receiver to the transmitter.

To use this CSV data a program has to be written which reads the data out of the file and inserts it into the Roomfinder database. In addition, each data set has to be enriched with the geographic coordinates of the room (referenced by the access point name), which is the best estimate of the transmitter location.

4.2.4 Roomfinder Database

For organizing data created on the server or client side, a central data storage is needed.

A MySQL 5.5[15] database is set up on an Ubuntu 10.04 LTS[16] system running on a virtual machine at Amazon's Elastic Compute Cloud (EC2)[17]. Everything is set up so that the Roomfinder server (implemented in section 5.1) and only this machine can access this database.

In this database everything that has to do with user data (like last known positions of users), the graffiti-like notes and the connected friends to a user are stored. The wireless access point data described in the last chapter is also part of this data collection.

The Roomfinder server, which has read and write access to this database connects to it via JDBC interface.

[15] open source relational database management system
[16] computer operating system based on the Debian Linux distribution
[17] cloud computing platform, part of the Amazon Web Services (AWS)

4.3 Technical Decisions

One of the main parts of the software design is technical decisions that lead to the system environment for the application prototype. The platform on which this prototype will be implemented as well as the interface to the ArcGIS server has to be evaluated.

4.3.1 Operating System

Currently there is a large variety of operating systems for smartphones. However two systems cover almost 80% of the entire market as shown in *Table 4-6*. On the one hand there is Google's operating system Android. And on the other hand iOS developed and distributed by Apple Inc. Comparing the market share in 1Q11 to the share in 1Q12 verifies that those two operating systems are the most important platforms for smartphones at the moment. The next operating system Symbian constantly lost big shares in the last couple of years and thus will not be a platform that would make sense to create the prototype for. The only other operating system at this moment that has over 5% market share is the BlackBerry OS developed by RIM[18]. Given the fact that the target group of this platform is business users it also does not fit this project.

Operating System	**1Q12**	**1Q12 Market Share (%)**	**1Q11**	**1Q11 Market Share (%)**
	Units		*Units*	
Android	81,067.40	56.1	36,350.10	36.4
iOS	33,120.50	22.9	16,883.20	16.9
Symbian	12,466.90	8.6	27,598.50	27.7
RIM	9,939.30	6.9	13,004.00	13
Bada	3,842.20	2.7	1,862.20	1.9
Microsoft	2,712.50	1.9	2,582.10	2.6
Others	1,242.90	0.9	1,495.00	1.5
Total	**144,391.70**	**100**	**99,775.00**	**100**

Table 4-6 - Worldwide Smartphone Sales to End Users in 1Q12 (Thousands of Units) [12]

To narrow the two choices - Android and iOS - down to one for the application prototype other aspects have to be evaluated.

[18] Research in Motion

Given the fact that there are native ArcGIS APIs for both platforms, this is not an elimination criterion.

The trilateration algorithm described in section 4.1.3 needs the signal strength and the MAC address of nearby wireless network access points.

In the current release of iOS[19] there is no method to access this kind of information. The CoreWLAN framework that is used for retrieving this data on Mac OS X is not available as a public API for iOS. The only wireless network information that is available via a public API is the SSID of the nearby networks. Since the SSID at the campus of the University of Calgary is the same for each access point managed by the IT department no location estimate can result from this information.

Contrary to iOS, it is possible to access more specific wireless network information on Android. The class `WifiManager`, which is available since API Level 1, is able to retrieve information of the nearby Wi-Fi networks. Via the API call `getScanResults()` a list of the entire reachable wireless networks is returned. [13]

Each dataset of this list contains the SSID as well as the BSSID, the frequency in MHz and the received power level in dBm. [14]

Given the fact that it is not possible to access wireless network data on the iOS platform, and for this reason no indoor location can be estimated, Android will be the target platform for the application prototype.

4.3.2 ArcGIS Interface

There are two ways in which an ArcGIS server can be accessed from an Android device.

The first method is the ArcGIS JavaScript API. It is possible to create an HTML page and display maps via this API on it. With JQTouch[20] and dojox.mobile[21] there are different frameworks which provide lightweight widgets optimized for mobile devices. CSS[22] can be used to easily give the mobile application a native look and feel. The resulting JavaScript enriched HTML page can be displayed in the Android application via a `WebView`[23].

[19] iOS 5.1.1 Build 9B208 (May 7, 2012)
[20] JQuery based framework for optimized controls of web pages on mobile devices [21]
[21] CSS3 based framework for optimized controls of web pages on mobile devices [22]
[22] Cascading Style Sheets, a style sheet language used for formatting documents written in a markup language
[23] a view that displays web pages in an Android Activity [30]

The big benefit of this technique is that it is platform independent. It almost needs no effort to include the HTML page with a UIWebview[24] into an iOS application or a WebBrowser[25] control on a Windows Phone device.

The downside of using the JavaScript API is that even though there is a compact build[26] of the API the user experience is limited due to latency issues. Scrolling a map view on a mobile device with this API is slow and it takes quite a long time to render new parts of the map. In addition to the latency issue there is no “pinch”-gesture[27] available to zoom the map, which reduces the user experience further.

The other approach to display ArcGIS server data can be achieved by using the native ArcGIS API for Android. This API includes methods to display maps, query information from the server and offers the ability to modify the view of the map by drawing graphics and shapes on it.

Compared to the JavaScript API the performance is considerably better. It has multi touch support as well as a good caching mechanism. Each native client API provided by Esri is designed to have a similar structure. That decreases the effort to port an application to other mobile platforms at a later date.

After comparing prototypes for both APIs the conclusion is that the far better user experience of the native Android API outweighs the bigger effort to port an application written with the native API to other operating systems.

[24] alternative to WebView on iOS
[25] alternative to WebView on Windows Phone
[26] an API build that is designed for slower internet connections and network latency issues [24]
[27] multi touch gesture for zooming on a touchscreen device (more details see chapter 5.2.2)

4.4 System Architecture

To sum up the technical decisions made in this chapter, the resulting system architecture is shown in *Figure 4-8*. It gives a quick overview of all components of the system environment and shows how they interact with each other. Arrows indicate the communication direction. Labels on the arrows represent the interface between both nodes.

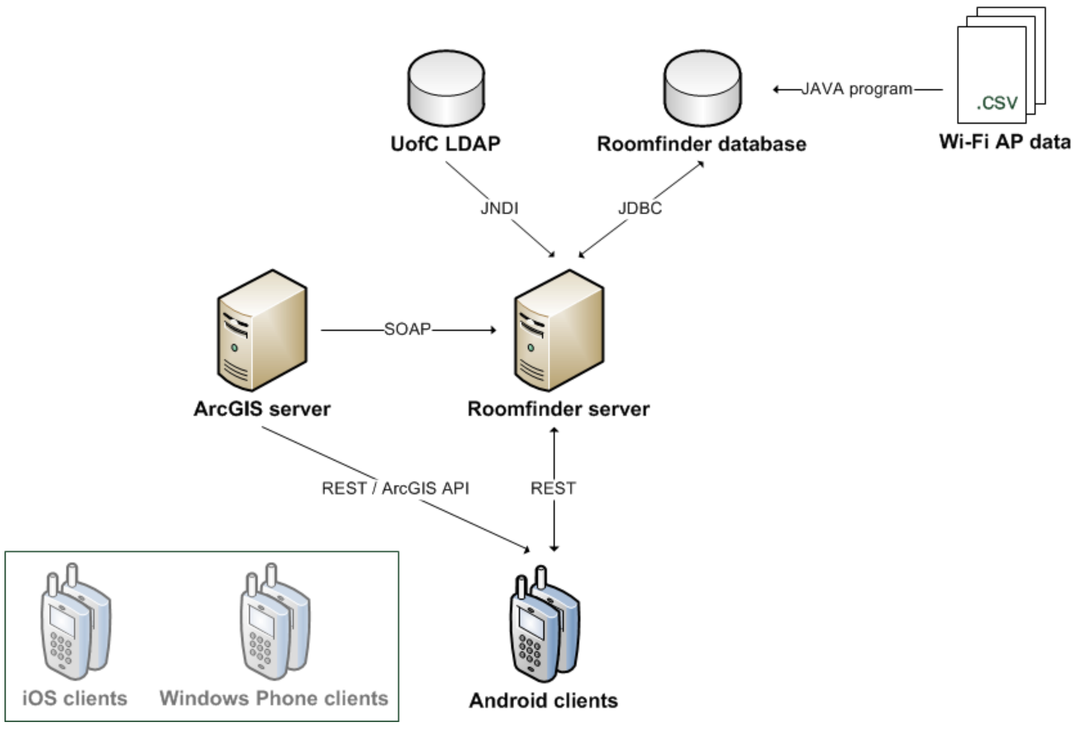


Figure 4-8 - System Architecture

The **LDAP directory** of the University of Calgary is an open directory, which provides any kind of address information regarding university staff (e.g. name, telephone numbers and offices). It is accessed by the Roomfinder server via JNDI.

The **Roomfinder database** is the main data source of the Roomfinder server. It stores data that cannot be accessed through the ArcGIS server like the Augmented Reality annotations or the Wi-Fi access point data. It is accessed by the server via JDBC.

The **Roomfinder server** is the central information source for the clients. It provides different REST interfaces (e.g. search for university staff, get specific augmented reality marker) for the clients. It connects to the ArcGIS server via SOAP web service to get routing data. The server processes this route (segmentation and refining) and provides the result as a REST method to the client. This server also handles the computation of the indoor location based on the Wi-Fi signal strength.

As described in the introduction chapter, the system should be easy portable to other platforms. If the iOS platform at some point offers an interface which provides more detailed information on the nearby wireless networks, it could be considered to port the application to this platform. ArcGIS also offers an API for the Windows Phone platform, so it would be a possible target platform, too.

For making the clients in this system as interchangeable as possible, all computations and business logic should be placed on a central server.

The **ArcGIS server** handles everything that has to do with maps and the underlying geospatial data. It provides the building maps, the floor maps as well as an aerial picture of the campus. Besides map data the server is responsible for the path finding on campus. Therefore, it can access a network dataset which contains every path on campus.

Clients in this system are smartphones. They consume the information of the servers and display it to the end user.

5 Implementation

After design and concept of the application have been developed in the last two chapters, this chapter will show the main steps to realize it. This chapter is divided into two parts. The first part describes the server side implementation, followed by the description of the client side implementation for the Android platform.

Used techniques are described, as well as how they interact with each other. To show results, screenshots of the prototype are shown.

