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Table of Contents

Section I: Wayfinding and Navigation

Section II: Spatio-Temporal Data Processing and Analysis

Section III: Visualization

Section IV: Positioning

Section V: LBS Application and Development

Visual demand for maps at different scales of in-route guidance and navigation system

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Abstract. This work evaluates drivers' visual demand for maps at different scales when they perform simple maneuver (i.e. 'Turn right') and complex maneuver (i.e. 'Take the second exit at the roundabout') using in-vehicle route guidance and navigation system. A group of 52 subjects (26 males and 26 females) participated of an experiment in a driving simulator. Drivers were required to navigate using maps at scale 1:3,000 and 1:6,000. Results show that both scales were equally satisfactory to support drivers in simple maneuver. However, the more generalized map was more efficient in complex maneuver, since it has required low visual demand for drivers. Results also show that drivers' performance is related to their gender. Results are discussed in terms of the different stages which compose the navigation task. To reduce drivers' distraction, it is suggested to adopt map scale according to complexity of maneuver. We also suggest driver's gender be taken into account on interface designs for route guidance and navigation system, since this group characteristic has influenced the amount of time that drivers spend their eyes off-road to get information on these interfaces.

Keywords. In-vehicle route guidance and navigation system, visual demand, map scale selection, usability

1. Introduction

The usability issues of In-vehicle Route Guidance and Navigation Systems (RGNS) interfaces have been widely discussed over the last decades (Green et al. 1995, Liu 2001, Nowakowski et al. 2003, Pugliesi et al. 2009, Ching-Torng at al. 2010, Lavie et al. 2011, Burnett et al. 2013). One of the main concerns is that drivers require diverting their eyes from the road to receive visual information from these interfaces. Diverting eyes from the road to interact with interfaces, like RGNS, has been linked with drivers' visual dis-

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traction, and this topic has become a major concern for traffic safety (NHTSA 2012) especially because the use of in-vehicle systems has grown significantly in recent years (ABIresearch 2014). Another important issue that should be highlighted, since it may enhance risks at driving task, is related to difficulties to get information from maps while car is moving due to cartographic communication problems (Lavie & Oron-Gilad 2013).

In-vehicle route guidance and navigation systems may be much more efficient if they provide relevant information without overloading drivers' cognitive processing system (Pugliesi et al. 2013). To avoid high mental workload on drivers and consequently serious impacts on transportation safety, designers of RGNS should take into account that drivers have to get information on navigation map in an easy and rapid way. The design of efficient and effective maps for RGNS involves several variables (Pugliesi et al. 2009, Lee & Jun 2010, Marques et al. 2012). One fundamental variable refers to map scale selection, since it can improve drivers' performance at decision points when following a route (Ramos et al. 2014c).

Several measures have been adopted to evaluate usability of in-vehicle route guidance and navigation system interfaces. One of them is visual demand which is related to drivers' visual distraction (Pugliesi et al. 2013). The visual demand refers to the amount of time that drivers need to acquire information in a visual interface and it can be quantified in terms of a several quantitative measures, such as the number of glances, the mean duration of glances and the minimum duration of glances (Tsimhoni & Green 2001, Pugliesi et al. 2013). The number of glances refers to the number of time that the driver looks at the display to complete a task (Tsimhoni et al. 1999). Duration of glance includes the time from the moment the driver's eyes were fixed on the road, started to move to the display, and then returned to the road again (Pugliesi et al. 2009). The minimum duration of glances consists of the shorter time required to get information from a visual interface (Pugliesi et al. 2009), and the mean duration of glances consists of the mean amount of time required to acquire information from a visual interface (Tsimhoni et al. 1999). The mean duration of glances is represented by the ratio between the sum of glances and the number of glances.

This work aims to evaluate drivers' visual demand for maps at different scales to perform simple and complex maneuver using RGNS. Number of glances, minimum duration of glances and mean duration of glances were the variables used to quantify the visual demand. The research questions are: "In which scale do navigation maps demand more number of glances?"; "Is mean duration of glances influenced by map scale?"; "In which scale are maps more quickly to be read?"; and " Is drivers' gender related to visual demand when using navigation maps at different scales?"

2. Method

2.1. Subjects

A total of 52 subjects from Presidente Prudente town (Brazil) participated voluntarily of a controlled experiment. The group of participants was composed of 26 males and 26 females with mean age of 28.05 years (±4.62). To recruit them, the following criteria were adopted: to be regular drivers for at least 2 years, having normal color vision and having no or little knowledge of the town used in the experiment.

2.2. Experimental route

The experimental route is located in a small town and is composed of thirteen maneuvers. The maneuvers were classified as simple (i.e.: 'Turn right') or complex maneuver (i.e.: 'take the second exit at the roundabout') according to the exits number of the junction. This route was filmed and used to represent the real world at the driving simulation task.

2.3. Map design

Maps were designed at two different scales 1:3,000 and 1:6,000. These values of scales were defined based on the results of the researches developed by Marques et al. (2012) and Ramos et al. (2014a). The map design was based on the proposal of map for RGNS implemented by Pugliesi et al. (2009) initially and then improved by Marques et al. (2012). This proposal is based on cartographic communication principles, like perceptive grouping principles and figure–ground principles as pointed out by MacEachren (1995), Dent et al. (2009) and Slocum et al. (2009). Moreover, we also designed the maps based on the results of Brazilian drivers' preference for color of map elements (route and direction arrow) which were recently presented by Ramos et al. (2014b).

2.4. Map production

Maps at different scales were implemented in a RGNS prototype using ESRI MapObjects with Microsoft Visual Basic. This prototype has been developed by members of research group (Pugliesi et al. 2009, Marques et al. 2012, Ramos et al. 2014c). Maps are presented in heading-up orientation with orthogonal view and are composed by features, such as car (RGB=250,0,0), route (RGB=0,0,0), direction arrow (RGB=0,255,0), street name (RGB=0,0,0) and road network divided into main (RGB=255,166,0) and secondary (RGB=255,255,255) road types. The RGNS prototype also presents a beep a few meters before each maneuver to indicate the beginning of each tactical task. This is an important task since it refers to the preparation for making maneuvers (Michon 1985) and it is responsible to overload the drivers' cognitive processing system (Kaber et al. 2012). Maps at 1:3,000

(Figures 1a and 1c) and 1:6,000 (Figure 1b and 1d) are shown to represent simple (Figure 1a and 1b) and complex maneuver (Figures 1c and 1d) for the tactical task.

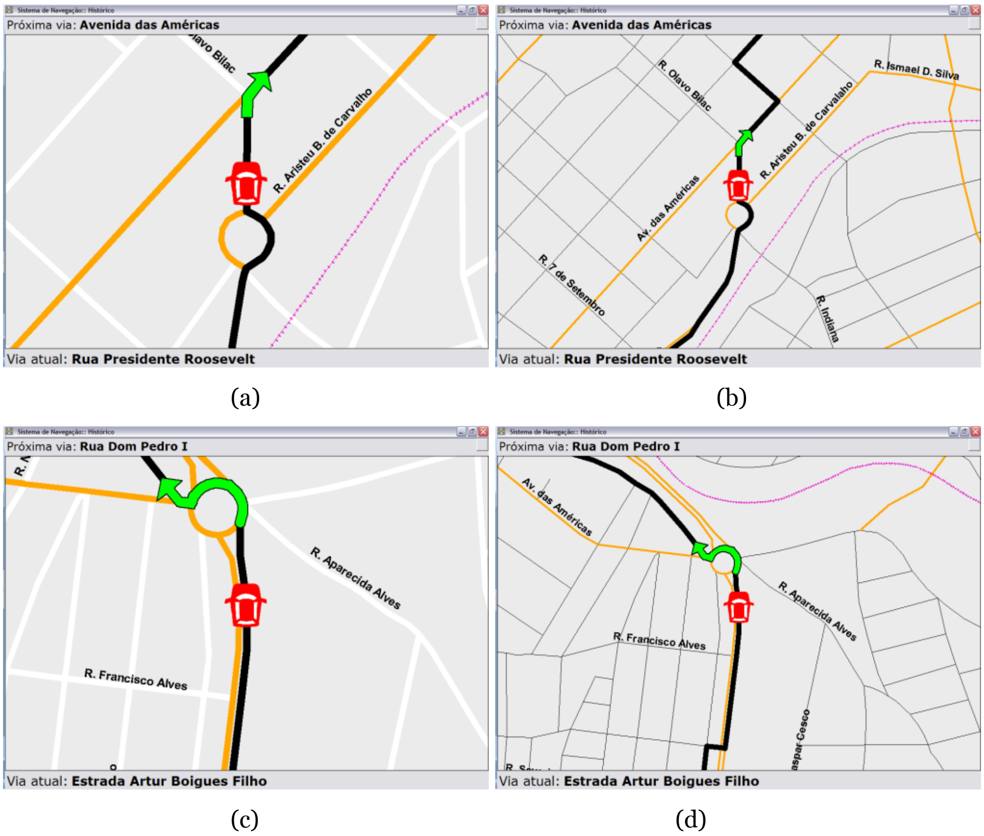

Figure 1. Maps at different cartographic scales representing different types of maneuvers.

2.5. Driving simulator

The experiment with 52 drivers was conducted in a low-cost and fixed-base driving simulator (Figure 2). This simulator is comprised by several materials and equipments. A large screen-image (180 cm height and 240 cm width) located in front of the car was used to display a video movie of the experimental road. To show the maps for drivers, it was used a small-screen LCD display of 7-inches (XENARC 700-TSV) with video resolution of 1024 x 768. This monitor was placed on the dashboard, in the right side of the steering wheel as recommended by Burnett et al. 2012.

The video movie of the route was displayed on the screen-image using a video projector which was connected to a computer via a serial connection.

Another computer was used to run the RGNS prototype which was connected via VGA port to the navigation display. The auditory information was presented using personal computer speakers which were positioned behind the driver's and passenger's seats. The drivers' visual demand was recorded using a Tablet of 7-inches with video resolution of 1024 x 768.

Figure 2. Driving simulator images.

2.6. Procedure

To perform driving simulation task, drivers were divided into two equal-sized groups of 13 males and 13 females. Group 1 started driving task using maps at 1:3,000 scale (maneuvers 1 to 6) and finished the travel using maps at 1:6,000 scale (maneuvers 7 to 13). Group 2 started the driving task in a different sequence, first with maps at 1:6,000 scale (maneuvers 1 to 6) and then maps at 1:3,000 scale (maneuvers 7 to 13).

For driving simulation task, initially drivers were familiarized with the simulator, map scales, tactical task and beep. After that, drivers were required to suppose that they should be navigating by car in an unknown town using a RGNS. Drivers were also advised to pay the necessary attention to the video movie to avoid traffic accidents and to look at the navigation display by taking quick glances to get map information, preferably after the beep. Finally, after driver signing a consent form and saying the test could begin, the driving simulation task started.

3. Results

The visual demand data were extracted using a manual video frame capture with Microsoft Windows Movie Maker. Because tactical task time is influenced by traffic conditions and road feature, the analysis and comparison of visual demand among different maneuvers was focused on the shortest tactical task time which corresponded to 11 seconds.

Table 1 lists the descriptive statistics (minimum, maximum and median value) and normality test results for each dependent variable, like number of glances, minimum duration of glances and mean duration of glances considering simple and complex maneuver which were visualized at two different scales 1:3,000 and 1:6,000.

