DELIVERABLE REPORT D4.1 "Mobile AR Driven Navigation"

MASELTOV
Mobile Assistance for Social Inclusion and Empowerment of Immigrants with Persuasive Learning Technologies and Social Network Services

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CONTENT

1. EXECUTIVE SUMMARY

This deliverable D4.1.1 is about the motivation and necessary steps to provide augmented reality navigation as a means for the support of immigrants in the host urban environment. This deliverable represents per se a concept paper that summarises important pre-cursors for a meaningful and intuitive navigation interface for recent immigrants in urban environments.

Based on these functional requirements and based on the interaction specifications, the mobile AR driven navigation interface will be shaped in design and functionality according to the requirements of the immigrants, i.e., following the findings of work package WP2. The final version of the software component, being adequate in functionality, layout and interaction design, will be described in the deliverable D4.1.2, being due at project month 18.

The deliverable represents a fundamental prerequisite for further studies on mobile navigation interfaces in the context of recent immigrants: it identify the pivotal requirements for immigrant specific navigation, it presents a basic mobile augmented reality interface for further design and interaction updates, and finally it determines the precision in the position estimation as a fundamental capability of the MASELTOV navigation tool which is dependent on appropriate location based service quality.

The first Section of this document considers the particular challenges immigrants have to face and what benefits an adequate navigation system would provide. In the sequel, a quick overview of existing solutions is given. In the third Section of this paper the general problems when using satellite navigation in urban environments are outlined and an alternative localization method is introduced. These positioning tools are then evaluated on a range of recent smartphones in a study in an adequate and challenging urban environment, i.e., the regional hospital of the city of Graz. The sixth Section of this deliverable describes the necessary data aggregation, processing and algorithms to perform pedestrian routing. Another Section follows then with a sample illustration of how core components for mobile AR driven navigation would look like and how MASELTOV plans to implement the core functionality. Finally, the next steps in improving the navigation experience for immigrants are described.

2. MOTIVATION

The MASELTOV app will be delivered with context awareness capabilities as developed in this work package WP4, in order to render mobile services more intuitive and persuasive. Recent immigrants represent highly sensitive user clients that require a most intuitive support in terms of information assistance, language learning and community building apps. A relevant issue in natural and barrier free interface use is how to access the information within an urban environment which is largely unknown, and with a foreign, mostly unknown and unpractised language. Mobile augmented reality has been shown to be a most intuitive user interface and will be investigated in MASELTOV to be applied as a key component to orientate, navigate and to access information of interest (POI, etc.) about the environment.

In this deliverable we present therefore a relevant prerequisite for further studies on the MASELTOV navigation interface in the context of recent immigrants: it

- identify the **pivotal requirements for immigrant specific navigation**,
- it presents a basic **mobile augmented reality interface** for further design and interaction updates, and finally
- it determines the **precision in mobile position estimation** as a fundamental capability of the MASELTOV navigation tool which is dependent on appropriate location based service quality.

MASELTOV requires a user interface that enables the **immigrant user a highly intuitive access** of data. Pivotal requirements for the use of the AR driven navigation aids are basically identified in work package WP2 (User Requirements and Interaction Design). However, in general the AR driven user interface has to provide the following fundamental functionalities. Firstly, it has to display the navigation information in a most intuitive way. This includes orientation information (arrow, annotation of environment), information about the next navigation target, and information about the route and the necessary efforts to reach the target location (e.g., walking time in minutes). Secondly, information about most important services in the near environment (points of interest, POIs) has to be displayed. This will include information on nearby health services, public transportation opportunities, legal advice, local government, shopping opportunities, as well as information on nearby volunteers ("geo-social radar" service, work package WP8). Furthermore, there should be a direct access available to apply the mobile text lens service (Task 4.3, "Mobile Text Lens"), a service of image based text translation. This service enables to translate text in front of the user, such as from noticeboards, billboards, information provided to public transportation and in governmental offices. Furthermore, opportunities for situated language learning would be displayed as well. The usability of the user interface will be investigated in detail using wearable human factor technologies, such as eye tracking glasses, in the context of Task 4.2 (Multisensory Usability Engineering, see Deliverable D4.2.1).

The **mobile augmented reality interface** should represent the general entry during navigation operations. MASELTOV will facilitate all available built-in mobile phone sensors like inertial sensor, digital compass, gyroscope, bluetooth receiver, and WiFi receiver for seamless indoor and outdoor location awareness. The framework is fundamental for the development of intelligent navigation assistance focused on MASELTOV user groups with special demands. The smart integration and cross-linking of existing routing services for pedestrians and public transport will enable a realistic integration of guidance services into the urban.

MASELTOV also targets to produce **high accuracy in the estimation of position** as well as orientation of the mobile interface device. Based on exact position estimation, advanced geo-awareness technology like augmented reality and image annotation can be adopted for more intuitive navigation assistance. By intelligent combing the multisensory location awareness with the available geo-information from maps, network plans from public transportation and also lists of point of interest a first idea on the geo-context of the user can be deduced. Knowing the geo-context, like knowing the user is at the bus-stop, at home, at the supermarket or at the doctor, can be used to focus the offered assistance of the mobile device to the real needs of the user in his/her current situation (see WP6). For example, if we know from location awareness that the user is currently on the bus-stop waiting for his/her bus, the MASELTOV service on the mobile phone will try to detect the estimated behaviour "entering an office" by analysis of acceleration and positioning data, being able to give the user a feedback that e.g. the navigation-task was accomplished successfully and will give information for another assistance component.