5.1 Server Side Implementation

The Roomfinder server acts as the central part of the system. As mentioned in chapter 4.4, the server connects to different data sources, processes the data and exposes the data through a RESTful web service for the smartphone clients.

The application server is based on the Java platform. It uses an Apache Tomcat server as a servlet container.

5.1.1 Data Sources

In this chapter the basic approach of accessing data sources is described.

Design Pattern - Data Access Objects

Given the fact that several data sources are used in this project a structured way to access them is necessary. As mentioned in section 4.2.1, the contact database (currently the public LDAP directory) is restructured and access to it can change within the next year. For that reason the access to the data sources should be encapsulated so that it can be replaced easily.

To fulfill these requirements the Data Access Objects (DAO) design pattern is used. A DAO provides an abstract interface for creating, updating and getting information for specific objects without exposing details of the underlying data source. For each entity in the system (e.g. buildings, AR marker, users) one DAO is created which handles the communication with its data source. The basic structure of the DAO pattern is shown in *Figure 5-1*.

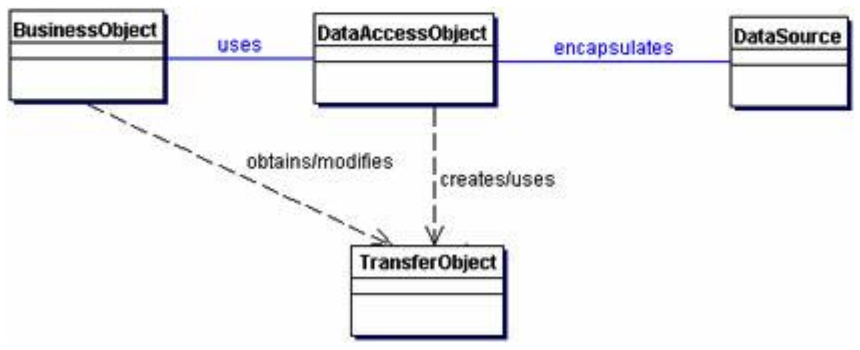


Figure 5-1 - Class Diagram of the DAO pattern [15]

Business objects create DAOs and use them to get information about specific objects. The DAO handles the communication to the data source and stores the queried data in a data transfer object (DTO) which is given back to the business object.

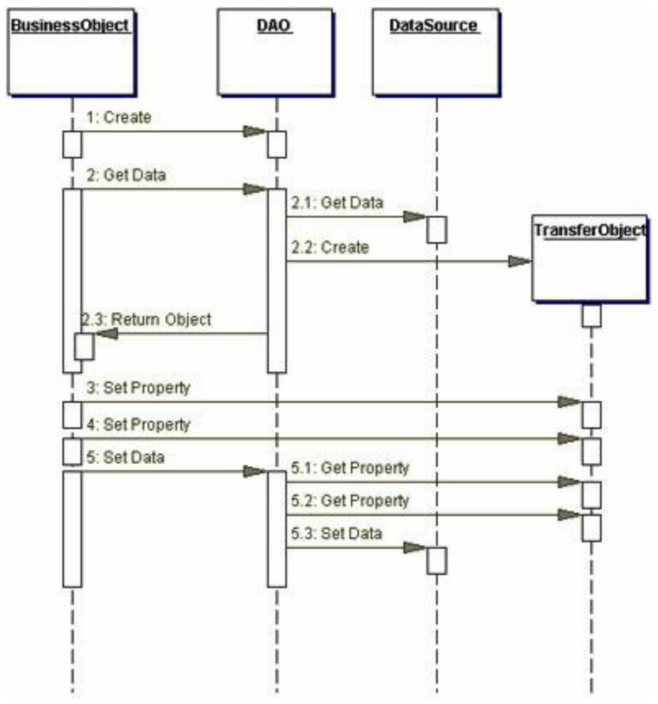


Figure 5-2 - Sequence diagram of DAO pattern [15]

Considering that DAOs encapsulate the data source, the data source can be exchanged very easily by just implementing a new data access object. The DTO stays the same and in the business object only the type of DAO has to be changed.

Roomfinder Database

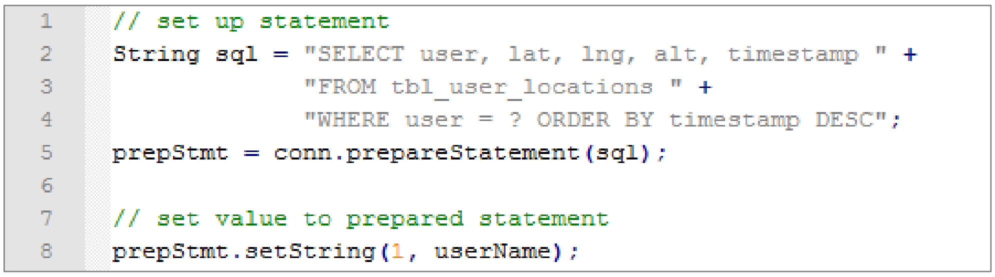
In order to connect to the Roomfinder database the Java Database Connectivity (JDBC) is used. It is the common way to create a connection to a relational database using the Java programming language.

To retrieve a connection to the database the JDBC driver for MySQL has to be loaded. Loading the driver with the method `Class.forName("com.mysql.jdbc.Driver")` instantiates the driver and registers it to the `DriverManager`. From there on a connection can be obtained through the `DriverManager` by calling the method `getConnection(String connectionString)`. The connection string is specific for each database vendor. For MySQL it has the form:

"jdbc:mysql://<DB_URL>:<PORT>/<DB_NAME>?user=<USER>&password=<PASSWORD>"

([18], page 1188f)

`PreparedStatements` are used for querying the database. A `PreparedStatement` is a precompiled SQL statement that has a question mark for each variable (see line 4 in *Figure 5-3*). It is very efficient if executed multiple times. Another benefit of this type of statement is that it is protected against SQL injections.



```
1  // set up statement
2  String sql = "SELECT user, lat, lng, alt, timestamp " +
3               "FROM tbl_user_locations " +
4               "WHERE user = ? ORDER BY timestamp DESC";
5  prepStmt = conn.prepareStatement(sql);
6
7  // set value to prepared statement
8  prepStmt.setString(1, userName);
```

Figure 5-3 - Code - PreparedStatement

DAOs and DTOs are created for each table of the database which represents an object.

CSV Files with Information about the Wi-Fi Infrastructure

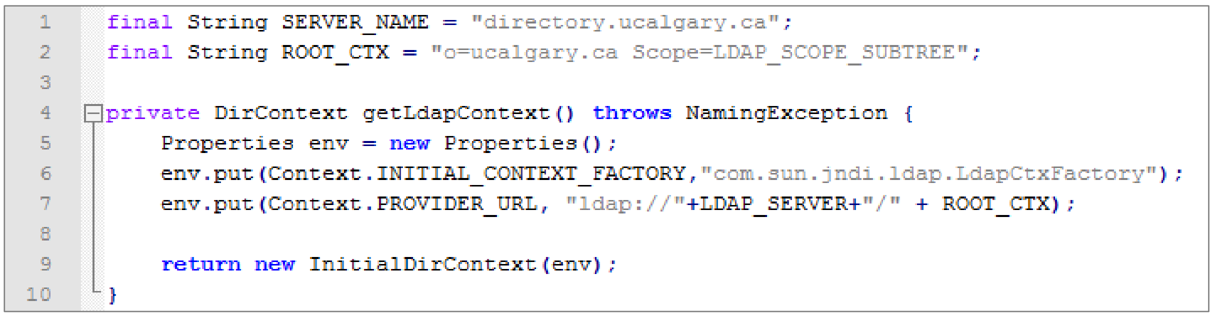
To access the data in the CSV files they have to be transferred into the database. A Java program is developed, which reads the data of the file through a file stream.

First it checks whether the dataset is already in the Roomfinder database. Based on this result, it inserts the new dataset or updates the corresponding dataset which is already in the database. In a second step the location of each Wi-Fi access point is queried from the ArcGIS server and added to the dataset in the database.

LDAP Directory of the University of Calgary

In order to access the LDAP directory of the University of Calgary the Java Naming and Directory Interface (JNDI) is used. It is an API for Java that offers developers to discover directories and look up entries in different directory systems.

The JNDI API uses contexts to specify where to look for entries. The initial context for the public LDAP directory of the University of Calgary is obtained with the following source code:



```java
final String SERVER_NAME = "directory.ucalgary.ca";
final String ROOT_CTX = "o=ucalgary.ca Scope=LDAP_SCOPE_SUBTREE";

private DirContext getLdapContext() throws NamingException {
    Properties env = new Properties();
    env.put(Context.INITIAL_CONTEXT_FACTORY,"com.sun.jndi.ldap.LdapCtxFactory");
    env.put(Context.PROVIDER_URL, "ldap://"+LDAP_SERVER+"/" + ROOT_CTX);

    return new InitialDirContext(env);
}
```

Figure 5-4 - Code - Initial context LDAP

After defining the context, search parameters have to be specified and passed to the method `DirContext.search(Name name, Attributes matchAttribs)`. This method searches on a single context for objects that contain the specified attributes. It returns them as a `NamingEnumeration` which can be iterated and transferred into a DTO. In the end the DTO is forwarded to the business object by the DAO.

Esri ArcGIS Server

There are two different types of information which have to be accessed on the GIS server by the Roomfinder server. Basic room and building information is provided by the map server and path finding information by the network analyst module of the GIS server.

The **REST interface** is used for querying data from the ArcGIS map server. To use this interface a URL has to be constructed. The basic format of a REST URL is *"http://<resource-url>?<parameter1=value1>&<parameter2=value2>"*, where `<resource-url>` is the destination of the queried layer on the map server. The question mark denotes the beginning of the parameter list and `<parameter1=value1>` is a key-value pair to define parameters.

In order to specify the response of the server several search parameters have to be specified. The parameter *outSR* defines the spatial reference system[28] of the result and should match the spatial reference on the clients map.

To limit results returned by the server a *where* parameter can be set. Any legal SQL "where clause" operating on the fields in the layer is allowed. An example "where clause", which queries rooms in the ICT building starting with "5" would be "*where=Building_Room.BLD_ID='ICT' AND Building_Room.RM_ID like '5%'".*

Furthermore, it is possible to apply a spatial filter to define a specific search extent. Only results within this search extent are returned by the server. The format of the response is set with parameter *f*. The formats provided by the ArcGIS server are HTML[29], JSON, KML[30] or AMF[31]. An example of a REST URL and the corresponding JSON result can be found in the appendix.

Since the REST interface in the current release of the ArcGIS server is not able to provide results with three dimensional coordinates, routing has to be done via the **SOAP interface**.