	Scale	Number of glances			
		Min.	Max.	Median	p-Value*
Simple maneuver	1:3,000	1	7	3	0.001
	1:6,000	1	5	2	0.001
Complex maneuver	1:3,000	1	6	3	0.121
	1:6,000	1	4	2	0.137
	Scale	Minimum duration of glances (seconds)			
		Min.	Max.	Median	p-Value*
Simple maneuver	1:3,000	0.48	1.76	0.80	<0.0001
	1:6,000	0.48	2.48	0.80	<0.0001
Complex maneuver	1:3,000	0.40	5.33	1.96	<0.0001
	1:6,000	0.58	2.68	1.04	<0.0001
	Scale	Mean duration of glances (seconds)			
		Min.	Max.	Median	p-Value*
Simple maneuver	1:3,000	0.49	1.79	1.03	0.001
	1:6,000	0.68	2.48	0.97	<0.0001
Complex maneuver	1:3,000	0.74	2.66	1.32	<0.0001
	1:6,000	0.81	3.17	1.31	<0.0001

Table 1. Some statistical for visual demand data. *p-Value was calculated by Shapiro-Wilk. When p-Value was greater than 0.05, the normality assumption was approved.

The Shapiro-Wilk test results showed that the majority of data related to each variable of interest has no normal probability distribution. The only exception was the data related to the number of glances in the case of complex maneuvers. Therefore, as recommend by Conover (1999), to perform statistical analyses considering data with normal distribution will be adopted non-parametric tests, such as wilcoxon and Mann-Whitney test. While to perform statistical analyses considering data with normal distribution will be adopted parametric tests, such as Paired-Samples T test and Independent-Samples T test. All data were processed using SPSS 16.0 (Statistical Package for the Social Sciences Software) for a confidence level of 90%.

Table 2 lists the statistical results and shows that the influence of scale was significant ($p<0.05$) in at least two of the three dependent variables. Taking into account tactical task in simple maneuver, Wilcoxon test results revealed that there is no difference between 1:3,000 and 1:6,000 scales in terms of the number of glances ($p=0.382$), of the minimum duration of glances ($p=0.809$) as well as of the mean duration of glances ($p=0.774$). Thus, both map scales are equally efficient to support drivers to perform this kind of maneuver. However, taking into account the tactical task in complex maneuver, statistical results show that both the number of glances ($p<0.0001$) and the minimum duration of glances ($p<0.0001$) were significantly higher when a more detailed map (1:3,000) was used by drivers. There is no difference between the two map scales in terms of the mean duration of glances ($p=0.456$) in complex maneuver. It may be pointed out that mean duration of glances is not influenced by the map scale, even if it has been considered maneuvers with different levels of complexity.

	Comparison between: First x second	Number of glances			
		Wilcoxon (rank sums)			
		First	Second	Z	p-Value
Simple maneuver	1:3,000 x 1:6,000	756	570	-0.874	0.382
Complex maneuver	1:3,000 x 1:6,000	Paired-Samples T test			
		Mean	SD	t	p-Value
		3.22 x 2.67	0.955 x 0.871	4.437	<0.0001*
	Comparison between: First x second	Minimum duration of glances			
		First	Second	Z	p-Value
Simple maneuver	1:3,000 x 1:6,000	662.5	715.5	-0.241	0.809
Complex maneuver	1:3,000 x 1:6,000	1141	237	-4,117	<0.0001*
	Comparison between: First x second	Mean duration of glances			
		First	Second	Z	p-Value
Simple maneuver	1:3,000 x 1:6,000	657.5	720.5	-0.287	0.774
Complex maneuver	1:3,000 x 1:6,000	742.5	583.5	-0.745	0.456

Table 2. Summary of the analyses for dependent variables. *Significant at $\alpha = 0.01$.

The results presented in Table 3 revealed that there is a significant relationship between drivers' gender and their performance on tactical task. We noted that women have to look at maps more frequently than men to perform the tactical task in simple maneuver, independently the map scale used, if 1:3,000 (p=0.008) or 1:6,000 (p=0.071).

	Map scale	Visual demand variable	Mann-Whitney test (ranks mean)			
			Gender		Z	p-Value
			Male	Female		
Simple maneuver	1:3,000	Minimum duration of glances	29.71	23.29	-1.533	0.125
		Mean duration of glances	29.27	23.73	-1.318	0.187
		Number of glances	20.94	32.06	-2.656	0.008*
Complex maneuver		Minimum duration of glances	24.46	28.54	-0.971	0.331
		Mean duration of glances	27.77	25.23	-0.604	0.546
		Number of glances	Independent-Samples T test			
			Mean	SD	t	p-Value
			3.09 x 3.35	1.075 x 0.820	-0.965	0.339
	1:6,000	Visual demand variable	Mann-Whitney test (ranks mean)			
			Gender		Z	p-Value
			Male	Female		
Simple maneuver		Minimum duration of glances	27.75	25.25	-0.596	0.551
		Mean duration of glances	27.38	25.62	-0.421	0.674
		Number of glances	22.79	30.21	-1.807	0.071*
Complex maneuver		Minimum duration of glances	24.71	28.29	-0.852	0.694
		Mean duration of glances	28.13	24.87	-0.778	0.437
		Number of glances	Independent-Samples T test			
			Mean	SD	t	p-Value
			2.67 x 2.67	0.939 x 0.817	0.250	0.980

Table 3. Summary of the analyses related to drivers' gender. *Significant at $\alpha = 0.01$.

4. Discussion

This section discusses the results obtained with a group of drivers from an experiment in a low-cost and fixed-base driving simulator. The results showed that drivers had better performance in complex maneuver when they were instructed by more generalized map. Probably this occurred due to the maps at 1:6,000 scale can support drivers to identify not only the direction of next maneuver clearly, but also to get surrounding information of the route (example Figure 1b).

According to Burnett (1998), navigation task is composed by a number of different stages, such as preview, identification, confirmation, trust and orientation, and the literature (Ross & Burnett 2001, Lee et al. 2008, Marques et al. 2012, Ramos et al. 2014c) has suggested that an efficient navigation map is that which supports drivers in each stages. The preview and identification stages are directly related to tactical task, while confirmation, trust and orientation stages are related to navigation task as a whole.

Based on Figure 1a and Figure 1c, for example, we can assumed that maps at 1:3,000 can also help the drivers to identify the direction of next maneuver in details. However, this map scale, when displayed in seven-inch monitor, allows drivers to visualize two and a half blocks only. This reduces the surrounding information of route, and it may negatively affect the trust and orientation stages. We assumed that navigate using cartographic representations which establish a proper relation between spatial information about route and details of the next maneuver seem to favor drivers to be more confident to comprehend map information and this, consequently, contributes to reduce the drivers' visual demand.

5. Conclusion

This section presents some conclusion from the obtained findings, some recommendations regarding the interface design for in-vehicle route guidance and navigation system and also some suggestions to future studies.

We conclude that cartographic communication performance of navigation maps depends on the scale selected, especially when they have to support drivers in complex maneuvers. In the study case, because the more generalized map requires low visual demand, it seems to be more appropriate to support the tactical task related to complex maneuver. We also conclude that gender is an important issue to be considered at map scale selection.

To improve usability of RGNS in terms of drivers' distraction, it is recommended that map scale should be set up considering a proper balance between spatial information about route and amount of information required for the next maneuver. Moreover, it is recommended to adopt scale according to complexity of maneuver.

We suggest that future studies explore deeper the relationship between drivers' performance and their gender, since this group characteristic has influenced the amount of time that drivers spend with their eyes off-road to receive information from RGNS interfaces. We also suggested to associate visual demand with other objective measures, such as navigational errors, as well as with subjective measures such as drivers' satisfaction. These will help to estimate more accurately the drivers' mental workload related to driving and using in-vehicle route guidance and navigation system

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A Framework for Navigating with Map Signboards on Smartphones Using Basic and Advanced Image Geocoding Methods

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Abstract. Map signboards are widely distributed in public places. The map signboards are more concise, thematic, artistic, and diverse than current web maps, but map signboards also have shortages on accessibility and mobility. We propose a framework to integrate map signboards with Location-based Services on smartphones. We provide basic and advanced geocoding methods for different situations. The basic geocoding includes direction alignment and point based referencing, which are easy to operate by ordinary users. The advanced geocoding is based on polyline referencing. It provides more accurate positioning result, but it is relatively difficult to build the referencing polylines. Professional users with background knowledge of GIS and cartography are supposed to make the advanced geocoding, and the results would be shared to ordinary users. Our experiments show that ordinary users can easily make correct basic geocoding; meanwhile, the advanced geocoding offers better positioning result, which could ensure the relative spatial relation between user's location and the roads on the map.

Keywords. Map Signboards, Pedestrian navigation, Polyline references

1. Introduction

Nowadays, people rely more and more on Location-Based Services (LBS). With smartphones, people can get access to maps, like Google Maps and Apple Maps, almost anytime and anywhere. However, as large companies, such as Google, Apple, Baidu, and so on, have dominated the web maps, the styles of web maps are limited. The web maps that are now usually used as standard tools for spatial searching and navigation are useful but not attractive.

On the other hand, another kind of maps that are widely distributed in public places and used by the public are map signboards. Compared with web maps, map signboards have advantages on their artistic expression and the diversity of styles, which make map signboards attractive and interesting. And compared with illustrated maps on guidebooks, map signboards are easier to find self's position with the help of YOU ARE HERE point. However, map signboards also have shortages: misaligned orientation, scattered distribution and immobility. These disadvantages make map signboards difficult to read and limit the accessibility for people.

If the advantages of map signboards and web maps could be combined on smartphones, it would make way finding easier and more interesting. With this idea, researchers have started explorations on this field when smartphones were not as popular as present. Schöning et al. (2009) proposed the technic to use GPS equipped mobile phones to take, geocode, and display You Are Here (YAH) maps. They proposed two ways of geocoding YAH maps: *two point referencing* and *smart alignment*. These methods are easy to operate but each has limitations. The two point referencing method is available only for northed maps while the smart alignment method asks that the user's trace overlaps with the spatial extend of the photo of the map. These are all critical requirements, and according to the paper, only 81% maps they collected meet the first requirement and less than half (%48) maps meet the second requirement. Morrison et al. (2011) made AR application *MapLens* which could timely overlay location-based media on the paper map image through the camera of mobile phone. It use predetermined map data files to position medias on the right place. This application only works on the predetermined maps, which limits the usability of it. Wang et al. (2012) proposed a three point referencing method to calculate user's location on the image of site maps. The method uses three referencing points, which are weighted by the horizontal accuracy of the GPS positioning, to calculate user's locations on the image. Although the method reduces the error, in some degree, that are brought by the error of GPS positioning, it does not necessarily reduce the error that caused by the reference points on the image and the distortions of the site maps. Thus the improvements of the results are very limited. Lu and Arikawa (2013, 2013 and 2014) studied on integrating illustrated maps on tour guiding books with the mobile devices. They did not only geocode the map part to position user's locations, but also geocode the texts and images to offer multimedia story telling and real time instructions. They also enables user's to make geocoding for spatial references and POIs. However, the editing tools are complex and it is difficult for ordinary users to operate. The related works did contribute a lot but the main shortages come in two aspects: accuracy of positioning and the feasibility of operation for ordinary users.

In this paper, we will introduce our work on embedding Location-based Services (LBS) in map signboards on smartphones. We provide two levels of map geocoding methods: a simple method for ordinary users to make basic geocoding of map signboards for accessing basic LBS like reorienting and positioning; and a relative complex method for GIS specialists and cartographers for more accurate positioning.

2. Framework of Geocoding for Map Signboards

To embed LBS in map signboards, we build the mapping relation between map signboards (the target maps) and base maps using web maps (like Google Maps and Apple Maps). Unlike topographic maps and photogrammetry images, whose distortions mainly come from map projection and are regular, map signboards sometimes are distorted irregularly for emphasizing themes and for artistic expressions. Such distortions increase the difficulty for mapping positions accurately from base maps to the image of map signboard.