3. STATE OF THE ART

The history of augmented reality interfaces started as early as in the year 1968 when Ivan Sutherland developed a prototype utilizing ultrasonic and mechanical tracking systems in combination with a head-mounted display (Sutherland 1968). The term "augmented reality" itself was coined by Boeing researchers Tom Caudell and David Mizell who outlined it as a viable alternative to virtual reality systems for simulation purposes (Caudell & Mizell 1992). Further research focused on both improving device tracking and processing of environmental features. These approaches include integrating markers (Rekimoto & Nagao 1995, Rekimoto 1996), object recognition (Thomas et al. 2000) and external positioning sensors such as GPS, ultrasound and magnetometers (Julier et al. 2000, Newman et al. 2001). The first system querying online services for data was introduced by (Kooper & Macintyre 2003). Following research aimed to reduce the dependency on infrastructure by using mobile computing devices such as PDAs and early smartphones. The popular augmented reality development library ARToolkit (Kato & Billinghurst 1999) has been ported to a wide range of mobile platforms, the first being Windows Mobile and Symbian (Wagner & Schmalstieg 2003, Henrysson et al. 2005). With the subsequent availability of sensor enhanced smartphones in the following years (iPhone introduced 2007, Android platform 2008) the application of infrastructureless, computational challenging, cloud-based augmented reality applications has been enabled for hundreds of millions of devices worldwide.

By utilizing tilt and magnetic sensors and combining this data with the internal GPS subsystem of modern smartphones it is possible to augment the image captured with the smartphone's camera with overlays containing meta-information. If the user moves the phone in another cardinal direction, the information overlays are being repositioned as well. This data representation method is very popular in the smartphone space and has sparked a wide range of applications such as tourist information (Wikitude 2008), games (Junaio 2009) and shopping (Layar 2008). Figure 1 shows an example application of augmented reality.

Within the MASELTOV project, this augmented reality approach should be extended to support augmented reality navigation for pedestrians with support for local public transport.

In Figure 2, an application scenario guiding the user to enter the building on the right is illustrated.

Figure 1: Application example for AR.

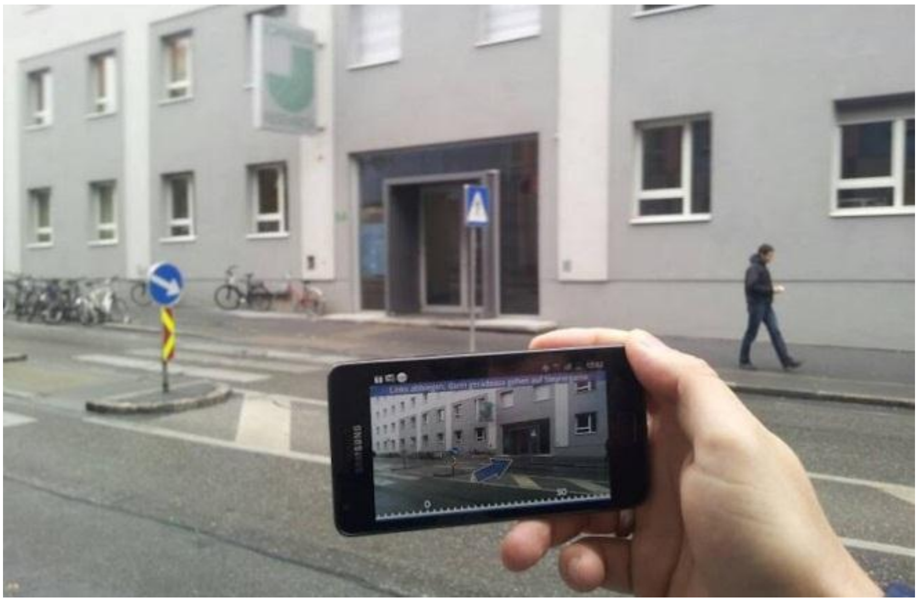


Figure 2: AR Navigation example

In the following sections, a quick overview of available augmented reality applications for navigation purposes is given.

3.1 MAP IN THE HAT / TINMITH

The first augmented reality application which supported user guidance through navigation was introduced by (Thomas et al. 1998). The system consisted of an off-the shelf portable computer and a differential GPS system contained in a backpack as well as a head mounted display with an electronic compass. The head mounted display was half-transparent enabling the user to see both the environment as well as navigation instructions.

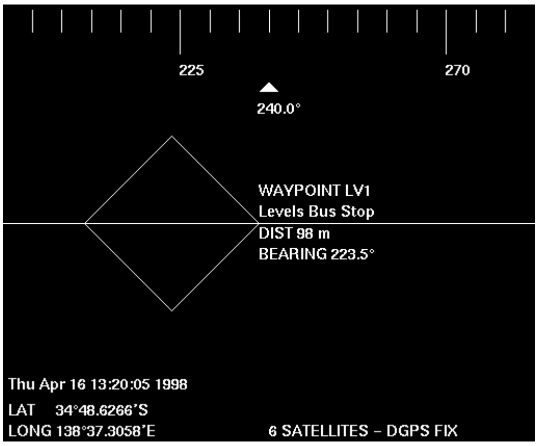


Figure 3: Illustration of user's view of first AR navigation system. The black area shows the user's environment while in operation.

Figure 3 illustrateds the instruction setup: The black area would show the real word image the user is currently seeing. In the top area of the image, the compass orientation is illustrated. The diamond shape represents the next waypoint. At the right side, descriptive text for the next waypoint is aligned. At the bottom, the current position and system information is shown. This project subsequently evolved into an AR development platform called Tinmith (Piekarski & Thomas 2001).