To connect to the SOAP service it is necessary to add the `arcgis_agsws_stubs.jar` of the ArcGIS Web Application Developer Framework (Web ADF) to the Java project. It contains pre-generated SOAP proxies for each module of the ArcGIS server. SOAP proxies handle the communication with the web service over HTTP. The proxy class in case of the network analyst module is named `NAServerBindingStub`. [16]

To initialize this class the URL of the XML file containing the Web Services Description Language (WSDL) has to be specified. The WSDL describes in a hierarchical structure the functionality of the web service and how services can be called on it.

Routing parameters are set to an `NAServerRouteParams` object which is passed to the `solve()` method of the `NAServerBindingStub` instance. It returns an object representing a route. It contains three dimensional points defining the path and basic information of the route like length and estimated time.

[28] a spatial reference system is a specific coordinate system to describe geographical entities
[29] HyperText Markup Language, main markup language for displaying web pages
[30] Keyhole Markup Language, XML notation for expressing geographic features
[31] Action Message Format, a binary format to serialize objects

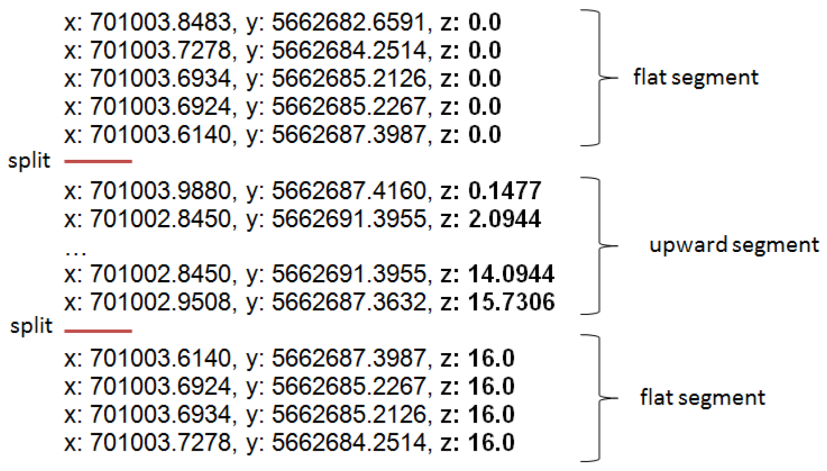
5.1.2 Data Processing

Not every data source can be forwarded directly to the client. Some of the results have to be processed and combined with data from other sources.

Route Enhancement

The route returned by the SOAP web service of the ArcGIS server is a simple path described by three dimensional coordinates. To display this route in a useful way on a smartphone it has to be split in different segments and enhanced with useful information.

The first attribute for splitting the route is elevation gain. Whenever the z-coordinate of consecutive route points starts to change (or stays the same after a segment of changing) the route is segmented.



```
      x: 701003.8483, y: 5662682.6591, z: 0.0
      x: 701003.7278, y: 5662684.2514, z: 0.0
      x: 701003.6934, y: 5662685.2126, z: 0.0      flat segment
      x: 701003.6924, y: 5662685.2267, z: 0.0
      x: 701003.6140, y: 5662687.3987, z: 0.0
split ------
      x: 701003.9880, y: 5662687.4160, z: 0.1477
      x: 701002.8450, y: 5662691.3955, z: 2.0944
      ...                                            upward segment
      x: 701002.8450, y: 5662691.3955, z: 14.0944
      x: 701002.9508, y: 5662687.3632, z: 15.7306
split ------
      x: 701003.6140, y: 5662687.3987, z: 16.0
      x: 701003.6924, y: 5662685.2267, z: 16.0     flat segment
      x: 701003.6934, y: 5662685.2126, z: 16.0
      x: 701003.7278, y: 5662684.2514, z: 16.0
```

Figure 5-5 - Example Result Set for a Route

Figure 5-5 shows a route section which starts on the ground layer (z = 0.0) of a building, followed by an upward segment and a third segment which is on the fifth floor (z = 16.0).

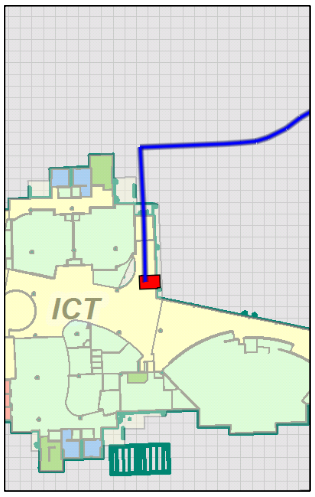


Figure 5-6 - Route Entering a Building

The second attribute for splitting the route is entering or leaving buildings (example shown in *Figure 5-6*). This part is more complex because additional data is needed. The ground plan of each building has to be joined with the path and intersections between both have to be computed.

The outline of on campus buildings can be obtained from the buildings layer of the ArcGIS map server. To reduce computations, only buildings within the extent of the route are queried from the server. Intersections of buildings and the route are determined using the `GeometryEngine` provided by the ArcGIS API. The method `crosses()` takes two geometries as parameters and returns a Boolean value which indicates if both geometries intersect in at least one point.

Given the fact that the underlying network dataset is not entirely correct and the path finding algorithm of the network analyst module does not always produce the best route, further enhancements have to be made.

In some cases the routing algorithm suggests to switch elevators (see *Figure 5-7*) on a floor in between the start floor and the destination floor instead of taking the elevator directly to the destination floor. For this case an algorithm that observes the elevator usage is created. If the suggested route uses more than one elevator within a certain distance the different routing segments are merged to one segment so that the user does not get confused.

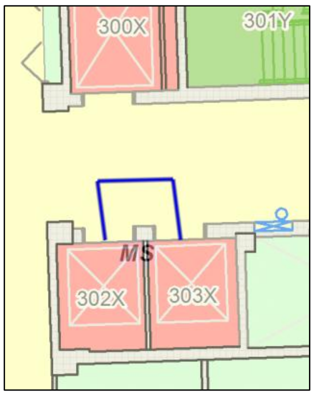


Figure 5-7 - Route changing Elevator on third Floor

Room and Building Search

As mentioned in section 3.1.2, the search for places on campus should be as easy as possible. The result should contain information regarding university staff stored in the LDAP directory of the University of Calgary as well as geographical data of their offices.

Lecture halls as well as other rooms without reference in the LDAP directory should also be returned by the search.

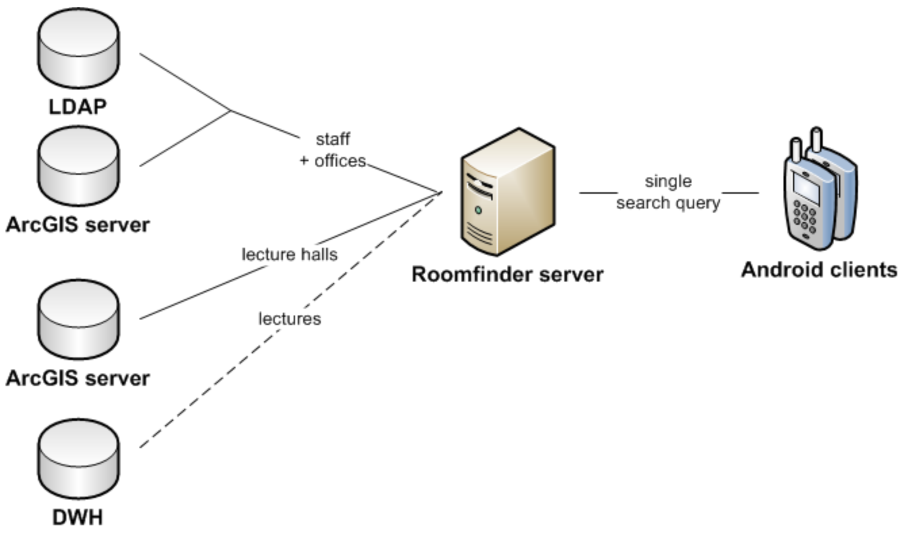


Figure 5-8 - Information flow of a search query

If the data warehouse of the University of Calgary offers public access to its data, lecture data (e.g. name of the lecture, start time) could also be integrated into the search result.

5.1.3 Web Services

To communicate with clients the server exposes different REST web services. These interfaces can be used by the client to either send or retrieve data. JSON is used for the data interchange between server and client.

JavaScript Object Notation

As an exchange format to communicate between server and client JSON is used. It is a structured way to store data in a text based format. The media type of JSON is *application/json* and is the only return type the Roomfinder server produces.

To transform Java objects into a JSON format and vice-versa the GSON[32] library developed by Google is used. It offers serialization and deserialization of basic JSON and Java objects. It can be extended with custom classes for handling the serialization (or deserialization) of more complex objects used in the project. This is achieved by implementing the `JsonSerializer` (or the `JsonDeserializer`) interface.

Given that the embedded augmented reality framework Mixare (see section 5.2.3) needs a specific JSON format, the option for custom serialization is very helpful.

REST Interfaces

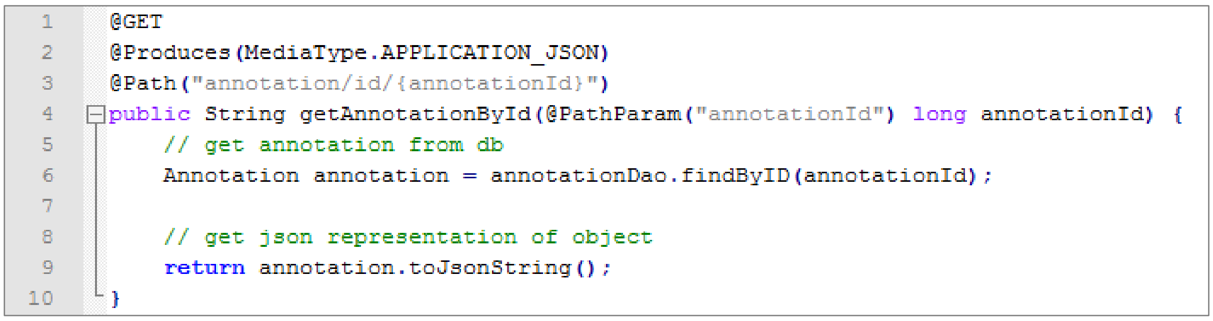
JAX-RS[33] is an API for creating RESTful web services. To simplify development of web services the API uses annotations like:

- `@Path`: relative path for a resource
- `@GET, @PUT, @POST, @DELETE, @HEAD`: request type
- `@Produces`: response media type

With annotations such as `@PathParam` or `@QueryParam`, POST and GET parameter can be passed to a Java method. Based on these parameters and the resource path the server gathers the requested information from one or more data sources and returns the result in JSON back to the client.