The number of map signboards is too large that it is difficult to geocode all of them for users beforehand. One solution is that users can take photos of map signboards and make geocoding by themselves. Considering the difficulties for ordinary users without special training on Geographic Information Systems (GIS) and cartography to make geocoding, we designed the strategy to offer two geocoding methods for different users and different situations. One is basic geocoding, which use north arrow and reference points to enable the functions of map auto-aligning and location positioning. The other is advanced geocoding based on polyline references, which offers better positioning function. The basic geocoding is simple for ordinary users to operate so that they could get a quick LBS on map signboards; while the advanced geocoding is relatively complex and users with background on GIS and cartography are supposed to make it and share the result with ordinary users.

2.1. Basic Geocoding Based on North Arrow and Reference Points

As mentioned above, ordinary users have limited knowledge and skills to make geocoding for maps. One of the most common difficulties that users may meet is to find proper places to add points on the image and to find the corresponding points on base maps. We have designed a basic geocoding method for ordinary users, which includes two steps.

The first step is to align the direction of the map. Usually map signboards show the north arrow, and to make the direction alignment, users need to rotate the map signboard on the screen to make the north arrow on the map signboard upward. By doing so, the system can get the angle from the upward direction of the device to the north of the map image, noted as α, as shown in *Figure 1*. Using the compass sensor, the system can get the angle from upward of the device to the real north direction, noted as β. Then system will calculate the angle from the north arrow on the map image to the real north $\theta = \beta - \alpha$. And by rotating the image with the angle of θ, the map signboard would be aligned with its north arrow being consistent with the real north and its forwarding direction being consistent with the direction the user is facing to.

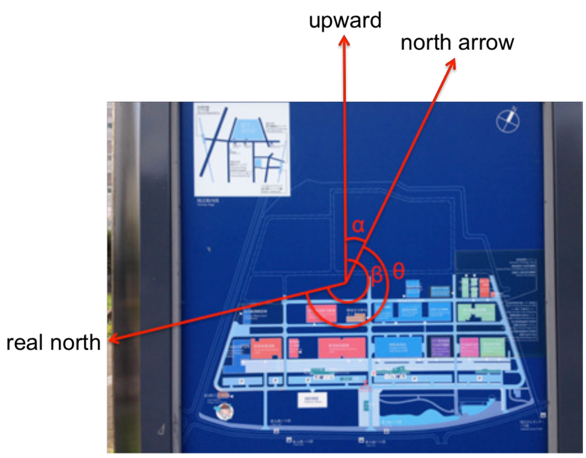


Figure 1. Direction alignment

The second step is to add reference points. For the point based referencing, at least two pairs of reference points are needed for positioning user's location on the target map. We provide two ways for making reference points: inputting reference points directly and matching the trajectory of the user's.

For directly adding reference points, a user has to add corresponded points on both the target map and the base maps. Users are suggested to add the first point at the YOU ARE HERE point when they take the picture of the map signboard, and use their GPS locations as the corresponding point on the base maps. And they could walk along the road and add the second pair of reference points at the first roads intersections in the same way. After the direction alignment, the map is automatically aligned. It is relatively easy for users to find their locations on target map with the hint of the first point and the heading direction. We also provide the way to add reference points on the base map manually, so that user can add many reference points without moving.

The second way is to add reference points by matching trajectory. It is designed for the situation that users cannot find their location on the target map. The system will record user's moving trajectory and display it on the screen, then user is supposed to match the trajectory to the corresponding road on the target map. Because of the different map projections and the irregular distortions of the map signboard, the whole trajectory of the user's sometimes could not be well matched with the target map. To solve the problem, we separate the user's trajectory into straight segments, and the user just need to match segment by segment. Once a segment of the trajectory is matched, the corresponding relations between the points of the segment on the target map and the points of the segment on the base map are built.

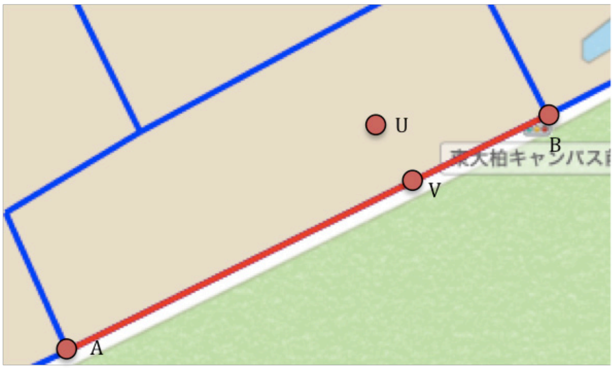
As long as there are two or more pairs of reference points, the application could position user's location on the image of the map signboard. For the detail of the algorithm of two-point referencing, we have taken the results of Schöning et al. (2009) and Lu (2013) as references.

2.2. Advanced Geocoding Based on Polylines

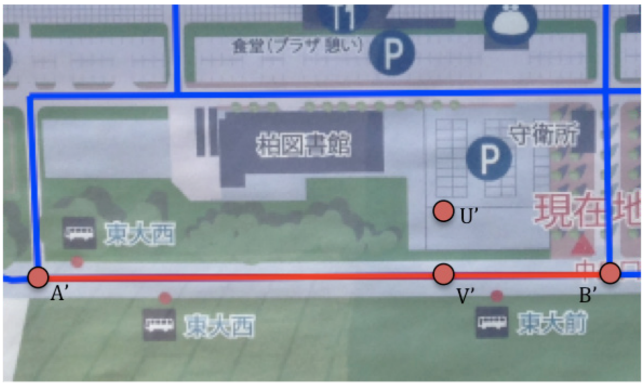
According to Lynch (1960), roads are important spatial references for navigating people. Wrong spatial relations between user's location and the roads will easily mislead the user. Because of the irregular distortions of map signboards, the positioning function based on point referencing does not ensure the correctness of relative spatial relations between user's location and the roads.

To solve the problem, we propose a mapping algorithm based on polyline referencing. It contains the following four steps:

- Digitalizing the target map: users need to depict the roads on the image of map signboard. Usually, roads are depicted by segments. The two nodes of the road are the intersections and should be located accurately. And the order of the start node and the end node on the both target map and the base map should keep consistent.
- Matching roads on target map and roads on base maps. For each road that has depicted on the target map, its corresponding road on the base maps can be picked out to build the mapping relation of the roads on the target map and the roads on the base maps.
- Mapping user's location from base maps to the target map. As shown in *Figure 2*, we can find the nearest road AB from the user's location U on the base maps, and calculate the nearest point V on polyline AB from user's location U. Then we pick up the corresponding road $A'B'$ on the target map, and calculate the point V' on polyline $A'B'$ so that $\frac{AV}{VB} = \frac{A'V'}{V'B'}$. Then we calculate user's location on the target map by making vertical segment from point V', so that $\frac{AV}{VU} = \frac{A'V'}{V'U'}$.
- Check and adjust. By the above three steps, we have got the user's location on the target map. It keeps the correct left and right relation with the road that used as the reference. However, as the distortion of the map signboards may be irregular, some other spatial relation may become incorrect. For example, when the map is asymmetrically scaled, the user's location calculated from the nearest road may be displayed more close to another road on the target map. We need to check the result and make adjustment. As shown in *Figure 3*, the left is the base map while the right is the target map. U is the user's location on the base map, AB and CD are the nearest and the second nearest roads to the user's location U, and the distances are noted as d_1 and d_2. $A'B'$ and $C'D'$ are the corresponding roads on the target map to AB and CD. U' is the user's location on the target map calculated using AB and $A'B'$. d'_1 and d'_2 are the distances from U' to $A'B'$ and to $C'D'$. If $d'_2 \geq d'_1$, we do not need to make adjustment. Else if $d'_2 < d'_1$, we calculate user's location on the target map by the relation that $\frac{d_1}{d_2} = \frac{d'_1}{d'_2}$.

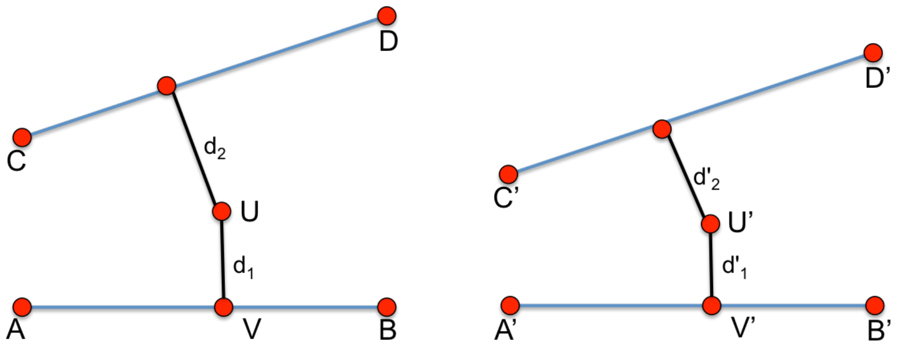


(a) Road AB, user's location U, and the nearest point V from the user's location to the road on base maps.



(b) The corresponding road $A'B'$, mapped user's location U', and the nearest point V' from the user to the road on target map.

Figure 2. Calculation of user's location on target map with roads references



(a) Base map (b) Target map

Figure 3. Adjust of user's location in the case that the target map is asymmetrically scaled

In this section, we introduced the framework to geocode the image of map signboard and to reorient map direction and positioning user's location on the map signboard. We considered the users' abilities to make geocoding of map signboards are different, and proposed two levels of geocoding method: point geocoding for ordinary users and line geocoding for professional users. Users can get quick LBS but rough positioning results using point geocoded maps, while get relatively accurate positioning results if they have downloaded the line geocoded maps.

3. Implementation of Prototype

We have developed a prototype application for geocoding map signboards on smartphones. *Figure 4* is the main interface for basic geocoding, and the map is a photo taken from the map signboard in the Kashiwa Campus of the University of Tokyo. There are three buttons for geocoding: *North Arrow*, *Ref. Points*, and *Trajectory*.

Figure 4. Main Interface for basic geocoding

The *North Arrow* is for direction coding. As *Figure 5* shows, users need to rotate (and scale and pan if necessary) the image of the map signboard to make the north arrow up.

The *Ref. Points* is for adding reference points. *Figure 6* shows the interfaces for inputting reference points. The user will at first insert a point on the image of map signboard, and then insert the corresponding point on the base map. The user can use the *Auto-Matching* button to add reference point of his/her current location on the base map automatically according to the GPS location; also, the user can use the *Manual-Matching* button to turn to the base map and input the reference point manually.

The *Trajectory* is another way to input reference points. As *Figure 7* shows, we separate the user's trajectory into straight segments by user's turns. And user is supposed to match the red segment of the trajectory (the segment before the last turn) with the corresponding road segment on the image of map signboard by moving, zooming and rotating the image. Then the connections between the trajectory points on the target map image and the corresponding points on the base maps are built, and the two end nodes of the segment would be used as reference points.

The advanced geocoding needs to edit polylines, which is not easy to operate by ordinary users. We have made a prototype of an editing tool separately and have built the test reference data of the map signboard of *Map of Distributions of Buildings of the University of Tokyo Kashiwa Campus*. The reference polylines are shown in *Figure 8*.