3.2 MAP NAVIGATION WITH MOBILE DEVICES

A project conducted by (Rohs et al. 2007) evaluated the benefits of using augmented reality and image analysis when browsing through a conventional map. For this study three usage patterns for panning a 2D map were tested:

1. Joystick navigation: As it was common for pre-touchscreen devices, a portion of a large map could be moved by pressing on four buttons in a crosshair arrangement. When panning the map the device itself was kept static.
2. Dynamic peephole: The smartphone is moved above a marker pattern. Marker recognition components sensing the moving pattern via the smartphone’s camera induce panning of the 2D map.
3. Magic lens method: The smartphone is moved above a conventional map equipped with a marker grid. As in the previous method, the movement is detected and a virtual 2D map is panned accordingly on the smartphone. However, in addition to this, the camera image is augmented with additional information.

Figure 4 illustrates the third operation mode. The project has shown that using either dynamic peephole or the magic lens method proved to be more efficient. The authors suggest that these methods could particularly help the visually impaired to fulfil certain search tasks on a large map.

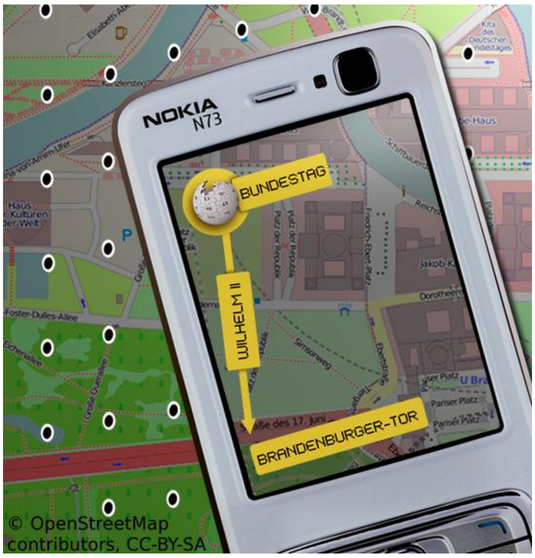


Figure 4: Map navigation with mobile devices in magic lens mode. While moving the smartphone above a real map, additional information is displayed.

3.3 WIKITUDE DRIVE

Wikitude Drive has been the only AR navigation system for smartphones which encountered a larger scale deployment (Germany, Austria, Switzerland). It was intended for car navigation. The smartphone relied on being placed in a dedicated dock. Its camera had to be aligned with the road. The proposed driving path was integrated in the smartphone's preview finder. Figure 5 shows an application scenario:

Figure 5: Application scenario of Wikitude Drive. A cyclist is moving towards the driver in oncoming traffic and is still visible when looking at the navigation system.

4. PREREQUISITES IN URBAN POSITIONING

Since the "selective availability" constraint for the United States' global positioning system named NAVSTAR-GPS has been removed in 2000 (White House 2000) its usage increased heavily (ABIresearch 2009). At the time of writing, other global navigation satellite systems (GNSS) are currently under (re-)construction:

- Russia: GLONASS (Russian Space Agency 1999)
- China: COMPASS (Xinhua News Agency 2009)
- Europe: GALILEO (European Space Agency 2010)

Those new systems will enable civilian usage too.

4.1 CHALLENGES

However, the accuracy of satellite based positioning methods is strongly dependent on clear viewing conditions to the sky. This is often not the case in urban canyons, where high buildings either prevent signal reception or induce multi-path wave propagation effects. In addition to this, moving indoors naturally leads to a total loss of signal. Figure 6 illustrates obstruction and multi-path effects of GPS satellites.

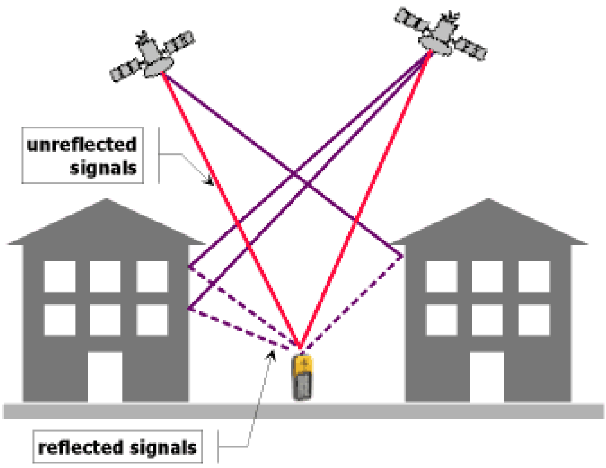


Figure 6: GPS obstruction and reflection effects (from Kamarudin & Amin 2004)

As a result, within this project, other sensor sources like received signal strength multi-lateration via available ground-based WiFi networks and digital maps are added to the location estimation provided by the GNSS through a particle filter model.

By fusing the data and incorporating its current reliability, the drawbacks of using a single sensor source can be compensated (Kalman 1960). The obtained information can be divided into data which is a direct result of user behavior and measurements of environmental indicators. While the first class of data only is generally recorded on-the-fly, the second requires a-priori information.

4.2 SOLUTION APPROACH

If we use signal attenuation for distance estimation, we can formulate (Rappaport 2002) the following relation for path losses (all values are in dBm):

$$PL(d) = \overline{PL}(d_0) + 10nlog_{10}\left(\frac{d}{d_0}\right) + X_\sigma$$

Equation 1: Path loss model

PL(d0) ... path loss at reference distance
n ... path loss exponent
Xσ... Zero mean Gaussian random variable

The unknown variable d is obtained via the received power:

$$P_r(d) = P_d(d) - PL(d)$$

Equation 2: Received signal power

The probability density for the RSSI is given as:

$$f(s) = \frac{1}{\sigma_{db}\sqrt{2\pi}} exp\left(-\frac{\left[S + nln(\frac{d}{d_0})\frac{10}{ln10}\right]^2}{2\sigma^2}\right)$$

Equation 3: Probability density for power levels

Because of the fact that a part of the access points used by the position fixing system are not in the line of sight of the user, small-scale fading (obstructions from vehicles, buildings or other people) will occur. This counteracts the formulated model. Therefore, a filter system is necessary, which can be deployed in non-Gaussian conditions. This can be achieved via particle filtering. Figure 7 shows a correction example of an erroneously determined GPS track by means of combining it with surrounding WiFi signal sources.