[32] GSON V2.2.1 [20]
[33] Java SE API, introduced in Java SE 5

To implement functionality for these REST web services a method is created and described with the mentioned annotations. For example, the source code for the REST service that returns a single annotation by its ID is shown in *Figure 5-9*.



```
@GET
@Produces(MediaType.APPLICATION_JSON)
@Path("annotation/id/{annotationId}")
public String getAnnotationById(@PathParam("annotationId") long annotationId) {
    // get annotation from db
    Annotation annotation = annotationDao.findByID(annotationId);

    // get json representation of object
    return annotation.toJsonString();
}
```

Figure 5-9 - Code - Example of REST Service

The request type of the interface is set with the `@GET` annotation. After that the definition of the returned media type is set to JSON, followed by the resource path for this web service. With `@PathParam("annotationId")` the URL parameter is set to a Java method parameter. Inside this method, the annotation DAO handles the retrieval of the requested object, which is then transformed into JSON format and returned to the client.

A list of exposed REST interfaces:

- */contacts/<search_string>*
  returns contacts considering search parameters in the search string
- */route/<routing_parameter>*
  returns a route describing the path to the specified destination
- */location/<wireless_network_information>*
  returns an estimated indoor position based on Wi-Fi data
- */annotation/id/<ID_of_annotation>*
  returns a single annotation
- */annotation/cat/<category_of_annotation>*
  returns multiple annotations of specific categories (e.g. building annotations, room annotations, position of friends)
- */annotation/navigation*
  returns annotations used for the augmented reality navigation mode

5.2 Client Side Implementation

The fundamental steps of creating the client application are described in this chapter. As mentioned in section 4.3.1 the prototype is based on the Android platform.

5.2.1 Location Handling

In case of this application where both main features are location based, the handling of these locations plays a big role.

Outdoor Location Tracking

The Android API has three location providers which are directly built-in.

To use them, the application has to take reference of the `LocationManager` class by calling `getSystemService(Context.LOCATION_SERVICE)`. This location manager is used for requesting location updates from the following three providers:

- `GPS_PROVIDER`
  This location provider determines the location using satellites. It needs a line of sight to the satellites and thus only works outdoors. Depending on the amount of satellites in the field of vision of the device, the accuracy differs. For the first location fix it can take up to 60 seconds.

- `NETWORK_PROVIDER`
  The network location provider is based on cell towers and Wi-Fi access points. It is less accurate than the GPS provider (100-500m).

- `PASSIVE_PROVIDER`
  The passive provider is a special location provider. It returns stored values generated by the other location providers.

For the outdoor location tracking in this project the GPS location provider is used. It is more accurate than the provider based on cell towers.

To receive certain callbacks from this location provider, it is necessary to create a location handler by implementing the `LocationHandler` interface and registering it by calling the `requestLocationUpdates()` method on the location manager.

The permission `ACCESS_FINE_LOCATION` has to be added to the AndroidManifest.xml[34] in order to receive callbacks from the GPS location provider.

Indoor Location Tracking

To determine indoor positions a custom location provider has to be implemented.

As mentioned in section 4.1 the sources of an indoor location estimate are the received wireless network signals (RSSI approach). By referencing the `WifiManager` object using the `getSystemService()` call, similar to `LocationManager` described in the last chapter, the application gets access to different Wi-Fi services. To receive information about the wireless networks which are in range of the smartphone the `BroadcastReceiver` interface has to be implemented and registered via the `WifiManager`.

A background thread is set up to query the necessary wireless network data in continuous intervals. The method `WifiManager.startScan()` is called on the thread, which invokes the `onReceive()` method implemented by the custom `BroadcastReceiver` class. This event triggers the computation of the indoor position estimate using the FSPL equation and the trilateration algorithm described in section 4.1.3 and section 4.1.4.

To receive Wi-Fi data `CHANGE_WIFI_STATE` and `CHANGE_WIFI_STATE` permissions have to be added to the AndroidManifest.xml.

Handling location data

Another background thread is set up for updating the map based on the current location. This thread draws a point on the map representing the estimated position of the user.

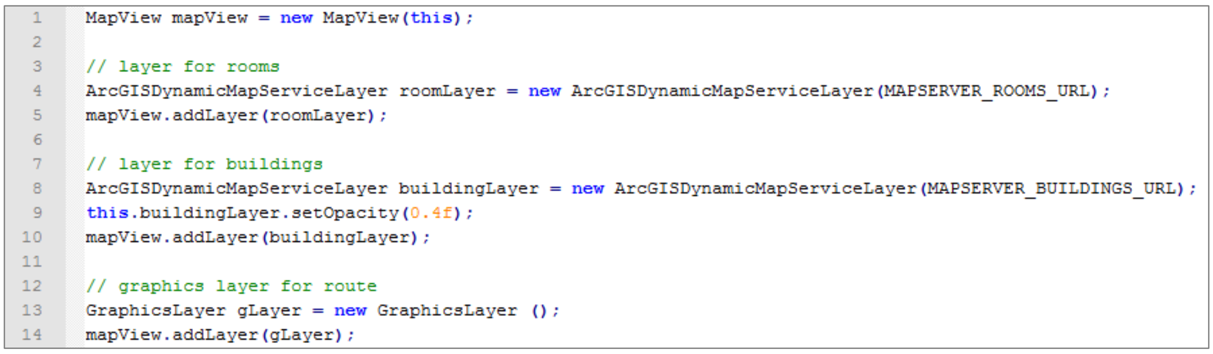
The standard source of the user's position is the GPS location provider. If the GPS accuracy falls under 20m it is assumed that the user is inside a building. In this case the Wi-Fi based position estimate is shown on the map. To indicate the less accurate position a Wi-Fi symbol is shown on the screen.

Furthermore, the thread changes the displayed floor map according to the z-coordinate of the user's position.

[34] XML file for basic application settings used by the Android platform

5.2.2 ArcGIS Integration

For adding ArcGIS capabilities to the application the ArcGIS SDK for Android[35] is used.



```
 1  MapView mapView = new MapView(this);
 2
 3  // layer for rooms
 4  ArcGISDynamicMapServiceLayer roomLayer = new ArcGISDynamicMapServiceLayer(MAPSERVER_ROOMS_URL);
 5  mapView.addLayer(roomLayer);
 6
 7  // layer for buildings
 8  ArcGISDynamicMapServiceLayer buildingLayer = new ArcGISDynamicMapServiceLayer(MAPSERVER_BUILDINGS_URL);
 9  this.buildingLayer.setOpacity(0.4f);
10  mapView.addLayer(buildingLayer);
11
12  // graphics layer for route
13  GraphicsLayer gLayer = new GraphicsLayer ();
14  mapView.addLayer(gLayer);
```

Figure 5-10 - Code - Initialize MapView

One of the basic functions of this SDK is adding maps to an Android application via the `MapView` class. Different layers (listed in section 4.2.2) are added to this view (see *Figure 5-10*).

The floor layer, which is initialized in line 4 of *Figure 5-10*, contains maps for floors in each building on campus. Based on the user's position the floor map is switched during runtime so that it always presents the floor on which the user walks.

The view allows the user to zoom in on the map using pinch (*Figure 5-11 a)*) and spread (*Figure 5-11 b)*) gestures. To change the map extent a scroll (*Figure 5-11 c)*) gesture is used.

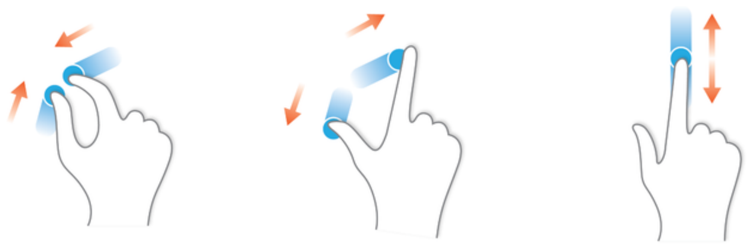


Figure 5-11 - Multi-touch Gestures: a) Pinch, b) Spread, c) Scroll [17]

Via a `GraphicsLayer` (line 13 of *Figure 5-10*) shapes can be drawn on the map. This is used for displaying the route on the screen.

For querying information from the ArcGIS server (e.g. room coordinates) the API provides different types of tasks. Similar to the REST interface several parameters can be set for these tasks, making it

[35] ArcGIS SDK V 1.0 (released in December 2011)

very powerful to specify the search result. To detach these queries from the UI thread they are run in an `AsyncTask` (described in section 5.2.4).

5.2.3 AR Integration

A fundamental goal of this project was to integrate augmented reality into the application. As described in section 2.3 this technique is quite new and therefore poses a big challenge.

Augmented Reality on Android

The concept of this technique is to augment the live data of the smartphone with additional meta data.

Accessing the live data of the smartphone is quite easy. The Android SDK offers a camera API that can be accessed by the package `android.hardware.Camera` and the determination of the location of the device is described in section 5.2.1. To compute the orientation of the device, access to the following sensors is offered via the `android.hardware.SensorManager` class:

- `Sensor.TYPE_MAGNETIC_FIELD`
- `Sensor.TYPE_ACCELEROMETER`
- `Sensor.TYPE_ROTATION_VECTOR`

The difficult part of the augmented reality technique is to combine those different parts of the smartphone live data and compute the position of the meta data in a way that it overlaps with the real world entities seen in the camera feed.