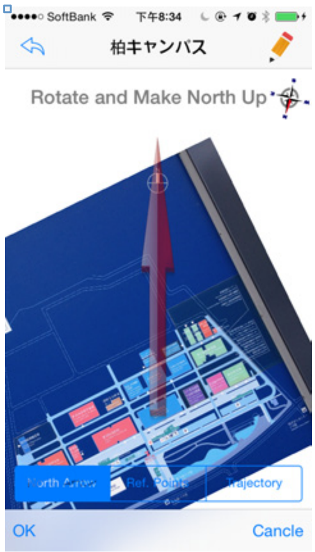


Figure 5. Interface for direction alignment

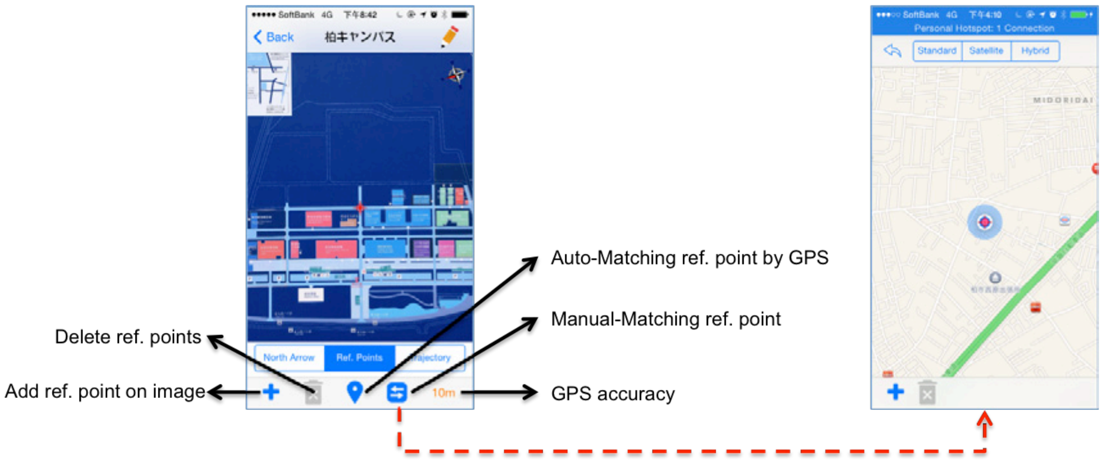
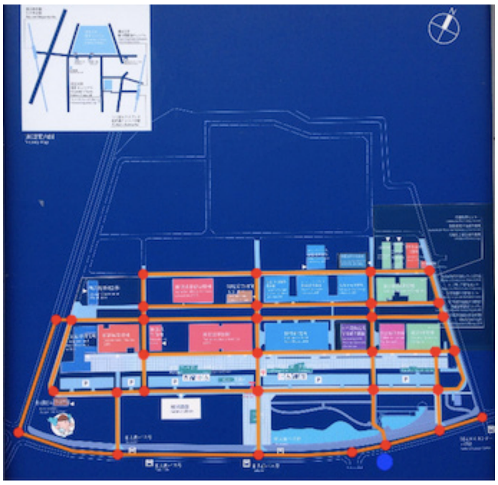


Figure 6. Interface for inputting reference points

Figure 7. Interface for trajectory matching



● Referencing points

▪ Referencing polylines

Figure 8. Editing referencing points and polylines on the map signboard of map of distributions of buildings of the University of Tokyo Kashiwa Campus

4. Experiments and Results

We have done experiments to test the feasibility of the basic geocoding methods for ordinary users, and tested the positioning results calculated by point referencing and polyline referencing.

Twelve volunteers have participated in the experiment. They were at first given a short training on the usage of the application and the editing tools. Then they were led to walk around the University of Tokyo, Kashiwa Campus and instructed to geocode the campus map. After the experiment, users were asked to answer questionnaires to judge the easiness of the process to geocode map signboards by four levels: very easy, easy, hard, and very hard. The results are shown in *Table 1*.

	Very easy	Easy	Hard	Very hard
Geocode map signboards (generally)	7	4	1	0
Make the direction alignment	6	4	2	0
Add reference points (use GPS to add users' locations on base maps automatically)	7	4	1	0
Add reference points (add corresponding reference points on base maps manually)	2	5	5	0
Match the trajectory with the map image	3	7	1	1

Table 1. Users' impressions on making map geocoding

According to the results, we can find that generally, most users (91.7%) feel it easy (or very easy) to geocode map signboards. Most of the geocoding tool functions are regarded to be easy to operate. To indicate corresponding reference points on base maps is the most difficult task for users. There are five users (41.7%) voted it hard to achieve this task. However, there is one user prefers this task because the user thinks it more efficient and convenient to add enough reference points one time at the beginning of the trip. Another user thinks all the operations are hard except for direction alignment. The user declared not good at reading maps and expected the application could provide directing and positioning functions without any operations. In conclusion, the basic map geocoding is not hard for ordinary users to achieve, and the different methods to add reference points that we provided could meet the preferences of different user groups.

(a) Trajectory on base maps

(b) Trajectory calculated by point referencing

(c) Trajectory calculated by polyline referencing

Figure 9. Comparison of point referencing and polyline referencing positioning results

To test the positioning results of advanced geocoding, we geocoded the campus signboard map based on the main roads, and we also built points referencing using the intersections of the roads. The referencing polylines and points are shown in *Figure 8*. We walked around the campus and recorded the trajectory, and mapped the trajectory to the map signboard by both point referencing and polyline referencing. The results are shown in *Figure 9*: *Figure 9(a)* is the base maps (Apple Maps) that shows the trajectory we have recorded; *Figure 9(b)* is the mapped trajectory using point referencing; *Figure 9(c)* is the mapped trajectory using polyline referencing. We can see that the trajectory mapped by polyline referencing is much stable than the trajectory mapped by point referencing.

5. Conclusion

This paper proposed a framework to navigate users with photos of map signboards on smartphones. The framework considered the capabilities of different users and offered easy point geocoding method for ordinary users and relatively complex polyline geocoding method for professional users. The results of the experiments have shown that point geocoding is easy for ordinary users to operate to get basic directing and positioning functions, while line based geocoding method could offer better positioning results.

However, in the experiments, many users expected not only directing and positioning functions, but also searching functions; and they hope that they could get helps and instructions when making the geocoding; also some users hope the interface would be more aesthetic. In the future, we will make improvements on these aspects, to make the system supporting POI searching, adding operating instructions, and make the interface more user-friendly.

For the advanced geocoding, sometimes the map signboards are more detailed than web maps, and some roads on the target maps are not shown on the base maps. These roads cannot be geocoded and the correct relative spatial relation between user's location and these non-geocoded roads cannot be ensured. And polyline geocoding is a time consuming task, which needs patience and skills to deal with inconsistencies of corresponding roads on target maps and based maps. These inconsistencies usually come from the generalization or exaggeration of the target maps. And finally, the polyline geocoding does not ensure the relative spatial relation between user's location and point objects, like buildings. In the future, we are going to improve the geocoding methods to make it easier and to keep the correct relative spatial relation between user's location and both line and point objects.

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Indoor Signposting and Wayfinding through an Adaptation of the Dutch Cyclist Junction Network System

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Abstract. Finding's ones way in complex indoor settings can be a quite stressful and time-consuming task, especially for users unfamiliar with the environment. There have been developed several different approaches to provide wayfinding assistance in order to guide a person from a starting point to a destination but none of them has emerged to be efficient enough in order to act as a uniform solution. Moreover, referencing to landmarks is not widely employed by wayfinding assistance systems despite the fact that landmark-based navigation is the most natural way for people to navigate through unfamiliar environments. In this paper, a new wayfinding method for indoor environments is proposed, which makes use of the landmark concept. The method to achieve it is by translating the main principles of an already existing outdoor wayfinding system which applies successfully for the case of cyclists in The Netherlands. The first step is to define the locations, i.e. decision points, where wayfinding assistance is needed in indoor settings and secondly, to supply them with a special type of landmark which will be in the form of signpost, which provides all the necessary information. A graph based representation of the indoor setting is generated in order to extract the decision points and create the network of all possible routes in the environment.

Keywords. Indoor wayfinding, landmark, signpost, decision point, node network, route graph, Constrained Delaunay Triangulation

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1. Introduction

In recent years, navigation has become a very active research area with a wide range of application fields. One of the main constituents of navigation is wayfinding. Wayfinding refers to the requirement to know where to go and how to get there and forms the goal-directed and planning part of navigation (Montello & Sas 2006). Successful wayfinding requires that people are firstly capable of orienting themselves in space, namely to know where they are and in which direction they are facing. Then, planning a route and following the planned route while maintaining a real-time understanding and heading is necessary.

Wayfinding in indoor environments has emerged to be a significant field of interest as people spend most of their times indoors. Therefore, indoor spaces should be effectively navigable and people need to know how to find their way from their current location to their destination, which is not always an easy task. Wayfinding requires solving problems involving explicit decision-making, such as selecting routes to follow, orienting towards non-perceptible landmarks and scheduling trips (Montello & Sas 2006). Moreover, the sense of orientation in indoor spaces is affected by several parameters. Firstly, indoor space is characterized by the existence of the third dimension which is expressed though the different floor levels (Brunner-Friedrich & Radoczky 2006). Vertical movement can have a serious impact on the wayfinding performance. Finally, indoor environments are composed of fragmented areas, with a limited field of view and change of direction is imposed more often than outdoors.

Consequently, people encounter significant difficulties in the pursuit of their destination target when they are navigating in unfamiliar indoor environments. Especially in semi-public buildings, such as airports and train stations, hospitals, offices or university buildings, individuals often fail to find their way immediately or under time pressure without external information and would, therefore, benefit from a well-established system offering wayfinding assistance (Millonig & Schechtner 2007). Therefore, they depend on wayfinding directions, either providing by other people or given by maps or other wayfinding services. People use landmarks when they give route directions to anchor actions in space or to provide confirmation that the right track is still being followed (Michon & Denis 2001). However, while it is commonly accepted that directions provided by people are based on using landmarks as references, especially at decision points, the directions given by wayfinding services are generated based on the geometry of the space.

In the past decades, empirical research has established the importance of landmarks in our understanding of and communication about space (Lynch 1960, Michon & Denis 2001, Raubal & Winter 2002, Snowdon & Kray 2009). By using landmarks the wayfinding task can be significantly simplified (May et.al., 2003). The outcome of spatial-cognition studies reveal the importance of salient objects for orientation and navigation. Wayfinding process based on landmarks relies on the presence of landmarks at each point along a route where wayfinders might need assistance.

Thus, the aim of this work is to propose a wayfinding system for indoor environments in order to direct people to a pre-determined destination by following a set of special landmarks of the type of signposts, defined as landmark-signs, containing all the necessary information to guide the wayfinder in the space. Signposts can play a special role when they are used as landmarks. They have the potential of serving as distinctive, recognizable and salient landmarks while at the same time they can provide additional information (Fontaine & Denis 1999, Millonig & Schechtner 2007). This approach will be based on an already existing and recognized outdoor wayfinding system which applies successfully for the case of providing directional instructions to cyclists. The term landmark in this research is used to indicate prominent physical objects that can be used in order to indicate people's location in complex buildings and guide them to their destination. The emphasis is not only to the visual attributes of objects but mainly to the relevance of the location of their presence as fundamental parameter for the provision of direction instructions to facilitate the wayfinding task. A geometrical model is proposed in order to calculate the decision points, which are the points along a route, where people need wayfinding assistance. The landmark-signs are proposed to be installed at the decision points in order to provide location and directional information. Consequently, the main concept of the system is that a network of nodes is created through which any possible route is mapped out. Pedestrians follow a sequence of graphical-given instructions delivered at key points along a set of routes in order to reach a destination.