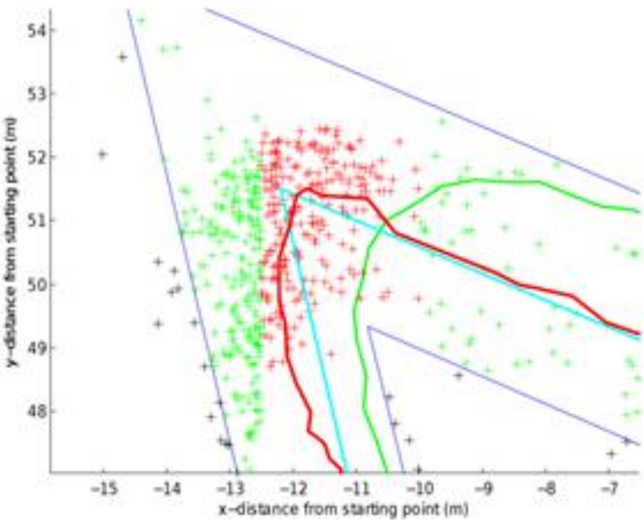


Figure 7: Particle distribution of WiFi signal measurements combined with erroneous GPS updates

Following (Shah et al 2007), the filter system can be formulated in 5 steps:

1. The particle cloud is initialized and the particle samples are drawn from some Gaussian distribution with the true position placed at the mean position of the cloud. All these particles have equal weight, such that the sum of the weights are normalized to one.

2. All the particles are moved forward according to the motion model described in D5.2.1 and in such a way that they do not enter a forbidden zone defined by a digital map. The particles are now referred to as the predicted particles.

3. At the new predicted positions of the particles, a new weight to each of them based on the cumulative distribution derived from the density f(s). This weight assignment is represented by:

$$w_t^j = \sum_{i=1}^{N} \frac{P(z_t^i | x_t^j)}{P_n}$$

Equation 4: Particle weight assignment

z_t^i ... signal strength received from AP i at time t
x_t^j ... position of particle j at time t
w_t^j ... weight of particle j at time t
N ... number of APs
P_n ... number of particles

4. Define the effective number of particles in the cloud

$$N_{eff} = \frac{1}{\sum_{j=1}^{P_n} (w_t^j)^2}$$

Equation 5: Particle number assessment

5. Go back to step 2 and move the particles again according to the motion model. If another source of position fixing (E.g.: GPS) is available, go to step 1 and re-initialize the cloud at the updated position.

5. POSITIONING STUDY

As part of the project MASELTOV, the positioning accuracy using GPS-, WiFi- and cell positioning over smartphones, was determined. The goal of the study was to determine whether a smartphone-based pedestrian navigation system, could be reliably used in urban areas. Urban areas pose a special challenge because of the GPS signal obstructions caused by tall buildings, inner yards, etc. The following devices, with GPS chipsets given in brackets, were used for the positioning study:

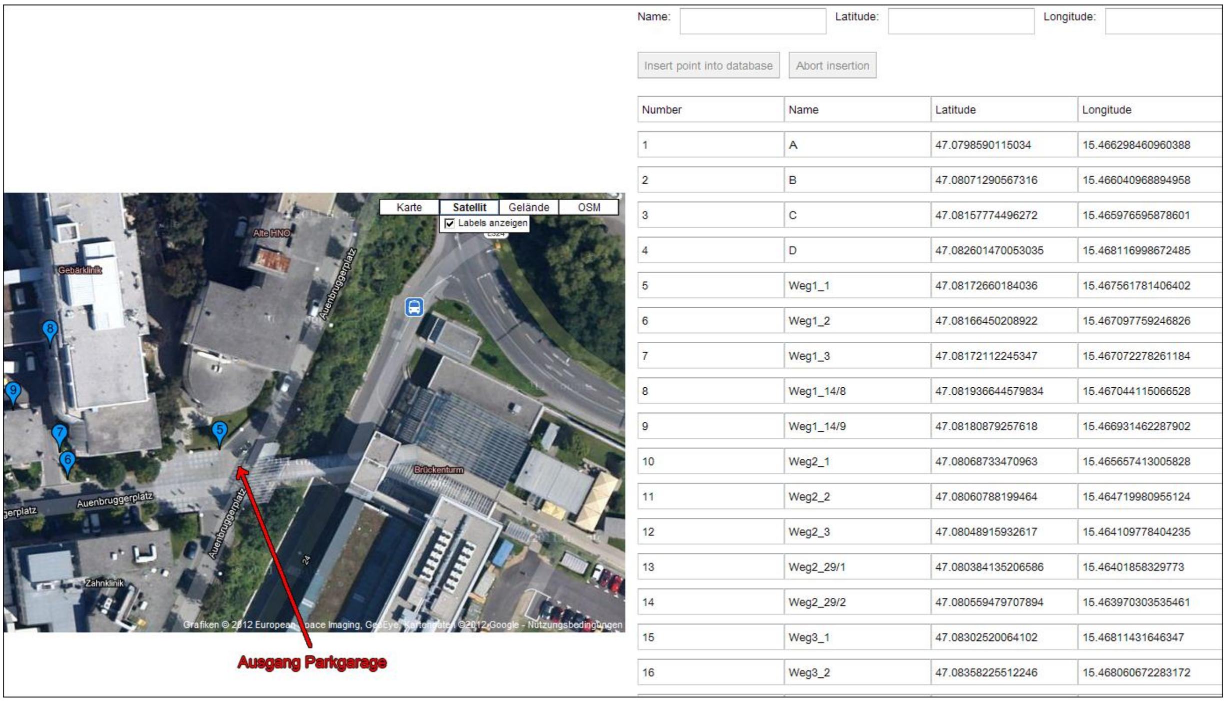
- HTC Hero (Qualcomm GPS one)
- Samsung Nexus S (Samsung Exynos)