Mixare - An Augmented Reality Browser

To display information in the correct position of the camera feed the open source augmented reality engine Mixare[36] is embedded into the client application. Mixare is mainly developed by Daniele Gobbetti and published under the GPLv3. [20] As described on the Mixare project page there are four ways to use this augmented reality browser:

1. Mixare as an autonomous application[37] (displaying predefined data sources such as Wikipedia, Twitter or OpenStreetMap)
2. launching the Mixare application by a link on an HTML page (whereby the data source is transferred to the application)
3. launching Mixare application from a custom Android application and passing a data source to it
4. direct integration into a custom Android application [18]

[36] Mixare V 0.8 (released in April 2012), Mixare stands for mix Augmented Reality Engine [20]
[37] available on Google Play and Apple App Store

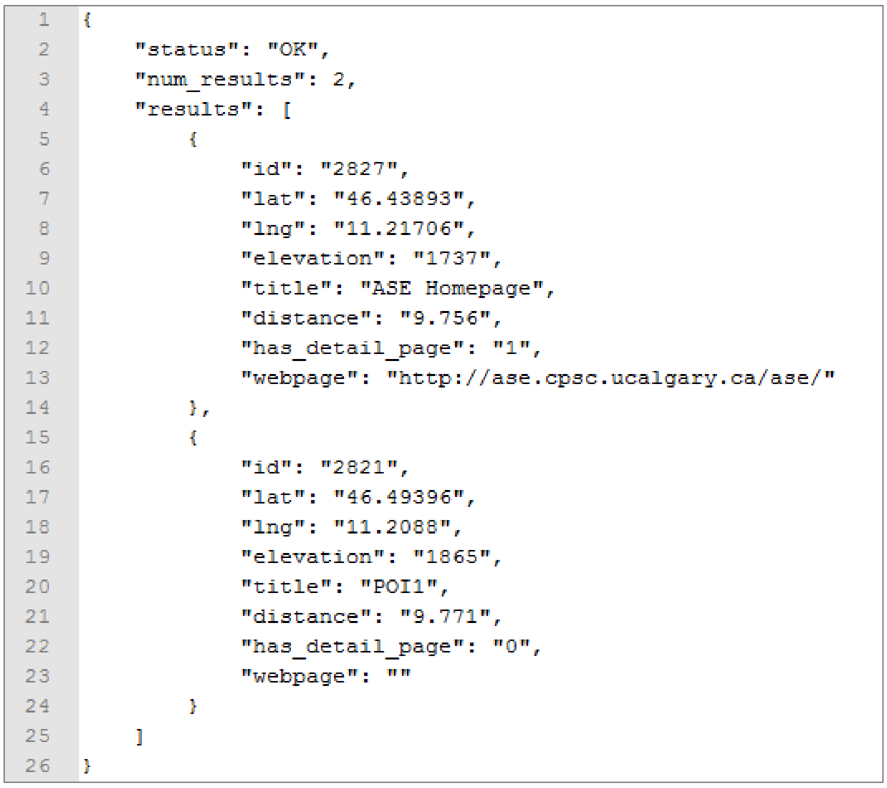
Considering that the Mixare framework does not cover the requirements for this project in regard to showing different markers on the screen, the fourth option, which offers the possibility to extend this engine in every way, is used.

Integration and Enhancement of Mixare

The source code can be accessed via Github [19] and is integrated into the Roomfinder application as an Android library project.

The main feature of the Mixare library is the class, which displays augmented reality information on the screen. To start this `Activity`[38] an `Intent`[39] has to be sent to the Android system. `Activities` can be registered to certain `Intents` in the AndroidManifest.xml so if the system gets a request for a specific `Intent` the defined `Activity` will be initialized.

The entry point of the augmented reality browser in this framework is the `org.mixare.MixView` class. It can be started by creating a new `Intent` and passing a URL to it. This URL has to point to a resource which contains data in a Mixare specific JSON format. The format looks like:



```
{
    "status": "OK",
    "num_results": 2,
    "results": [
        {
            "id": "2827",
            "lat": "46.43893",
            "lng": "11.21706",
            "elevation": "1737",
            "title": "ASE Homepage",
            "distance": "9.756",
            "has_detail_page": "1",
            "webpage": "http://ase.cpsc.ucalgary.ca/ase/"
        },
        {
            "id": "2821",
            "lat": "46.49396",
            "lng": "11.2088",
            "elevation": "1865",
            "title": "POI1",
            "distance": "9.771",
            "has_detail_page": "0",
            "webpage": ""
        }
    ]
}
```

Figure 5-12 - Mixare JSON Format

[38] an application component in Android which represents a single screen (further description in chapter 5.2.5)
[39] a certain operation screen (further description in chapter 5.2.5)

The Mixare API only supports one single data source calling it by `Intents`. For this project the functionality of supporting multiple data sources is added to this API. An option menu[40] is added to handle switching between these data sources.

As a further enhancement to the API, different augmented reality markers were added. Each created marker represents a single data source. To help the user differentiate between different data sources, each marker has a different design (see figures in chapter 5.2.5).

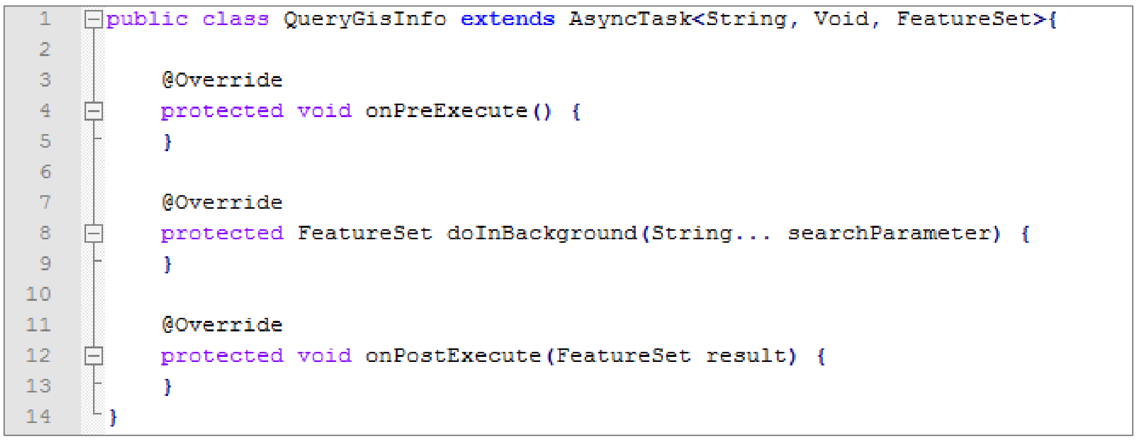
5.2.4 Multithreading

The GUI framework in Android is like most of the modern GUI frameworks single threaded. Given this fact, each long-running process, such as queries on the ArcGIS server or web service calls, should run in separate threads.

Otherwise, the UI cannot update the `Activities` or respond to user inputs. Different methods of multi-threading are provided by the Android API.

AsyncTask

One way to detach a long-running task from the UI thread is to use the `android.os.AsyncTask`. It is mainly used for querying any kind of information from a remote data source. The skeleton of the implementation for the ArcGIS server query is shown in *Figure 5-13*.



```
public class QueryGisInfo extends AsyncTask<String, Void, FeatureSet>{

    @Override
    protected void onPreExecute() {
    }

    @Override
    protected FeatureSet doInBackground(String... searchParameter) {
    }

    @Override
    protected void onPostExecute(FeatureSet result) {
    }
}
```

Figure 5-13 - Code - AsyncTask Skeleton

[40] a menu which appears by pressing the menu button on an Android device (further description in chapter 5.2.5)

The first called method is `onPreExecute()`. Basic initialization is handled in this method. In case of the server query in this project, the background animation (a simple loading animation) is installed. It runs on the UI thread.

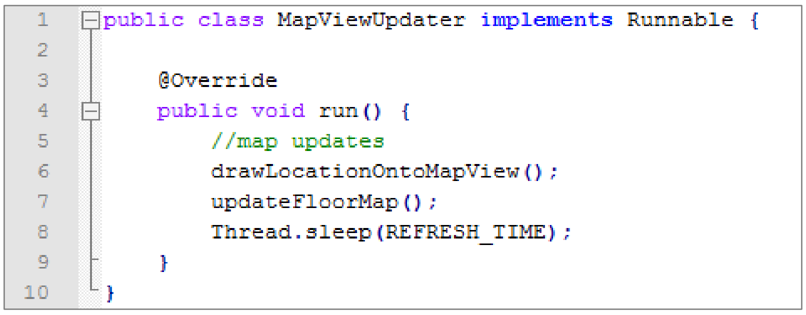
The method `doInBackground(String...)` runs in a new thread. In this method the actual work is done. A query of the type `com.esri.core.tasks.ags.query.Query` is instantiated and specified with the parameters passed to the method via arguments.

When the task created in the `doInBackground(String...)` method finishes, the `onPostExecute(FeatureSet)` method is invoked. The background thread gets deleted and the result of the computation is passed to this method as an argument. This method runs on the UI thread again. ([23], page 143f)

Threads

Whereas an `AsyncTask` is used for single queries, `java.lang.Thread` is used for continuous tasks in the application. Tasks like drawing the current coordinate on the map view or switching the displayed floor map according to the current position have to run the entire time the map view is active.

One way to create a thread in Java is to implement the `Runnable` interface (see *Figure 5-14*).



```java
public class MapViewUpdater implements Runnable {

    @Override
    public void run() {
        //map updates
        drawLocationOntoMapView();
        updateFloorMap();
        Thread.sleep(REFRESH_TIME);
    }
}
```

Figure 5-14 - Code - Thread Example

The interface `Runnable` only contains the method `run()` which is called by starting the thread. In this method a loop can be created in which the required functionality is executed.

5.2.5 Graphical User Interface

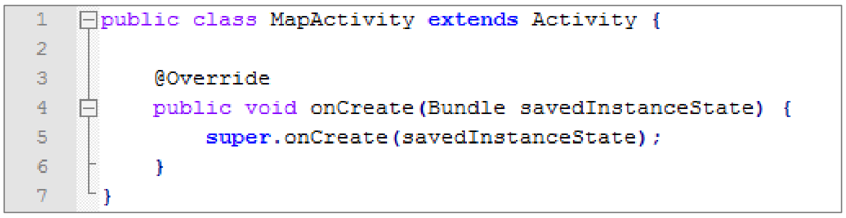
This section explains the basic approach of implementing user interfaces on the Android platform and shows some of the major interfaces created in this project.

Implementing GUIs on Android

The basic element of a user interface on Android is the `Activity` class. It takes up the entire area of the display. Typically each `Activity` represents one screen.

Internally `Activities` are stored on a stack. Whenever a new `Activity` is created it gets pushed on top of the stack. The back button on Android devices pops the top `Activity` off the stack and resumes the previous one.

To create a new `Activity` for the map screen, a class has to be implemented which extends `Activity` (see *Figure 5-15*).