2. Background Research

2.1 Human Wayfinding

Human wayfinding research investigates the processes that take place when people orient themselves and navigate through space (Raubal and Egenhofer 1998). McKnight, Dillon and Richardson (1993) summarized the three primary ways that people employ in order to find their way:

landmark-navigation, in which people select easily identifiable points of reference in the environment and use them as a base, route-navigation, in which they put the landmarks in a sequence creating navigation paths and they navigate in the space by learning routes between locations, and map-navigation in which people create a general frame of reference (mental/cognitive map) containing the spatial relationships between objects and use it to navigate. People's perception of the real world develops gradually through these three levels by recording information about the environment. Accordingly, for successful wayfinding information about the environment - what is in the environment and where it is - are required.

Weisman (1981) distinguished the four classes of environmental variables which influence the wayfinding process. These four categories are: a. visual access to familiar cues or landmarks; b. the degree of architectural differentiation between different parts of a building; c. use of signs or room numbers; and d. plan configuration. The influence of each one of the abovementioned variables as well as of combinations of them on people's wayfinding performance has been examined in several studies (Weisman 1981, O' Neill 1991, Montello and Sas 2006, Hölscher & Brösamle 2007). From these studies it is revealed that when visual access is restricted, orientation becomes difficult and wayfinding performance is decreased. On the other hand, wayfinding performance is increased with the presence of signage. When the floor plan complexity is increased, people's understanding of the spatial layout is decreased and consequently wayfinding performance.

According to the degree of familiarity with the building the wayfinding strategy of the people can be changed. According to Hölscher et al. (2006), inexperienced users rely mostly on a central point strategy by sticking as much as possible to a central part of the building even if it entails more detours (Hölscher et al. 2006). On the other hand users familiar with the environment use mainly the direction strategy or the floor strategy in order to find their way. The first one corresponds to choosing routes that head and lead directly at the horizontal position of the destination target irrespective of level-changes, while the second one focus on firstly finding the floor of the destination and later on the horizontal position (Hölscher & Brösamle 2007).

2.2 Wayfinding Approaches

People perform wayfinding tasks in unfamiliar environments relying on common-sense knowledge of the geographic space and their previous obtained experience. Wayfinding is a natural skill that people develop throughout their lives (Raubal and Egenhofer 1998). However, external information can simplify the wayfinding task. Therefore, several systems have been developed in order to provide wayfinding assistance. The most common way of navigating in indoor spaces is by using the information systems of the building comprising by maps and signs.

Maps are fundamental tools in the wayfinding process. Traditional paper map is the oldest mean of supporting wayfinding. Nowadays, digital maps and route descriptions on a smartphone are becoming more and more popular with the wide-spreading of smartphones and Google Maps applications as well as GPS maps. Various presentation formats of spatial information have been developed, such as verbal navigational instructions, static and interactive maps, 3D visualizations and animations. However, this approach of supporting wayfinding is not very popular in indoor environments and creates difficulties and disorientation to the users. Additionally, digital maps in mobile devices can act as a wayfinding support tool only for users familiar with technological advancements who possess a wireless mobile device. These systems are not helpful for inexperienced users.

Signage is the most commonly employed physical means of enhancing wayfinding efficiency in indoor environments. Most building complexes posses wayfinding systems in the form of building and room names, directional signs or other graphical elements. Several studies (O' Neill 1991, Hölscher & Brösamle 2007) indicated the positive relationship between signage and wayfinding performance. However, it is also possible signs to create disorientation. People may have problems to understand the signs in case they are not clear or they have too much information or even confusion is generated when there are too many signs (Montello & Sas 2006). Difficulties with understanding and following the signs can be attributed to the fact that there is no common reference regarding the language and nomenclature used in the signs or the locations of providing assistance.

2.3 Landmarks

Presson and Montello defined landmarks as features that are relatively well-known and which define the location of other points. According to this definition anything that sticks out from the background can serve as a landmark (Presson and Montello 1988). Landmarks are stationary, distinct, and salient objects or places, which serve as cues for structuring and building a mental representation of the surrounding area (Millonig and Schechtner 2007).

Communication about an environment is facilitated by using landmark references. Landmark-based navigation is particularly important when people navigate through unfamiliar environments. Landmarks support clarity of a specific route. Route directions enriched with landmark references lead to less wayfinding errors. Therefore, incorporating landmarks along a route is a crucial task of navigation systems in order to provide more efficient and reliable guidance.

Most approaches to include landmarks in wayfinding instructions focus either on landmark identification (Nothegger, Winter and Raubal 2004, Elias 2003) by specifying the area in which landmarks has to be sought and then identifying the features that act as outliers in the area, or on the integration of landmarks into the generated instructions (Klippel, Richter and Hansen 2005, Caduff and Timpf 2005). However, today's navigation systems still give guiding assistance in terms of metric distances, based on the current position and the underlying digital map. The failure of incorporating landmarks in commercial applications can be attributed to the costs associated with the acquisition of the required data and the highly skewed distribution of landmark candidates in available spatial data (Richter 2013).

2.4 Route Directions in Wayfinding

Route directions are a primary means to guide someone in finding one's way. It can also refer to instructions on how to follow a route providing the actions to be carried out in order to reach the destination (Richter & Klippel 2005, Richter, Tomko & Winter 2008). To successfully navigate, wayfinders need to know which directions to turn to at the crucial spots along their way where they have to make a decision on how to move further, namely the decision points (Richter, Tomko & Winter 2008). A variety of details can be given when providing directions for wayfinding, such as landmarks, cardinal directions, street names, distances and turn descriptions (Hund & Padgitt 2010). In human route directions we almost never find numerical references to distances or turning angles, instead people use landmarks to anchor actions in space or to provide confirmation that the right track is still being followed (Michon and Denis 2001, Richter 2013).

The processing and representation of angular (direction) information is essential for wayfinding and route planning. Directional relations are used in several respects in route directions: they state the location of entities encountered along the route (like landmarks) with respect to the wayfinder or other entities; they announce a change of heading at decision points, i.e. represent turning actions; and they may relate these actions to an entity's location to better anchor them in space. In general, it can be stated that wayfinding can be characterized as following a route segment up to a decision point, making a directional choice, following the next route segment up to the next decision point, making a directional choice, and so on (Klippel et al. 2004).

3. The Proposed Wayfinding Approach

3.1 The Original 'Junction Network System'

The 'Junction Network System' (or originally 'knooppuntensysteem') is a special approach of providing direction instructions that help cyclists plan and follow a route. The system is widely used in the Netherlands and Belgium in order to enhance wayfinding for cyclists. This system is an innovative signposted network based on numbered junctions as it is illustrated in *Figure 1*. The main concept of the system is that users rely on a network of nodes, which is created by exploring the locations where the cycling paths intersect and placing a signpost containing a unique number and directional information to the next-encountered nodes/intersections. The number in the sign gives to the junction a unique identity and cyclists become aware of their relative location in the space. Additionally, by remembering a sequence of numbers a user-specified route is determined. The most important principle of the system is that assistance is provided to the users where they actually need to take a decision on how to go on. The signage system that dominated is a green sign with the node numbers in a white circle (*Figure 2*), which has emerged to be a special type of landmark along the cycling paths as it is easily identified by cyclists.

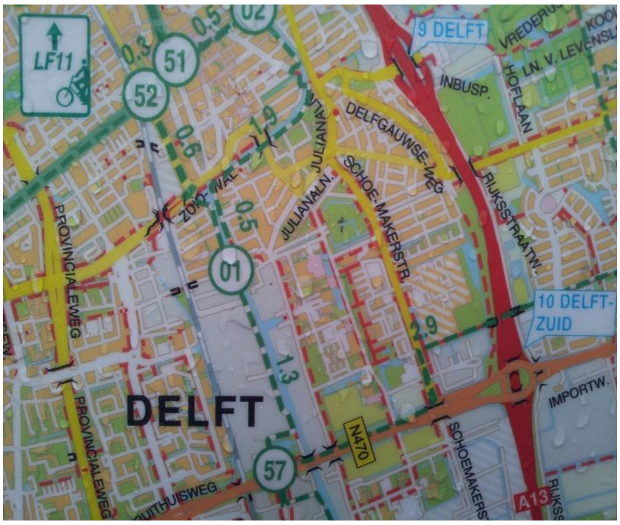

Figure 1. Numbered nodes to indicate a route

Figure 2. Signage system of Junction Network System

3.2 The 'Junction Network System for Indoor Settings' - Conceptual Model

The proposed system, 'Junction Network System for Indoor Settings', is registered as a first attempt of translating and applying the main principles of the original 'Junction Network System' in indoor space, having as a target group pedestrians of all age groups, with no physical impairment that prefer to be independent from a mobile navigation system. The whole concept and main principles of the proposed system derive from a direct mapping of the main principles of the Junction Network System to the case of indoor wayfinding. In terms of wayfinding communication, the system should be able to respond to three major questions: what information should be presented, where will the information be provided, and in what form.

More specifically, the proposed approach is based on the creation of a network of locations, equipped with a special type of signpost, the landmark-sign, containing a unique number for every location and directional information of the other numbered locations in the vicinity of it. In that way any possible route in an indoor setting is mapped out. The proposed landmark-signs will be placed in a prominent spot at these locations in order to be easily distinguished by people. Floor mounted signs will be used. One of the advantages of this choice is that they attract people's caution as they are visible from a distance. Moreover, there are no important limitations regarding their size, they do not interfere in the configuration of space and do not intervene in people's movement.

One of the main building blocks of the proposed system is the physical presence of the landmark-signs throughout the entire space. Landmark-signs, as depicted in *Figure 3*, signal the occurrence of the decision points, which are the crucial points where people need assistance in order to proceed further (junctions of the original system). Moreover, the location and directional information are revealed through the landmark-signs. By supplying every landmark-sign with a unique number the closest destination spaces to this sign are automatically registered to it. So, when the wayfinder is located at number 5 he can infer his relative location in the building. Additionally, directional assistance is provided by the signs that contain directional arrows indicating the closest numbered decision points or the arrival at a destination space in all possible directions of moving. The destination spaces are also marked with a unique number. The numbering of destination spaces starts after the numbering of the decision points. The location of the signs makes easier the conceptualization of turning instructions, enhancing the understanding of direction instructions.

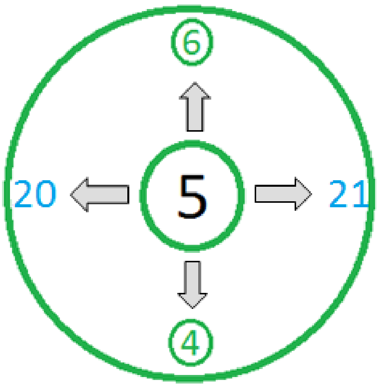

***Figure 3*:** Landmark-sign

The connections between the landmark-signs and the destinations attached to each one of them create the whole network of nodes which provides all possible combinations of routes between starting points and destinations. This is the second important constituent of the system. The basic representation underlying the system is a sequence of decision points with their accompanying actions. Guidance is given by referring to numbers of signs and anchoring actions to them. The network of nodes has a twofold role: firstly, it acts as a routing system that enhances the successfully reach of destination while secondly, it plays the role of a referencing system which provides location information to the users.

There are several aspects that can make the system a special approach and a useful tool for users in the wayfinding task. Firstly, it is based on an already existing and recognized system meaning that people can easily get used to it. It is applied successfully not only for cyclists but also for hiking and boat guidance purposes. The fact that it is successfully applied in different navigation modes makes it a promising solution for indoor wayfinding problem. Secondly, it provides an indication of the relative position of the user in the environment. It acts not only as a wayfinding/routing system but also as a referencing system. Thirdly, it is based on a physical object that acts as a unique identifier and plays several roles. This unique identifier is the landmark-sign, which expresses the critical points where people need to choose direction of moving and provides location and directional information. Finally, it is a solution that with minor modifications can be applied to different building cases.