- Samsung Galaxy Nexus (Texas Instruments SIRF GPS)

5.1 DEFINITION OF TEST POINTS

At first, it was necessary to determine an exact data-basis for the definition of the test points. According to this basis, the test points were defined and afterwards measured with each of the three test devices at the LKH Graz area. From the resulting deviation between the defined test points and the measured points, an average positioning accuracy could be determined for every device and measurement method. Ortho-images by Microsoft Bing Maps and Google were used as a basis for the definition of the test points. Additionally vector data of Open Street Maps (OSM) was used, which was already very detailed for the area LKH Graz. However entrances and entryways were missing and had to be inserted manually.

The test points were represented by a self-developed reference point marking tool also showing ortho-images and OSM data of the area. The image below shows the reference points of a test track.



Number	Name	Latitude	Longitude
1	A	47.0798590115034	15.466298460960388
2	B	47.08071290567316	15.466040968894958
3	C	47.08157774496272	15.465976595878601
4	D	47.082601470053035	15.468116998672485
5	Weg1_1	47.08172660184036	15.467561781406402
6	Weg1_2	47.08166450208922	15.467097759246826
7	Weg1_3	47.08172112245347	15.467072278261184
8	Weg1_14/8	47.081936644579834	15.467044115066528
9	Weg1_14/9	47.08180879257618	15.466931462287902
10	Weg2_1	47.08068733470963	15.465657413005828
11	Weg2_2	47.08060788199464	15.464719980955124
12	Weg2_3	47.08048915932617	15.464109778404235
13	Weg2_29/1	47.080384135206586	15.46401858329773
14	Weg2_29/2	47.080559479707894	15.463970303535461
15	Weg3_1	47.08302520064102	15.46811431646347
16	Weg3_2	47.08358225512246	15.468060672283172

Figure 8: Definition of measurement points

5.2 MEASUREMENT RESULTS

To determine the positioning accuracy of the three smartphones, all predefined reference points had to be measured with each device. It was possible to receive GPS information at any time however the accuracy of the signal was poor between buildings and inner yards. WiFi- and cell positioning accuracy was within the expected range.

The following table shows the average positioning accuracy of all three test devices using GPS, WiFi or Cell positioning based on the deviation from 14 predefined reference points:

	GPS	WiFi	Cell
Samsung Galaxy Nexus	± 11m	± 40 m	± 157 m
HTC Hero	± 14 m	± 50 m	± 231 m
Samsung Nexus S	± 14 m	± 43 m	± 239 m

Table 1: Position deviation

Figure 9 shows the deviation of the GPS- and WiFi-position from the exact reference point 34/5 (Kinderklinik) (the cell position exceeds the limit of the image snippet and is therefore not visible). The measurements were taken with the device "Samsung Galaxy Nexus (Texas Instruments SIRF GPS)". The deviation of the GPS-position amounts to 5 meters, the WiFi-position 35 meters and finally the cell position 200 meters. At this reference point, a good GPS accuracy was to be expected because of the clear sight southwards.

Figure 9: Measurement result for reference point 34/5 (Kinderklinik). The GPS fix for that position was within 5 meters accuracy. The positioning fix obtained by wifi deviated 35 meters.

In Figure 10, a slightly worse measurement example is illustrated. The measurement was taken within an inner yard, using the same test device as above (Samsung Galaxy Nexus). As expected, the GPS positioning was rather poor. The GPS position deviates 29 meters, the WiFi position 49 meters from the reference point. It was not possible to determine the cell position. The poor measurements resulted from obstruction of the GPS signal caused by the tall buildings.

Figure 10: Measurement result for reference point 14/9 (Frauenklinik). The GPS measurement's deviation is in the same range (29 meters) as the Wifi position result (49 meters).

5.3 CONCLUSIONS ON THE STUDY

The measurements have shown that it is sufficient for a pedestrian navigation system to use positioning via GPS. However problems occur, when navigating between high buildings or within inner yards, through obstruction of the GPS signal. This may result in poor accuracy of the GPS position. Nevertheless the positioning study has shown that a satisfactory positioning via GPS can be achieved in the described area.

6. PEDESTRIAN ROUTING APPROACH

Pedestrian navigation in urban areas naturally requires detailed information about the street grid. In contrast to motorized vehicles, pedestrians also access stairways, park walkways and shortcuts through buildings, for example. In addition to this, pedestrians are able to use small sized way points such as address signs, nature of pavement or prevalent structures. In order to access this kind of information, the popular crowd-sourced mapping project "OpenStreetMap" (OSM) can be interfaced. This project is maintained and complemented by thousands of people all around the world. Depending on the involvement of the various contributes in a certain area the level of detail is on par with commercial services. Figure 11 shows a comparison between OpenStreetMap (left) and Google Maps (right) for a famous tourist site in the Inner City of Graz - the Schlossberg.