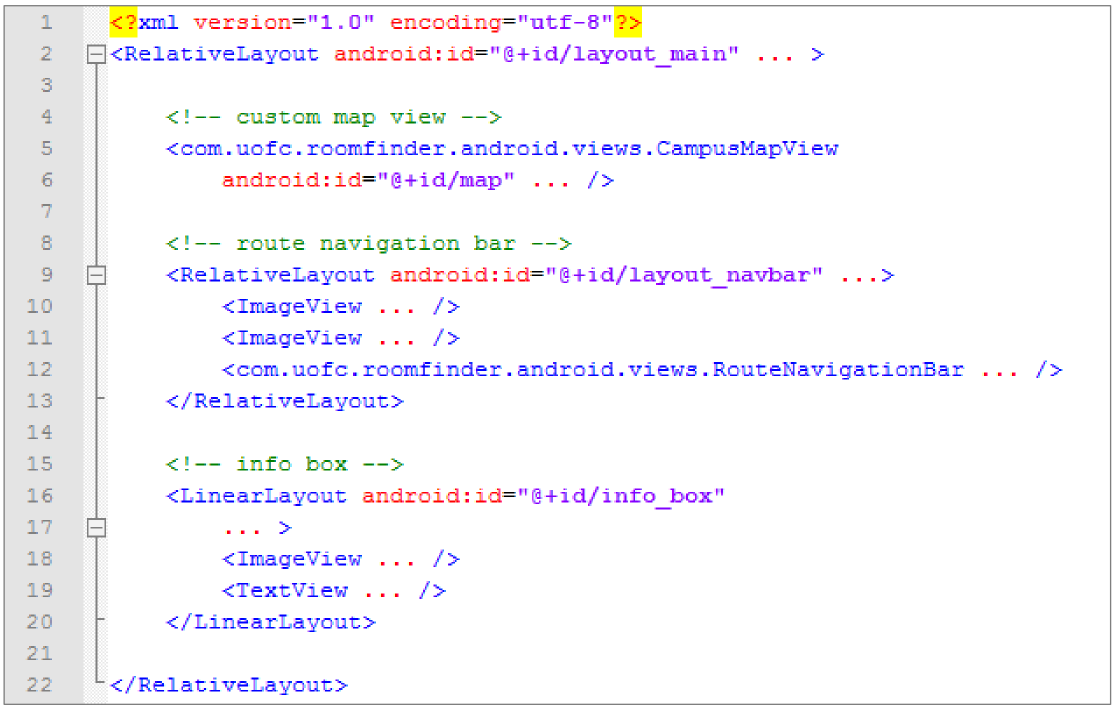
```java
public class MapActivity extends Activity {

    @Override
    public void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
    }
}
```

Figure 5-15 - Code - MapActivity

The basic user interface components like text fields, buttons or images are subclasses of `View`. `Views` occupy a rectangle area on the screen and are responsible for drawing themselves and event handling.

The `Activity` created in *Figure 5-15* comes without any interface components. In order to add `Views` to an `Activity` a layout XML file is created. For each `View` a specific XML tag is added to the XML structure. XML attributes define the behavior (e.g. position, color, visibility) of those components. XML tags can be arranged in view containers such as `LinearLayouts` for single row or single column presentation or `TableLayouts` for a table structure.

The basic XML layout of the `MapActivity` used in the application is shown in *Figure 5-16*.



```xml
<?xml version="1.0" encoding="utf-8"?>
<RelativeLayout android:id="@+id/layout_main" ... >

    <!-- custom map view -->
    <com.uofc.roomfinder.android.views.CampusMapView
        android:id="@+id/map" ... />

    <!-- route navigation bar -->
    <RelativeLayout android:id="@+id/layout_navbar" ...>
        <ImageView ... />
        <ImageView ... />
        <com.uofc.roomfinder.android.views.RouteNavigationBar ... />
    </RelativeLayout>

    <!-- info box -->
    <LinearLayout android:id="@+id/info_box"
        ... >
        <ImageView ... />
        <TextView ... />
    </LinearLayout>

</RelativeLayout>
```

Figure 5-16 - Code - Android XML Layout of CampusMapView

To link this XML layout to the `MapActivity`, `setContentView(R.layout.map_activity)` is called.

Main Menu

The main menu shown in *Figure 5-17* is the entry point of this application. It offers four self-explanatory options to the user.

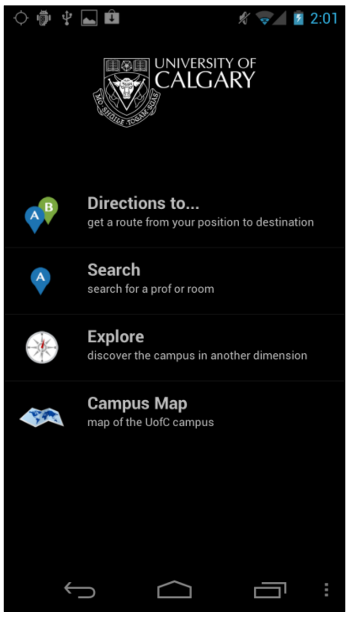

2:01
UNIVERSITY OF CALGARY
Directions to...
get a route from your position to destination
Search
search for a prof or room
Explore
discover the campus in another dimension
Campus Map
map of the UofC campus

Figure 5-17 - Main Menu

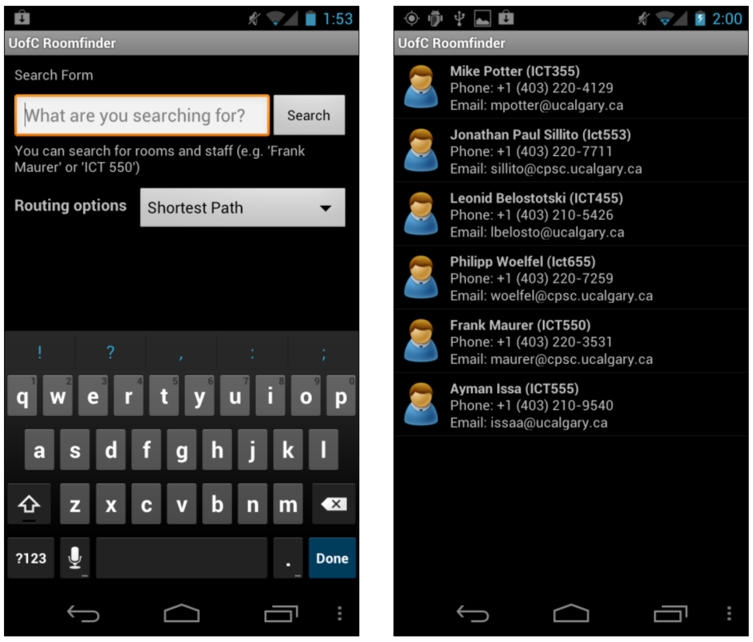
Search Form

This search form can be accessed by a click on the two first menu items of the main menu (see *Figure 5-17*) or the corresponding items in the options menu of the `MapActivity` (see *Figure 5-20 a)*).

As suggested in the user interaction chapter the search form only contains one input field for the search request (see *Figure 5-18 a)*). For navigation purposes a drop down box (named `Spinner` on the Android platform) with the following three routing options is added:

- Shortest Path (default)
- Prefer Indoor
- Prefer Outdoor

With the standard Android keyboard the user can specify his search criteria and with a tap on the "Search" button he submits his query.


1:53
UofC Roomfinder
Search Form
What are you searching for?
You can search for rooms and staff (e.g. 'Frank Maurer' or 'ICT 550')
Routing options: Shortest Path

2:00
UofC Roomfinder
Mike Potter (ICT355)
Phone: +1 (403) 220-4129
Email: mpotter@ucalgary.ca
Jonathan Paul Sillito (Ict553)
Phone: +1 (403) 220-7711
Email: sillito@cpsc.ucalgary.ca
Leonid Belostotski (ICT455)
Phone: +1 (403) 210-5426
Email: lbelosto@ucalgary.ca
Philipp Woelfel (Ict655)
Phone: +1 (403) 220-7259
Email: woelfel@cpsc.ucalgary.ca
Frank Maurer (ICT550)
Phone: +1 (403) 220-3531
Email: maurer@cpsc.ucalgary.ca
Ayman Issa (ICT555)
Phone: +1 (403) 210-9540
Email: issaa@ucalgary.ca

Figure 5-18 - a) Search Form, b) Search Results

If the search query returns exactly one result, the user gets forwarded to the map screen to display the result on there. If there is more than one result he gets those displayed on a list screen (see *Figure 5-18 b)*). In the case of no match, the search form stays present and displays a message telling the user that his search was not successful.

Map View

The main `Activity` of this application is the `MapActivity`.

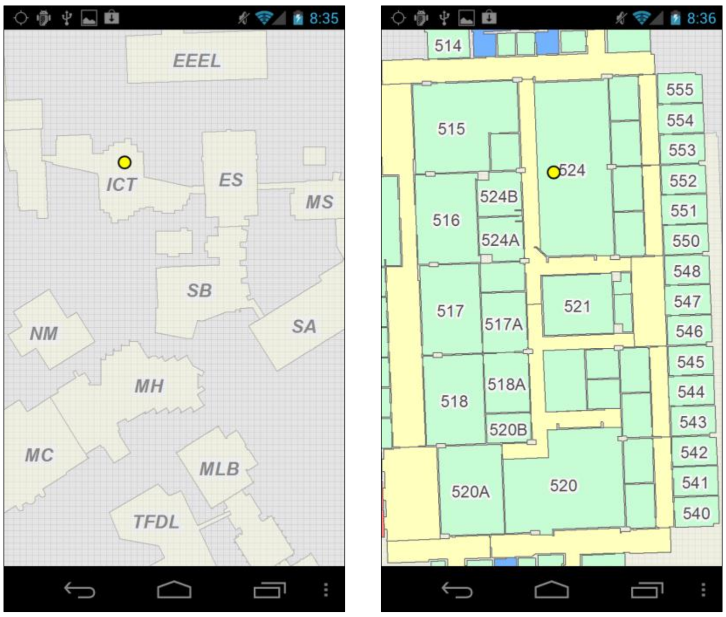


Figure 5-19 - a) Map View with Building Plan, b) Map View with Floor Plan

It displays the campus map of the University of Calgary (see *Figure 5-19 a)*). The user can zoom and scroll this map with multi touch gestures as mentioned in section 5.2.2. The building map is the basic layer of this screen. If zoomed in, the floor plans of the buildings (see *Figure 5-19 b)*Figure 5-20) will be displayed on top of the building plans.

To interact with this `Activity` the user can click on the Android menu button. An option menu appears as seen in *Figure 5-20 a)*. The "Satellite View" menu item exchanges the building and floor plans with a satellite image of the campus, the "Explore" leads to the augmented reality mode, which is explained in the following section.

The "Search" item in *Figure 5-20 a),* as well as the "Search" item in the main menu (see *Figure 5-17*) lead to the search form, described in the last section. After submitting the search query the user is redirected to the map view and gets the searched result highlighted as it is shown in *Figure 5-20 b).* Basic information of his result is displayed in an information box (see bottom of *Figure 5-20 b)*).