3.3 Indoor Space Modelling

The proposed system aims at providing assistance for the simplest case of wayfinding, which is finding the way to a room when navigating in public buildings. This is though one of the most commonly repeated human activities. Therefore, the navigable space that is of our interest for the purposes of this research are the connecting spaces (connectors) between other entities which act as destinations and for which people are usually in search, e.g. rooms. People are using the corridors as the backbone of the building in order to reach their destinations. They correspond to main orientation of the building and they are the first parts of the building to be experienced. Consequently, for indoor space the areas that apply to this concept are the main ring (backbone of a building) or well-structured paths where movement occurs in big open spaces and which can arise from the observation of people's flow. The determination of all the connectors of an indoor setting provides the circulation routes in the space. The points where two or more of these spaces intersect or where an intermission of the continuity of the boundary of the connector occurs are the decision points for indoor space. The intermissions/gaps indicate the presence of an opening, which gives the opportunity of changing direction.

A graph model, as the one in *Figure 4*, is going to be used to represent the structure of the indoor environment. An approximation of Medial Axis Transformation generated by using Constrained Delaunay Triangulation is applied in the connecting spaces in order to extract their middle line, which is a good approximation of depicting the human movement in these spaces (Mortari et al. 2014). The Medial Axis Transformation extracts the topological skeleton of the polygons used to represent the geometry of the spaces. Connecting space polygons are mapped to nodes and edges of a graph, which is able to provide all possible routes. The other building spaces that act for this approach as destination spaces are represented by their central point, which are also components of the graph, and they are connected to the skeletons of the connecting spaces at the closest decision points node through the transition spaces (doors). These connections are implemented in order to illustrate the adjacency and connectivity relations between all the different parts of the indoor environment. In that way a network of nodes and edges is created which represents all the possible routes that humans can employ in a certain environment. The idea of a route skeleton corresponds to the central-point wayfinding strategy that people usually employ in unfamiliar environments.

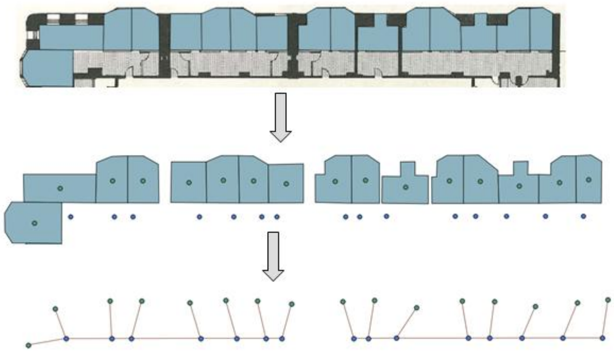

Figure 4. Graph Model of part of building

4. Implementation

GeoFort, which is an educational attraction in the field of cartography and navigation in The Netherlands, was selected as the most suitable place to implement and test the reliability of the system. The concepts of the proposed approach are illustrated using 2D floor plans of one of the buildings of the place (Figure 5).

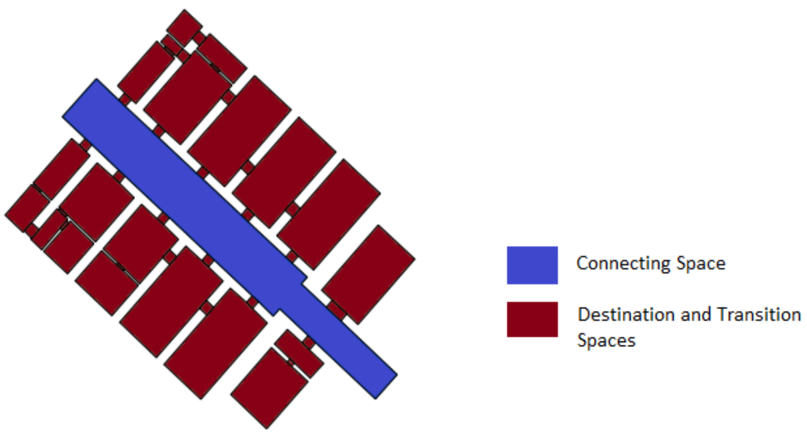

Figure 5. 2D floor plan of GeoFort building

The graph structure of the indoor environment is extracted in two levels. Firstly, in the more detailed level a Constrained Delaunay Triangulation is performed on the connecting spaces. This method subdivides the plane into a number of triangular-shaped non-overlapping facets, while it retains the boundary information. The space subdivision is shown in *Figure 6*. The main advantages of selecting this approach is the simplicity of the implementation and the precision in the resulting geometries. Constrained segments can be perceived as entities blocking the movement in the space, e.g. walls.

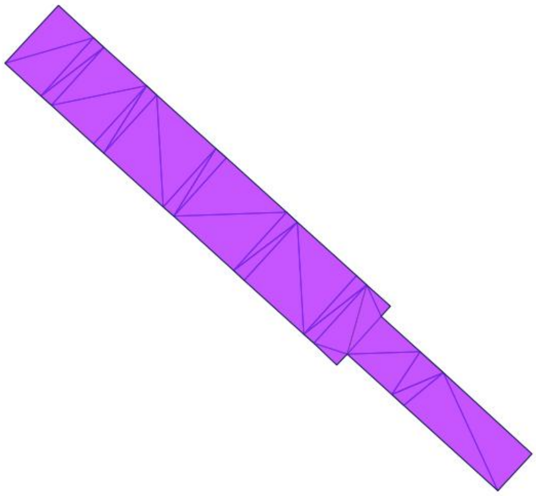

Figure 6. Constrained Delaunay Triangulation of connecting space

After applying the CDT two types of generated triangular facets can be distinguished: these that are built from edges that consist part of the user-specified constraints and others that are free of these constraints (*Figure 7*). The last type of triangles are adjacent to other generated triangles from all three sides. Thus, people standing at these sub-spaces are allowed to walk to three possible directions - there are no constraints to limit them to any direction. This type of generated sub-spaces corresponds in reality to areas that two or more navigable connecting spaces intersect. Consequently, in these sub-spaces decision points are located. By classifying the triangles the decision points are determined. The distinction between the two triangle types is performed based on their topological overlay relations with the originating polygon. Therefore, the topological spatial relations between the generated sub-spaces and the originating polygon are examined by using the Dimensionally Extended Nine-Intersections Model (DE-9IM) (Strobl 2008). If the result of the intersection of the boundaries of the two geometries is a point set then the triangle contains zero constrained edges.

Otherwise if it results in a line set the triangle has at least one constrained edge. In that way the triangles without constrained edges are selected.

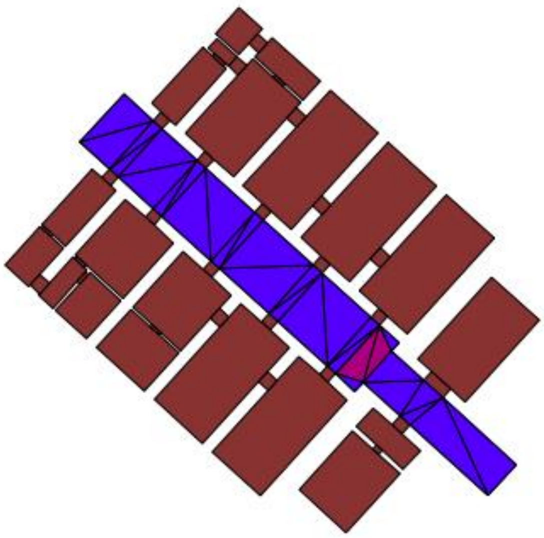

Figure 7. Triangles with (blue) and without (purple) constrained edges

However, the CDT takes into account the positions of the openings of the connector polygon. If both starting and ending points of a door are mapped, the generated output will entail a facet whose constrained edge is spanning over the whole length of the door frame. However, in reality this is not a real constraint. Therefore, the semantics of objects indicating openings should be considered in the process of discriminating between triangle types. Thus, a classification of the segments used as an input for the triangulation is performed and the set of triangles without constrained edges is extended by these triangular sub-spaces that are adjacent to transition spaces, i.e. openings (*Figure 8*). The arrival at a destination space can be signified through the landmark-signs located at these decision points.

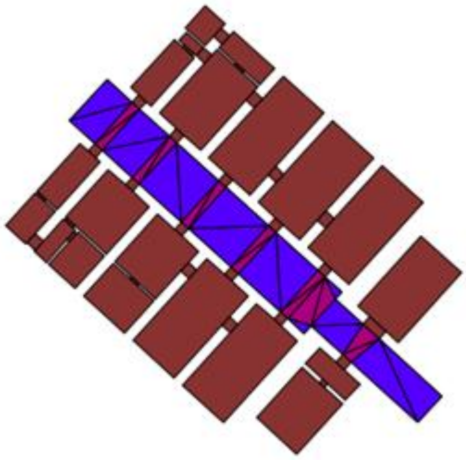

Figure 8. Final triangles with (blue) and without (purple) constrained edges

Finally, the centroids of all the triangles that contain zero constrained edges are calculated as they are the most representative points in order to act as decision points. However, in some cases some of them are very close to each other. The problems arising from this situation is that firstly, two or more signs can be installed very close to each other or even partially overlap depending on the sizes of the selected signs and secondly, this entails the risk of creating confusion or misinterpretation of the assistance. In order to deal with the redundancy, adjacent triangles are merged into one polygon and its central point represents the final decision point (*Figure 9*) by replacing the previous generated centroids.

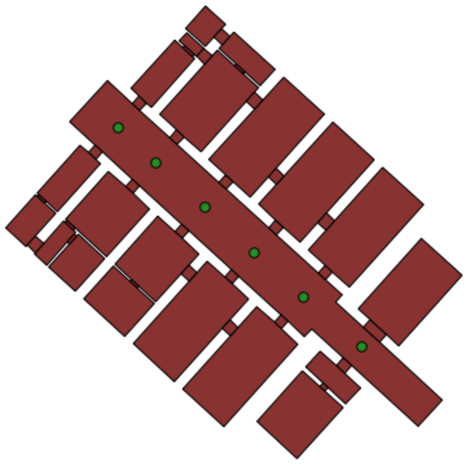

Figure 9. Decision Points

5. Next Steps

In order to finalize the graph representation of the connecting spaces, the middle points of the edges of triangles with at least one constrained edge are going to be calculated and all the nodes (decision points and middle points) are going to be linked based on their adjacency relationship. Finally, for the generation of a network of the entire building the central points of polygons representing destination spaces and transition spaces are going to be calculated and linked to the closest decision point node. In that way all the possible routes of the building are represented and distances between the nodes can be estimated as the graph reflects not only the topological relationships between spaces but also the geometry of the building.

The proposed approach is going to be verified by determining the decision points at the entire GeoFort area and installing the proposed landmark-signs. A human-based survey is going to be carried out. People will be asked to follow the numbered signs in order to reach various destinations and their movement is going to be observed in order to test the usability of the system. The time to reach the destination and the number of detours are the main measures to be estimated in order to infer about the reliability of the approach as an indoor wayfinding aid.

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Towards a Dedicated Data Model for Seamless Pedestrian Navigation

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Abstract. Awareness of one's location at any given time is a fundamental human need. To navigate vehicles or persons, geodata are indispensable for calculating the route. At present, there is a lack of a proper database that meets the specific requirements for spatially inclusive and comprehensive pedestrian navigation. Therefore, firstly, real-world objects relevant for pedestrian navigation need to be determined. The selected and captured data, secondly, need to be structured and stored in an application-specific database to make proper use of them for orientation and navigation purposes. This paper deals with a pedestrian-focused data model and feature catalogue and selected aspects of data quality relevant for pedestrian navigation.