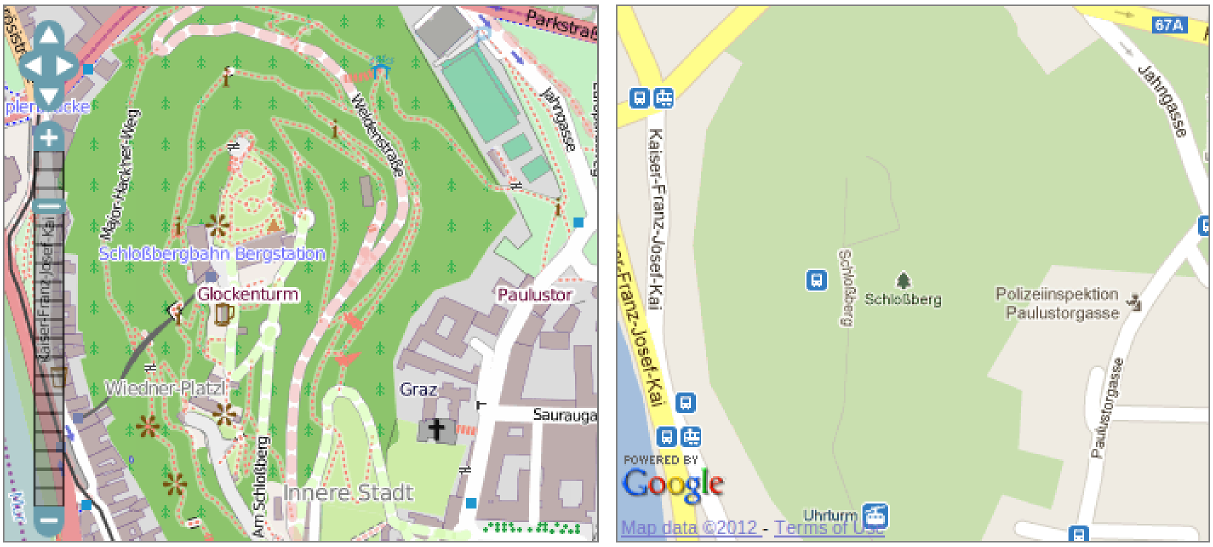


Figure 11: Comparison between Google Maps (right) and OSM (left) for a famous tourist site in the Inner City of Graz - the Schlossberg.

Here, aside from the exact course of the walking paths, also shapes of buildings nearby are available. In addition to this, various points of interests, like pubs, bars and even sitting benches can be accessed via the OpenStreetMap interface.

6.1 DATA AGGREGATION

OpenStreetMap data is being edited and complemented by thousands of people all around the world via means of a browser plugin. This input method allows for manual assignment of attributes such as structure shapes, building names or address numbers. Additionally it's possible to import tracks which have been recorded by using a GPS receiver. In Figure 12 the modification of an address value in the study test area is shown.

As reference, the user is provided with an detailed aerial photograph. The shape of already included buildings is denoted in transparent magenta, main entry doors are light blue (secondary ones are black) and pedestrian walkways are colored in white.

6.2 PROCESSING OF OPENSTREETMAP DATA

The hosting servers of the OSM project use a relational database system with geospatial extensions (PostgreSQL with PostGIS) to store the aggregated data. In addition to this, a rendering component called Mapnik which finally is responsible for displaying the map data is installed. The rendering results are stored formatted according to the Tile Map Specification (TMS) and saved as Portable Network Graphics (PNG). It can be assumed that the state of the majority of the map data remains unchanged. Therefore the data set is checked for modifications (and re-rendered) on a weekly basis. Since the popularity of the OSM project surged rapidly over the last years (and with that the server usage), the project members require heavy data traffic applications to utilize their own hardware infrastructure.

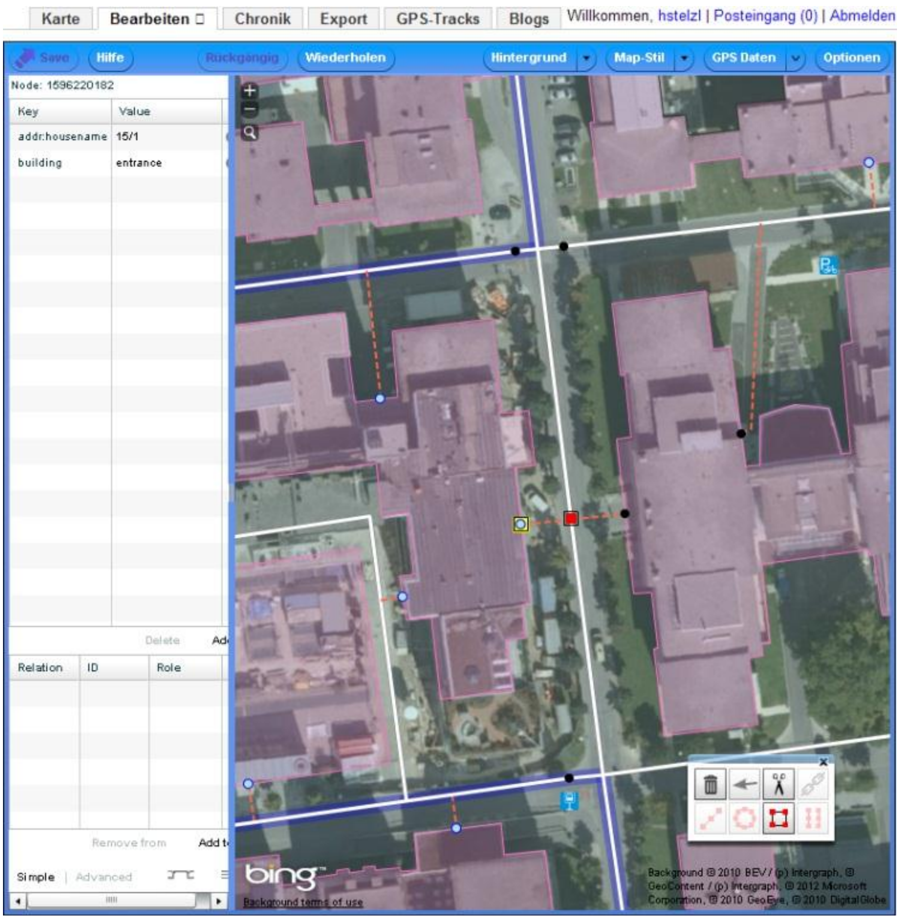


Figure 12: Web browser tool for creating and editing OpenStreetMap data. As a reference, a high resolution aerial photograph is displayed as underlying image.