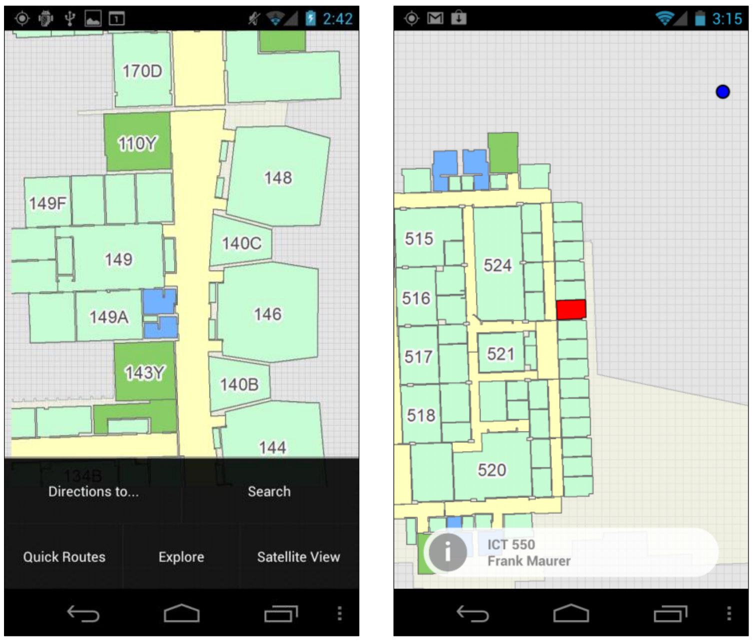


Figure 5-20 - a) Map view with option menu, b) Map view with search result

With the menu items “Directions to...” and “Quick Routes” the user has access to the navigation feature of this application. After defining a target with the search form, the route navigation bar (see top in *Figure 5-21 a)* and *b)*) and the information box (see bottom in *Figure 5-21 a)* and *b)*) are added to the `MapActivity`.

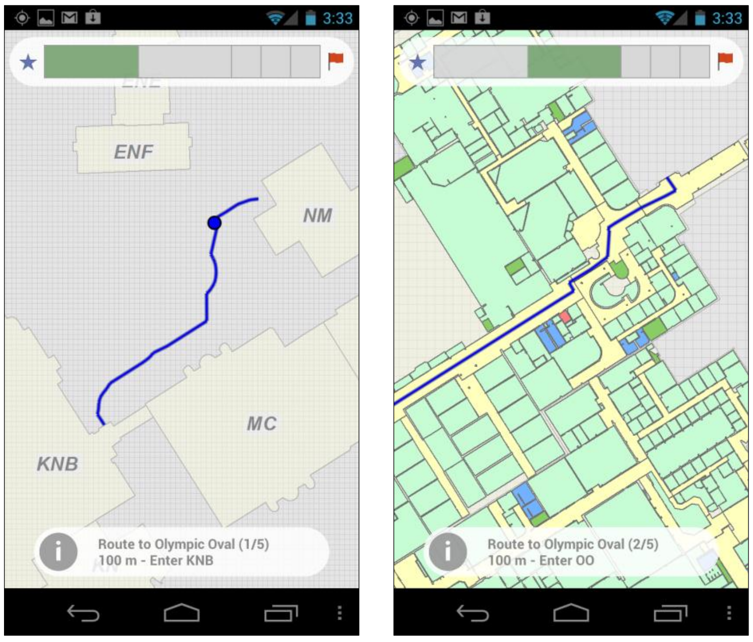


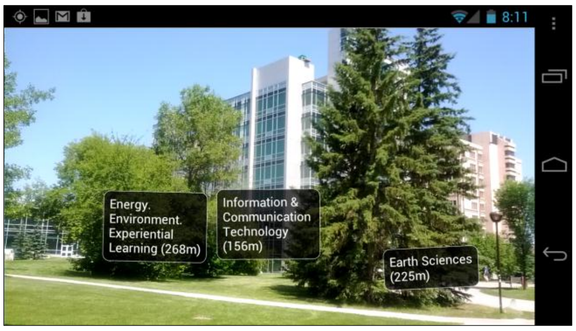
Figure 5-21 - a) Navigation View 1st Segment, b) Navigation View 2nd Segment

The route navigation bar gives the user an overview of his route. It contains rectangles representing sections of his path to his destination. By clicking on them, the user can change the active segment, which is shown by a blue line on the campus map. The info box describes in a short text what the destination of the active segment is.The blue dot in *Figure 5-21 a)* indicates the current location of the user.

Augmented Reality View

Figure 5-22 a) displays the standard view for augmented reality information. The text in the rectangle box describes the object which is represented by the marker. In this figure the nearby buildings are shown.

To change the displayed data source there is an options menu integrated in this `Activity` (see *Figure 5-22 b)*).


8:11
Energy. Environment. Experiential Learning (268m)
Information & Communication Technology (156m)
Earth Sciences (225m)

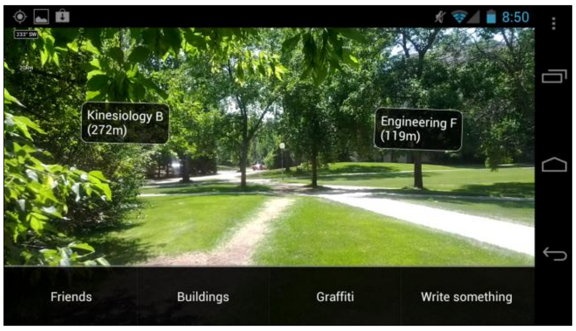
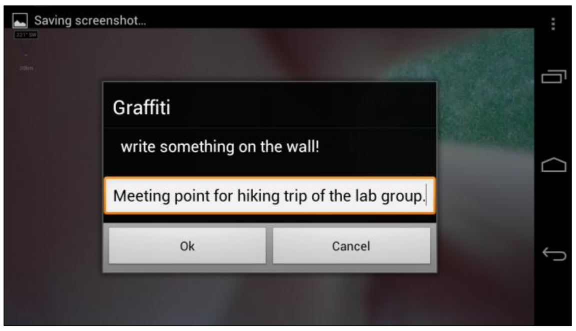


Figure 5-22 - a) AR View with Building Markers, b) AR View with Option Menu

The “Write something” item on the menu leads to the screen shown in *Figure 5-23 a)*. Users can post geo-referenced texts on the campus which are displayed as shown in the *Figure 5-23 b)*. To separate these user created markers from the building markers, they are displayed with different background colors.


Saving screenshot...
Graffiti
write something on the wall!
Meeting point for hiking trip of the lab group.
Ok
Cancel

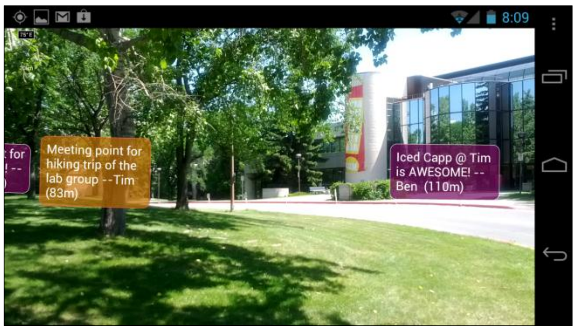

8:09
Meeting point for hiking trip of the lab group --Tim (83m)
Iced Capp @ Tim is AWESOME! -- Ben (110m)

Figure 5-23 - a) AR Text Input, b) AR view With Graffiti Markers

Figure 5-24 a) and *b)* show the augmented reality navigation mode. The left screen has two markers. The marker with the white border ("Enter KNB (130m)") shows the next waypoint, the one with red border ("Olympic Oval (320m)") shows the destination of the route. The screen of *Figure 5-24 b)* shows a compass based arrow pointing to the next waypoint.

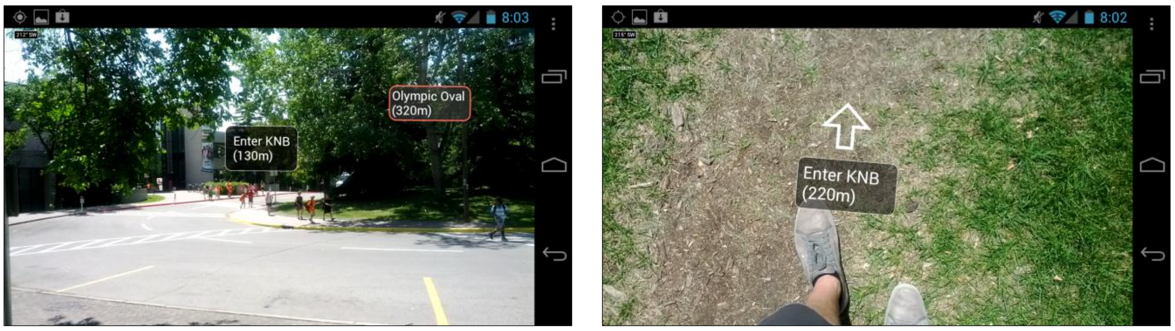


Figure 5-24 - a) AR View with Waypoints, b) AR View with Arrow Marker

When selecting the "Friends" item on the option menu of *Figure 5-22 b)* the last known position of the user's friends is drawn onto the camera feed as it is shown in *Figure 5-25*.

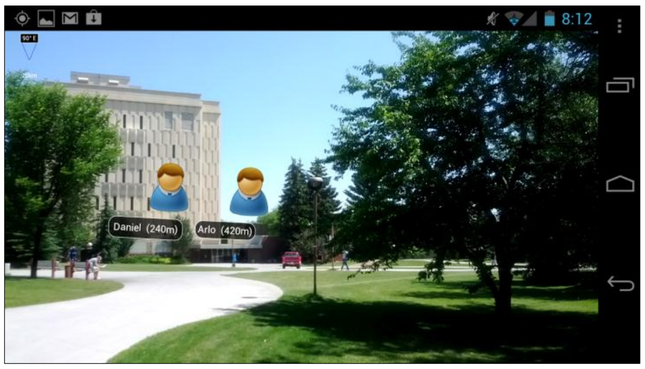


Figure 5-25 - AR View with Friend Markers

6 Conclusion

In this chapter the results of the thesis are discussed. Problems which occurred during this work and the limitations that came along with them are listed here. Furthermore, a brief look-out on future work is given.

6.1 Summary and Evaluation

The goal of this thesis was to create a mobile application which helps people on the campus of the University of Calgary to orientate themselves and find their destination.

In order to achieve this, a system environment was designed based on the requirements from chapter 1 and the techniques described in chapter 2. Different data sources have been analyzed and integrated into this system. A server that acts as a central point was implemented so that clients based on different platforms can access information in an easy way via RESTful web services. Finally, a prototype for the Android platform was developed which connects to these data sources and supports users on the campus with routing features and other information.