Keywords. Pedestrian-focused data model, Feature catalogue, Data quality, Pedestrian navigation

1. Background and Objectives

Awareness of one's location at any given time is a fundamental human need. This mental and geodetic determination of position is facilitated through mental maps and landmarks or maps and navigation systems, respectively (Asche 2014).

Navigation is a movement resulting from positioning and route selection (Bollmann & Koch 2002). To navigate vehicles or persons, geodata are indispensable for calculating the route. At present, there is a lack of a proper database that meets the specific requirements for spatially inclusive and comprehensive pedestrian navigation. The divergent claims notwithstanding, navigation today is still mainly based on data for vehicle navigation,

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e.g. GDF data (Geographic Data Files). In recent versions (ISO 2011), a number of pedestrian-relevant objects have been included. Nevertheless, a uniform, seamless geospatial database dedicated to pedestrian navigation is not available for the time being, at least not in Germany.

To compensate for this situation, the investigation of databases with similar geospatial data is an appropriate R&D starting point. In Germany, the following databases, among others, can be analysed for the identification of spatial objects relevant to pedestrian navigation and inclusion in a dedicated database:

(1) Topographic data of the mapping agencies of the German federal states (FMAs). Existing data of the ATKIS or the recent AAA system[1], termed Digital Landscape Models (DLM), suffer the following shortcomings:

- Landscape objects captured by geodetic data acquisition are included in the DLM database only.
- Cadastral data of the ALK[2] database, recently integrated in the AAA system, and ATKIS data vary in granularity of geometric and attribute features due to differences in original data acquisition.
- ATKIS or AAA, respectively, lacks a uniform database for the whole of Germany in large to medium scales (< 1:200,000), since DLM data models are constructed and updated for the federal states only.

As a consequence, a seamless geospatial database that might be used as a basis for pedestrian navigation is not available from the FMAs to date. Hence, selected objects only can be relevant for setting up a database for pedestrian navigation.

(2) Topography-like data of the OpenStreetMap project (OSM), a free global geodatabase created by non-professional volunteers in large to small scales. As any user-generated content, OSM data display the following deficiencies:

- Both on a global and regional scale, completeness, topicality and quality of the OSM data pool varies considerably.

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[1] AAA system describes (AFIS-ALKIS-ATKIS-model). ATKIS- *Amtliches Topographisch-Kartographisches Informationssystem* of the *Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland* (AdV), ALKIS- Amtliches Liegenschaftskatasterinformationssystem, AFIS- Amtliches Festpunktinformationssystem

[2] ALK -Automatisierte Liegenschaftskarte, which has been recently integrated in the AAA system, specifically in ALKIS.

- OSM operates on a less detailed geospatial data model and rather loosely defined data acquisition rules to make it possible for volunteers to contribute to the database.
- Depending on region or scale under investigation, reliable geotopographic data relevant to pedestrian navigation may or may not be included in the database.

For these reasons, the OSM database, like its FMA equivalents, can only be made limited use of as a homogenous, seamless database for pedestrian navigation. Figure 1 depicts an extract of the OSM dataset for a study area – the city centre of Potsdam (Germany). It can be seen that several spatial objects and relations relevant to pedestrian navigation, in this particular case from Jaegerstrasse (left) to Friedrich-Eberst-Strasse (right), are lacking. The red line shows the route calculated on the basis of OSM data between the two points in the centre of Potsdam. The green line represents an optimal pedestrian route through inner courtyards. The respective data are not available in the OSM database.

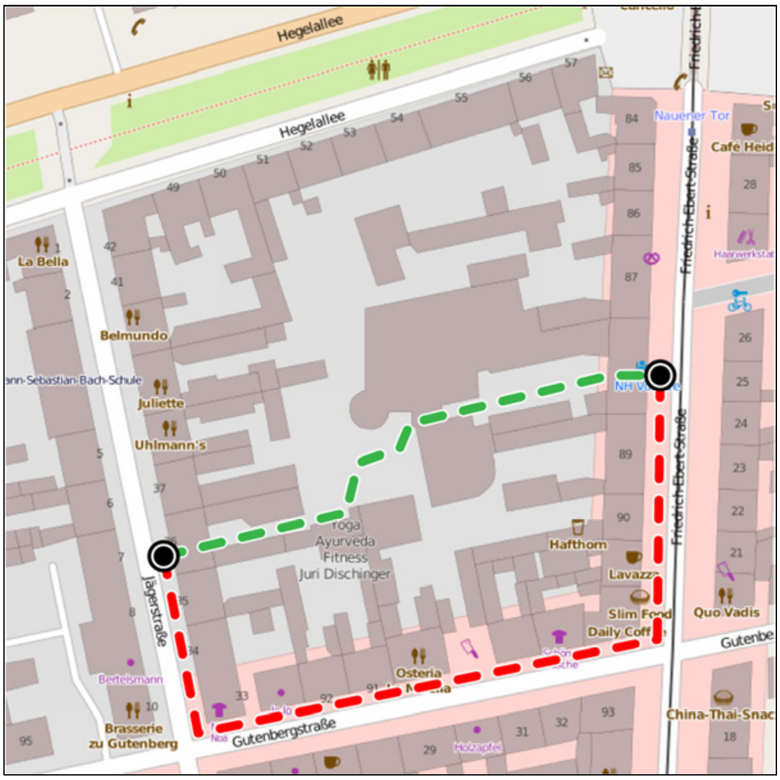

Figure 1. Reality vs. data base – the red dashed line shows the route calculated on the basis of OpenStreetMap data between two points in the centre of Potsdam, the green dashed line represents a shorter way through inner courtyards a pedestrian may take in reality.

What can be seen from the above examination of existing geospatial databases is that a reliable, uniform large-scale geospatial database for seamless pedestrian navigation is not available. Using databases of vehicle navigation systems instead is no alternative, as, e.g. Kluge & Asche (2008) have shown, since, in general, they do not include pedestrian-specific objects. One significant difference between pedestrian and vehicle navigation is manifest in the routing functions available. While cars drive on defined roads only, pedestrians are able to move freely in the whole of public space. This includes movement on/in, e.g., pavements, footpaths, public squares, shopping arcades, publicly accessible courtyards, public greens, parks, all inaccessible to automobile traffic (Figure 1). Pedestrian moving and navigation space, on the other hand, is much lesser restricted. This, however, only applies when pedestrians are considered a homogenous group, which, of course, they are not. Restrictions, such as barriers, become particularly apparent when considering mobility-impaired persons like wheelchair users or persons reliant on walking frames. Relevant barriers include stairs, steep paths and specific surfaces of roads, footpaths or pedestrian overpasses, such as cobblestones.

Both individual and requirement-matched pedestrian navigation therefore requires the definition of different user groups. For these groups as well as for the entire pedestrian community criteria need to be determined which real-world objects will have to be acquired, processed and included in a geospatial database specifically dedicated to pedestrian navigation. As with vehicle navigation systems, binding standards do not exist as guidelines for building and populating such database.

2. Concept and feature model for a pedestrian navigation database

In the following, we present an elaborated concept for a pedestrian navigation data model. This data model is conceived as a generic, modular, scalable system. Its structure is based on a hierarchy of objects and relations relevant to pedestrian navigation. In a first step, data model components can be sepatated into thematic data specific for pedestrian orientation and navigation, such as landmarks, points of interests, footpaths, and topographic data for a precise geospatial reference. In a second step, the data model can be broken down into a granular feature catalogue (FC), detailing objects, structures and relations.

A FC is a repository for geographic features the creation of which is covered by the ISO standard 19110 *Methodology for feature cataloguing* by the *International Organization for Standardization*'s *Technical Committee* (ISO/TC) 211 *Geographic information/Geomatics* (Kresse & Fadaie 2004).

Accordingly, a FC is a classification of real-world phenomena usable as a standard in many applications: a standardised and modular framework that enables the transferability to multiple applications and therefore minimises the time-consuming creation of a FC. At the same time, a FC should be an application-orientated abstraction of the real world accessible to users of the corresponding data. All in all, a FC is to provide a clear description of the contained features to facilitate a differentiation or combination of different FCs.

Data models and corresponding FCs do already exist for topographic data. It has been mentioned that the majority of those include, at most, a limited range of features of interest (FOI) relevant for a database of a pedestrian-focused navigation system. Among the existing FCs are those of FMAs, e.g. ATKIS in Germany and the OS MasterMap of the Ordnance Survey (OS), the National Mapping Agency (NMA) for the UK (OS 2006, Kuhn 2005, AdV 2008). The ATKIS data model, e.g., classifies areas and structures in six primary categories or domains: settlement, traffic, vegetation, water, relief and administrative divisions. These domains are subdivided in groups of objects, resulting in a structured model of the topographic landscape. The OS MasterMap is based on a similar data model with nine so-called top-level themes.

A comparable structure can be found in the OSM FC, which categorises features according to their thematic classification (Haklay & Weber 2008, Ramm et al. 2010). Of particular interest within the OSM FC is the *points of interest* (POI) category which includes many pedestrian-related FOI.

Investigation of existing FCs, like those of ATKIS and OSM, suggests a general structure of geospatial data models that a pedestrian navigation-orientated data model and FC should be based on. This includes the thematic domains of *traffic*, *settlement*, *water* and *vegetation* supplemented by a separate category for POIs (compare Feature Identifiers (FIDs) 1000-8000 in Figure 2). Further structuring in feature groups might be useful, e.g. by specifying the different means of traffic (FIDs 2100-2400) or kinds of POIs (FIDs 8100-8900). Single features can then be assigned to these feature groups (e.g. FID 2101). For instance, the domain *2000 Traffic* and the group *2100 Pedestrian traffic* would include the object class *2101 Path* with the attributes (e.g. function, surface or gradient) associated with it. Because of its modular design the FC is easily adjusted when other domains or new features need to be included.

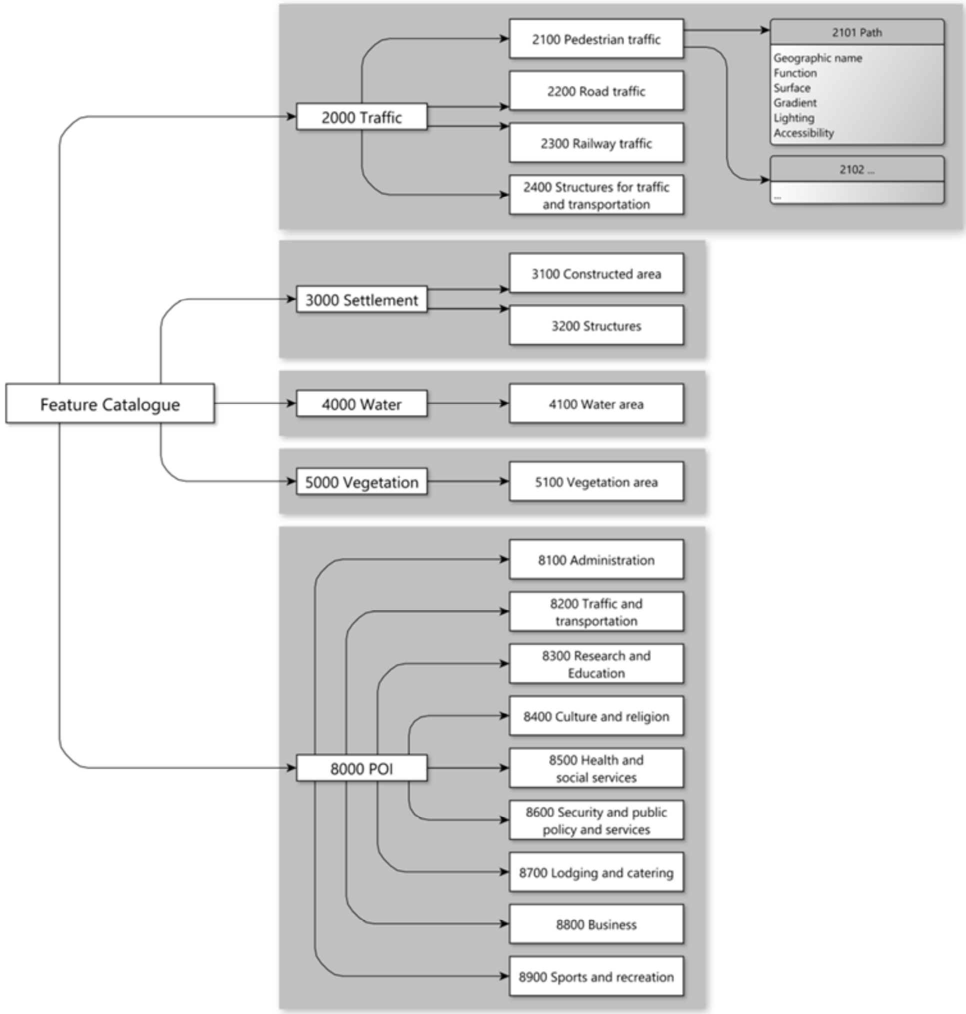

Figure 2. General structure for a FC detailing a data model for pedestrian navigation systems.