External one-time access to the OSM data is possible either via XML or in a faster processable (albeit human unreadable) format called protocol buffers. Since the MASELTOV test areas are bound to specific regions, cloning the complete data set (corresponding to the whole planet earth) would be unnecessary. Fortunately, there are various services (Cloudmade, Geofabrik) available which provide country-based pieces of the dataset. If a country-wide selection is still too large, the area of interest can be restricted further with additional tools (Osmosis). The command for specifying a bounding box ranging from Peterskirche to Stephansplatz in Vienna is as follows:

```
$ osmosis.bat --read-xml file=austria.osm.bz2 --bounding-box top=48.210241 left=16.370532bottom=48.207956 right=16.373847 --write-xml file=extracted.osm
```

Here, a BoundingBox with WGS84 Coordinates for the upper left (48.208907, 16.372298) and the lower right (16.373847, 48.207956) is specified. This limit could also be extended to match a pedestrian area, or a polygon shape such as a district border. An example extract of the data looks as follows:

```
<node id="567057048" version="3" timestamp="2012-08-13T12:14:06Z" uid="51552" user="kfg"
changeset="4825828" lat="48.2081643" lon="16.3734772">
   <tag k="addr:city" v="Wien"/>
   <tag k="addr:country" v="AT"/>
   <tag k="addr:housenumber" v="1"/>
   <tag k="addr:postcode" v="1010"/>
```

```
   <tag k="addr:street" v="Stephansplatz"/>
   <tag k="note" v="die Hausnummer 1 gehört nicht dem Dom, sondern nur der Sakristei - der Dom selbst hat keine Hausnummer, daher an der Südseite anzuordnen"/>
</node>
```

Apart from the unique identification number, every OSM node consists of its modification timestamp, the global changeset counter, the contributor and the position in WGS84 coordinates. Additionally, nodes can be attributed more descriptive tags. Here, the XML representation of the address "Stephansplatz 1" in Vienna is shown. A sidenote from the editor translates to: "House number 1 doesn't belong to the dome, but the sacristy - the dome itself doesn't have a number, therefore [the node] has to be placed at the south".

6.3 ROUTING ALGORITHM

Finding the optimal route between a starting point A and a destination point B can be formulated as a problem in graph theory, where vertices correspond to possible locations (places, addresses, kilometre of road) and edges establish possible connection vectors (roads, elevators, walking paths, stairs, etc). These are attributed a cost function which represent different characteristics of the chosen route (length of road, slope, pavement structure). If one-way streets are part of the routing network, a directed graph with a very high cost function in the forbidden direction is normally used, however, for pedestrian routing applications this is normally not an issue. Figure 13 shows an example of an undirected graph.

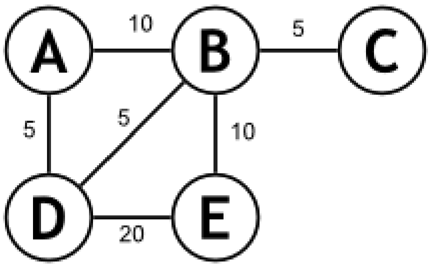


Figure 13: Example routing graph

As shown in the data extract above, the OSM data representation lacks the necessary graph structure for routing purposes. In order to convert the original data to the desired format, a tool called osm2po is used. This program is able to convert OSM data in XML or protocol buffer form directly to relational database tables which can be spatially queried efficiently. Additionally, it is possible to optimize the output format for pedestrian usage purposes. To convert the XML data format, the following simple command is necessary:

```
$ java -jar osm2po-core-signed.jar extracted.osm
```

osm_name	source	target	cost
Goldschmiedgasse	1	2	0.098895214
Jasomirgottstraße	3	4	0.10540362
Bauernmarkt	5	4	0.04869171
Bauernmarkt	4	6	0.026703665
Freisingergasse	6	2	0.03827294

Table 2: Converted OSM nodes.

This produces a ".sql" file with one Table containing (amongst others) the following important columns (excerpt, see Table 2).

Here, the node names are given by the source id. The target column specifies the edges between the different nodes. The cost values have been determined by slope and pavement parameters of the walkway. The standard method for finding the optimal (=lowest cost) route between two arbitrary points is provided by (Dijkstra 1959). In this project, an extended version employing heuristics called A* is used. For that approach, the world coordinates of the different nodes have to be known too.

7. SAMPLE APPLICATION

The following section describes the main components of the smartphone application. The components basically consist of an input option, departure monitor, route calculation, navigation and augmented reality navigation. Subsequent to this section some screen examples of the mentioned components will be shown.

7.1 OVERVIEW

In Table 3, the various components of a smartphone sample application for augmented reality navigation purposes is shown. The application is organized in several modules which aid the user in foreign environments in a clearly structured way.