The source code of this project is released under the GPLv3 and can be accessed via SVN on Google Code Project Hosting[41].

Roomfinder server:	http://code.google.com/p/uofc-roomfinder-server/
Android client:	http://code.google.com/p/uofc-roomfinder-android-app/

The strength of this application is the easy to use navigation feature which is able to find paths on campus to user-defined locations. With the indoor location tracking feature the application always knows where the user is located and shows him context based information about his environment.

The augmented reality feature is an innovative addition to this application. It invites the user to play with the application and explore the university campus from another point of view.

A lot of different techniques and data sources were integrated into this application. Although not every feature could be implemented, the application offers a fully functional routing feature which is enhanced by augmented reality and an indoor location tracking algorithm.

[41] http://code.google.com/hosting/

6.2 Problems

Several problems came up during this work. They are described in this section.

Indoor Location Tracking

In one of the first project meetings it came up that a group of people at the University of Calgary are working on an indoor location tracking framework. This framework should be integrated into the application developed in this project. Unfortunately the framework was not supposed to be finished before the end of this project. A method for indoor location tracking had to be created from scratch.

The data of the wireless network infrastructure which is needed for the trilateration was the next obstacle. On a more precise evaluation of the data source, it turned out that there is no useable location information of the access points in the management system. In addition to that problem the vendor of the management software does not support any direct connection to the database. The only way to export data was to create CSV reports which led to the problem that additional effort was needed to transfer this data into a database. The other downside of not having a direct connection to the database was that there was no way to access the live power levels of the access points, which significantly reduced the accuracy of the indoor location tracking.

Integration of Data Sources

The application uses a range of different information sources. To find out where to get this kind of information from and how it can be accessed was also a time consuming factor.

Meetings with several people from the IT department of the University of Calgary were arranged, where topics like content of these data sources and access to them were discussed.

ArcGIS SDK for Android

The ArcGIS SDK for Android, which is needed for features that require geospatial information and show maps, is quite new. It was released in December 2011, so at the beginning of the project it was not even two months old. Due to this fact, the developer community for this SDK was really small. It was hard to find useful tutorials and source code examples that demonstrated how to work with this SDK. The documentation from the vendor Esri is also relatively small and especially when it comes to more complex components it was nearly impossible to find information about the usage of specific methods.

Another downside of V1.0 of this SDK was that it did not support the built-in Android emulator. So before getting an Android smartphone the application could not be tested.

ArcGIS Server and the Network Analyst Extension

The ArcGIS server and the entire ArcGIS software suite is a complex software package.

Before data could be displayed on the client, different services had to be set up on the server. Settings had to be adjusted and modules activated. Learning how to set up a map server with a network analyst module which uses a predefined network data set took a long time.

The integration of server features into the Android application, especially the routing provided by the network analyst module, caused more problems. The native Android SDK offers no way to directly access this service and the next preferred way to get information from the server, the REST web service, was only capable to return two dimensional coordinates, which is not sufficient for indoor navigation.

In addition to the integration problems of the routing feature it turned out, that the underlying data for the path finding was not entirely correct and caused inaccurate routes.

6.3 Limitations

Based on the problems described in the last chapter and the limited timeframe of this thesis, not every feature described in the design chapter could be implemented.

Augmented Reality

Although the basic features of the augmented reality part was implemented, a couple of compromises to the suggestions made in the design chapter had to be made.

Given the fact that the indoor location tracking and most notably the orientation of the device could not be determined with a suitable accuracy, the displaying of augmented reality markers indoors was not implemented into the application prototype.

In addition to that, not every part of the information filtering (see section 3.2.2) could be added to the prototype.

Navigation

Due to the lack of a database containing information about stores and other points of interest at the moment, it could not be integrated into the search query. A workaround was created where users can navigate to a limited amount of hard coded POIs via the “quick link” view.

The “silent navigation mode” suggested in the design chapter in section 3.1.2 was not implemented at all.

Indoor Location Tracking

Considering the inaccurate position of the access points by approximating them over their name (room number) and the fact that the live outgoing power levels of the Wi-Fi access points could not be accessed, the accuracy of the indoor location estimate is limited. The ideal value for an accuracy of less than ten meters could not be achieved.

6.4 Future Work

As mentioned in section 6.3, not every feature, described in the design chapter, could be implemented in the Android prototype.

To give the user the opportunity to find more places on campus, more data sources (e.g. for the food court and other stores) could be integrated.

Indoor location tracking in the current version of the application is not very accurate. With more exact information about the location of the access points and a direct access to the database that stores the Wi-Fi infrastructure details, a more accurate indoor position could be estimated. The current plan of increasing the access point density on campus would enhance the accuracy even further.

Another huge benefit for the application would be to refine the network dataset for the campus of the University of Calgary. As described in section 5.2.2 there are several problems with the basic routing data which led to incorrect routing paths.

Besides eliminating these limitations, new features to help users on campus could be added to this application. For example people could get access to helpful institutions on campus like the university library. Students could access information about their loaned books or get notifications if a required book is available. An integration of the university recreation center could help students to check for fitness classes or outdoor courses. They would be able to book outdoor equipment or facilities like the squash court through this mobile application.

Considering that the limitations for accessing wireless network information on the iOS platform will be removed in future, it would be possible to create a client application for this platform. The Windows Phone platform, which is increasing in popularity, would also be suitable operating system.

The technology used in smartphones is relatively new and makes great steps forward every year. A long term perspective, based on more accurate location sensors, could offer users better interaction with their environment in the augmented reality view. Whereas in the current version of the prototype users just post comments based on their current position, in later releases with an accurate method to determine the orientation of the device indoors, users could post comments directly to walls or other real life objects.

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Example of a REST Map Server Query

URL of a sample REST query:

```
http://136.159.24.32/ArcGIS/rest/services/Rooms/Rooms/MapServer/111/query?
text=&geometry=&geometryType=esriGeometryPoint&inSR=&spatialRel=esriSpatial
RelIntersects&relationParam=&objectIds=
&where=SDE.DBO.Building_Room.RM_ID%3D%27550%27+AND+SDE.DBO.Building_Room.BL
D_ID%3D%27ICT%27
&time=&returnCountOnly=false&returnIdsOnly=false&returnGeometry=true&maxAll
owableOffset=
&outSR=4326
&outFields=SDE.DBO.Building_Room.RM_ID%2C+SDE.DBO.Building_Room.FLR_ID%2C+S
DE.DBO.Building_Room.BLD_ID
&f=pjson
```

The result in JSON format:

```
{
  "displayFieldName" : "SDE.DBO.Room_Info.RM_NAME",
  "fieldAliases" : {
    "SDE.DBO.Building_Room.RM_ID" : "Room_ID",
    "SDE.DBO.Building_Room.FLR_ID" : "Floor ID",
    "SDE.DBO.Building_Room.BLD_ID" : "Building ID"
  },
  "geometryType" : "esriGeometryPolygon",
  "spatialReference" : {
    "wkid" : 4326
  },
  "fields" : [
    {
      "name" : "SDE.DBO.Building_Room.RM_ID",
      "type" : "esriFieldTypeString",
      "alias" : "Room_ID",
      "length" : 8
    },
    {
      "name" : "SDE.DBO.Building_Room.FLR_ID",
      "type" : "esriFieldTypeString",
      "alias" : "Floor ID",
      "length" : 16
    },
    {
      "name" : "SDE.DBO.Building_Room.BLD_ID",
      "type" : "esriFieldTypeString",
      "alias" : "Building ID",
      "length" : 25
    }
  ],
  "features" : [
    {
      "attributes" : {
        "SDE.DBO.Building_Room.RM_ID" : "550",
        "SDE.DBO.Building_Room.FLR_ID" : "05",
        "SDE.DBO.Building_Room.BLD_ID" : "ICT"
      },
      "geometry" : {
        "rings" : [
          [
            [
              -114.13010771669641,
              51.080278398839006
            ],
            [
              -114.13011628694338,
              51.080278395286676
            ],
            [
              -114.13011628524627,
              51.080276902525171
            ],
...
            [
              -114.13015271685008,
              51.08030311781846
            ],
            [
              -114.13015271922107,
              51.080302812085996
            ],
            [
              -114.13010774561654,
              51.080302831513457
            ],
            [
              -114.13010771669641,
              51.080278398839006
            ]
          ]
        ]
      }
    }
  ]
}
```

Example CSV Data for Wi-Fi Access Points

Excerpt out of the .csv file, which contains ~2000 data sets.

```
Name,1st MAC,1st Ch,1st TxP,2nd MAC,2nd Ch,2nd TxP
PF_4240,00:0B:86:C8:01:C0,11,37,00:0B:86:C8:01:D0,36,40
ST_29n,00:1A:1E:15:FA:20,6,38,00:1A:1E:15:FA:30,60,40
PF_2291,00:0B:86:CB:94:A0,1,37,00:0B:86:CB:94:B0,153,40
EDC_363U,00:0B:86:CA:C5:00,6,37,00:0B:86:CA:C5:10,157,40
PF_1140,00:0B:86:D6:CA:A0,6,37,00:0B:86:D6:CA:B0,149,40
MFH_3342,00:0B:86:DC:BA:40,6,37,00:0B:86:DC:BA:50,153,40
EDC_386,00:0B:86:CE:60:00,11,37,00:0B:86:CE:60:10,165,40
OO_251Z,D8:C7:C8:E0:15:E0,6,41,D8:C7:C8:E0:15:F0,100,42
EDC_264,00:0B:86:C8:8D:A0,6,37,00:0B:86:C8:8D:B0,48,40
EDT_1017,00:0B:86:CD:FC:A0,6,37,00:0B:86:CD:FC:B0,48,40
PF_1254v,00:0B:86:CB:C7:20,1,37,00:0B:86:CB:C7:30,165,40
PF_1286,00:0B:86:CD:F1:C0,11,37,00:0B:86:CD:F1:D0,40,40
ST_20n,00:1A:1E:15:E8:60,1,41,00:1A:1E:15:E8:70,108,42
EDC_290,00:0B:86:CA:C7:60,6,37,00:0B:86:CA:C7:70,44,40
PF_3233,00:0B:86:C9:93:80,1,37,00:0B:86:C9:93:90,165,40
MFH_3340,00:0B:86:DC:B8:C0,11,37,00:0B:86:DC:B8:D0,48,40
EDT_1412,00:0B:86:CB:C1:40,11,37,00:0B:86:CB:C1:50,165,40

[...]
```