Component	Description
Input Option	This component allows the user to define the starting point, destination and arrival- or departure time for the route. It is possible to search for locations or to browse through categorized locations.
Departure Monitor	The departure monitor shows all departures of public transport vehicles within the users vicinity. Time until departure and distance between the current position and the particular stop is also shown.
Route Calculation	After having entered the route query, this component calculates several possibilities for the routing. Besides a list representation of the route suggestions, a map view provides an overview for each route.
Real-time Navigation	This component implements the real time navigation of the application. The navigation is supported by a detailed list of routing instructions together with a map view and text-to-speech output.
Augmented Reality Navigation	In addition to the navigation component, the augmented reality navigation provides real world information about the current heading and the desired heading.

Table 3: Components of example application

7.2 SCREEN EXAMPLES

This section shows some possible screen examples of the smartphone application for augmented reality navigation purposes. Screen examples for the components "Input Option", "Departure Monitor" and "Augmented Reality Navigation" as described in Table 3, are shown. The screen examples are in Turkish language.

7.2.1 INPUT OPTION

After the start of the application, the route planner, as shown in Figure 14, appears. The route planner allows the user to specify starting- and destination point, as well as arrival- and departure time for the route.

Figure 15, shows the search screen for the starting- and destination point of the route. Also browsing through bus- or tram stations or services, such as pharmacies or banks, in the nearby area is possible.

Figure 14: Routeplanner

Figure 15: Start/Destination search

7.2.2 DEPARTURE MONITOR

The departure monitor shows all departures of public transport vehicles within the user's vicinity. In Figure 16, a list of stations in the nearby area is shown. Figure 17 shows all departures for a selected station. Time until departure and distance between the current position of the user and the particular stop is also shown.

Figure 16: Stations in vicinity

Figure 17: Departures of the chosen station

7.2.3 AUGMENTED REALITY NAVIGATION

The augmented reality navigation, as shown in Figure 18, consists of real time navigation with an augmented real-world camera view. It provides information about the current heading and the desired heading, in addition to the textual navigation instruction, for an easier navigation through foreign areas.

Figure 18: Augmented reality navigation with navigation instruction, heading and info about the next destination

8. SUMMARY AND OUTLOOK

For mobile information-applications it is essential to have an appealing, easy to use graphical user interface, offline availability of the content and location-aware features.

In addition to these features, a number of services can be added to improve convenience through intelligent and context-aware support for the user. The following Sections describe fundamental cases of application and their possible implementation.

8.1 OPTIMIZED PEDESTRIAN ROUTING

Below, a possible description of a path from *Karmeliterplatz* to *Uhrturm* in Graz is given.

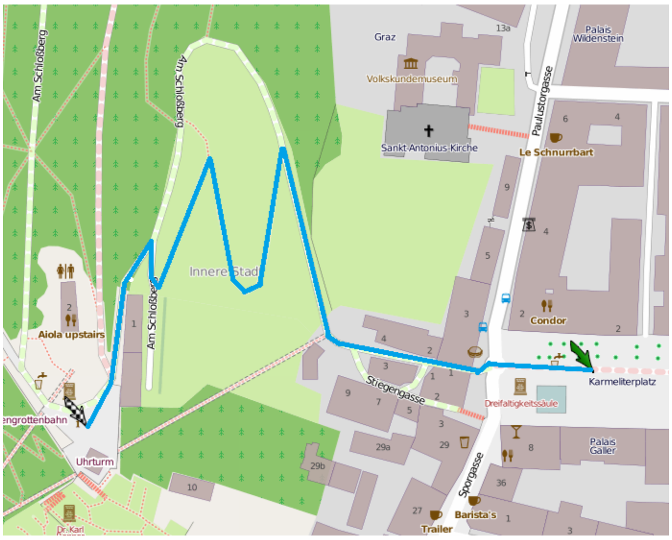


Table 4: Track between Karmeliterplatz and Uhrturm in Graz

Start from the bus stop at Karmeliterplatz and walk towards the big archway. You are going to pass by a statue on the left hand side. At the gateway to Dom im Berg, follow the road to the right. After 150 meters, walk on the stoned path on the left hand side. After reaching the street again, turn to the left. Pass by two more houses on the right hand side and you have reached the Uhrturm.

In contrast to the above example, a conventional route description is given here:

Start from Karmeliterplatz towards west to Am Fuße des Schloßbergs. Walk 150 meters. Turn right to stay on Am Fuße des Schloßbergs. Walk 120 meters. Turn left to Unbekannte Straße. Walk 180 meters. Turn left. Walk 100 meters, then you have reached your destination.

In addition to the information about the distance, context-sensitive route descriptions also consider special characteristics about the surrounding, such as the condition of the path or special buildings. This is very useful for streets, where the name is unavailable or unknown and no useful navigation would be possible without additional information.

8.2 USER PROFILE-BASED RECOMMENDATION SYSTEM

Smartphones can provide a rich offer of information and support on behalf of the user. To overcome this mass of information, recent research was concerned with the issue of filtering relevant information and providing recommendations based on the situation-dependent context of the user's environment.

With the help of context-aware smartphones, it would for example be possible to automatically warn about bad weather conditions, if the user is planning to make a trip. Also useful would be, to inform the user about discounts of nearby shops or hotels. Of course the protection of the privacy has first priority. It must be possible for the user to control the privacy options, in a clear and understandable manner.

8.3 WORK PLANNED TOWARDS THE FINAL DELIVERABLE

The next steps towards the final deliverable will involve the necessary work to integrate the augmented reality component described above into the MASELTOV system. The user interface will be improved further to ease navigation in urban areas. Furthermore the navigation system will be evaluated with the different target user groups at the test sites Vienna, London and Madrid. Finally, the feedback gained from that evaluation will be integrated as a further iteration in the software prototype.

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