Based on the FC and the underlying data model data requirements for the FC objects can be defined. Data requirements are mandatory when it comes to assessing potential data sources and data acquisition techniques relevant to populate a pedestrian navigation database. Paramount in evaluating data suitability for a pedestrian navigation FC is the concept of data quality. Some elements of this concept are detailed below.

3. A tentative concept for data quality

For any spatial analysis, decision or application, the quality of input data is crucial, since the quality of a solution is directly dependent on the quality of the data available. Hence, pedestrian navigation (from calculating an optimal route to the design of communication media like map visualisations) can only be as good as the geodata on which it is based. For this reason it is necessary to formalise and standardise spatial data quality. ISO 19113:2002 defines quality as the "totality of characteristics of a product that bear on its ability to satisfy stated and implied needs" (ISO 2002). There are different parameters and indicators to describe and assess the quality of geodata. In principle, the selection of possible objective quality criteria and its associated quality measures has to be performed according to the respective application purpose (van Oort 2006). Selected quality criteria of significance for pedestrian navigation are described below (Laufer 2011, PAS 1071 2007, van Oort 2006).

Positional accuracy: Positional accuracy is defined as the accuracy of the coordinate values measured, compared to the real position of the object. A distinction can be made between absolute (comparison with another dataset) and relative positional accuracy (internal comparison in the same dataset).

Thematic accuracy: Thematic or attribute accuracy refers to the accuracy of quantitative attributes, the correctness of qualitative attributes as well as the classification of the features.

Completeness: Completeness defines the presence or absence of spatial objects, attributes or relationships. Data may exhibit a loss of quality not only with regard to incompleteness (error of omission) but also overcompleteness (error of commission).

Logical consistency: Logical consistency is the degree of compliance with logical rules concerning the data structure. Aspects can be valid values, conceptual, format, geometric, thematic and topological consistency.

Temporal quality: In addition to the spatial and attributive information geodata may include temporal information, too. Temporal quality can be described by the accuracy of time measurements, temporal consistency and temporal validity.

Timeliness: Navigation in general requires up-to-date data. Timeliness defines the degree of conformance between the information and the time-varying conceptual reality.

Availability: Availability indicates the level of existence of the information at a given point in time and a defined location.

Inconsistent, inaccurate or incomplete data as well as imprecise location information lead to low-quality data resulting in errant datasets effecting faulty decisions. For this reason, a definition of objectives and application-dependent quality criteria and related quality measures and their subsequent formalisation in a criteria catalogue is needed. This catalogue can be used to decide if an existing dataset is suitable for the intended purpose, or to ensure the demanded quality when capturing new data.

An evaluation of data quality is based to the application of direct or indirect methods (ISO 2005). Direct methods are applied when the available data are compared with the real world or a reference dataset of higher quality. Evaluating data based on descriptive parameters (e.g. metadata) is the application of indirect evaluation methods. Generally, a data quality model consists of two components: data quality and model quality (Joos 2000). Hence consideration of both parameters is important to conceptualise and implement an effective system for pedestrian navigation.

4. Conclusion and Outlook

This article focuses on the importance and requirements of pedestrian specific geodata for orientation and navigation. It has been demonstrated that there is a lack of spatial information adapted to the need of pedestrian navigation as well as missing standards concerning the collection of these data.

Establishment of a geospatial database adjusted to pedestrian-specific requirements is of paramount importance. It will fill the existing data gap and minimise the redundancy of already existing data sets.

The purpose of data processing is to complement existing spatial data by expansion of user-group-related attributes. One method of obtaining data for pedestrian navigation can be the identification and extraction from remote sensing imagery, if possible, in an automated process (Tyrallová 2013). The extraction of, e.g., pedestrian paths from operational remote sensing data can be used to enhance the existing OSM database. Geometric and spectral resolution of the remote sensing images has been greatly improved in the last 30 years. For the identification of pedestrian-specific objects and their attributes the current data resolution is sufficient.

Additional services such as detection and mapping of traffic signals, traffic signs and pedestrian and bicycle paths can be effected by crowd-sourcing. Volunteers are provided with detailed data capture rules and are remunerated for the objects acquired. Before inclusion in a pedestrian navigation, these data will be subjected to a rigorous quality assessment. One option is to these newly gathered data with existing data in automated data fusion. In this conflation process two (or more) suboptimal datasets are merged into a new optimal data set with enhanced geometric and/or thematic quality (Stankute & Asche 2012). This method can also be employed to minimise data redundancy.

Next steps towards a dedicated data model for seamless pedestrian navigation include the specification of a granular FC on feature and attribute levels. The FC will detail a pedestrian navigation data model that has to be finalised and validated. The existence of such data model is a prerequisite for target-oriented data acquisition, such as high-resolution operational remote sensing imagery or crowd-sourcing acquisition techniques applied by volunteers or micro-jobbers. Concept and content of a data model dedicated to pedestrian navigation have been presented and discussed in this paper.

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Personalized Routing for Car Navigation Systems

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Keywords. Location Based Services (LBS), Routing, Car Navigation

Abstract.

From a personalized computing standpoint, current in-car routing systems are somewhat primitive. Usually routing options are dependent on the fastest (usually default) or the shortest route from a start point to an end point. Start and end points are matched to an address or another point of interest (POI) via geocoding functions.

Currently attempts are made to consider other parameters. For example BMWi started to consider energy consumption for electric vehicles that limit the driving range. Depending on the setting of the cars systems the range may vary. Additionally specific routes may use more energy than others. Special routing functionalities are considered for example for the transportation of nuclear waste to find the safest route. These are special cases and the route is selected on a case by case basis. Additionally data streams, such as near-real-time traffic information are considered for in-car routing systems. The “data quality of this information” is seen as a “product” and to some extent users are willing to pay extra for high quality traffic information that is used in the computation of an optimal route. This optimal route is the fastest route depending on the near-real time traffic situation.

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Generally the consideration of these parameters is technology driven. The user may not even notice a change in the route; he or she would like to arrive in the scheduled time that is given by the routing system. The complexity of way-finding tasks has been investigated by a number of researchers. In user centered research, Heye and Timpf (2003) investigated the complexity of routing decisions in a broader framework including public transportation. They determine complexity measures for physical complexity of routes, which can be calculated based on information about the environment at transfer points and on the network structure.

We suggest to provide specific users (or user groups) with an in-car routing system that can offer a personalized route. With an increase of available dynamic data streams (weather, traffic etc.) and growing computing functionalities on mobile devices, the parameters for routing functionalities need to be extended. Therefore we aim on more personalized routing included in car navigation systems that have functionalities depending on the users' interests and abilities. A number of different parameters that could be considered may provide the user with a shortest, fastest, safest, most beautiful, least fuel / energy consumption, male/female (Häusler et al., 2010), easiest (to drive) (Krisp et al., 2014) or most difficult (to drive) route. Various road features need to be examined and ranked. Knowledge of road data is a basic prerequisite, especially the attribute features that are created in databases. The functionalities need to consider the available data and the computational algorithms. Duckham and Kulik (2003) investigated "the simplest route" in terms of how easy it is to explain, understand, memorize or execute the navigation instructions for the route. Most automated navigation systems rely on computing the solution for the shortest path problem, and not the problem of finding the "simplest" path (Duckham and Kulik, 2003). Technically this way of computing a personalized route can assist users to drive a perhaps more "reasonable" or more "natural" route. First implementation attempts to provide the user with an "easy to drive route" have been successful. They route the users around "complicated crossings", which are defined as obstacles (Krisp et al., 2014). Still challenges remain within the area of user modeling or user profiling.

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Context-aware Navigation Model supporting Way-finding of Vision Impaired People in Indoor Environments

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Abstract. An indoor navigation model for vision impaired people, which would support (a) path planning and (b) orientation establishment, based on a user centric approach is proposed in this study. Building structures, the environmental factors and individual characteristics related to mobility of the people with vision impairment are identified as influential contexts for the proposed model. The contributions from these contexts for indoor navigation of vision impaired people are analyzed. The building structures will be assigned with an orientation and mobility ranking and this information will be dynamically passed to a path planning engine. The engine will handle the optimum path planning integrated with orientation establishment support via visual and nan-visual landmarks meaningful for VI people, considering individual user characteristics. The model can be used by electronic travel aids for a better indoor path planning for vision impaired users.

Keywords. vision impairment, indoor navigation, orientation & mobility

1. Introduction

With the different perceptual capabilities to sense the environment, establishing the orientation and independent navigation becomes a difficult task for people with vision impairment (Golledge 1993; Loomis et al. 1998).

Different travel aids such as white canes and guide dogs are commonly adopted by people with vision impairments (VI) to strengthen their orientation and mobility capabilities. Electronic travel aids (ETAs) for people with VI are meant to provide complementary support for conventional travel aids used by them. Navigation aids for people with VI can play a vital role

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in indoor environments as loss of orientation is more prominent in indoor than the outdoor areas (Huang and Gartner 2010). Even though the ETAs are meant to assist people with VI to overcome a major mobility barrier and increase independence, their popularity is quite low (Legge et al. 2013) and no single acceptable solution is currently available (Ivanov 2012). Not considering user's perspective and how they move around an unknown environment are identified as some of the main weaknesses of present generation of indoor navigation systems for blinds (Ivanov 2012). Bradley and Dunlop (2004) had summarized some important findings related to the context of a user with VI and the clues they use. They had identified that the clues (landmarks) use by VI people vary with the level of impairment and questions they ask vary when considering indoor and outdoor navigation.

The importance of user centric design is highlighted in different models for assistive technology development such as human activity assistive technology (HAAT) model (Cook and Hussey 2002) and comprehensive assistive technology model (CAT)(Hersh 2008). According to Hersh (2008), context, human person, activity and the assistive technology are the main components of HATT model and its extension CAT model both. Huang and Gartner (2010) have recommended that context awareness needs to be incorporated to indoor navigation aids.

Path planning or route calculation is a main component of indoor navigation aid tools, with other components being related to localization, representation and interaction (Fallah et al. 2013; Huang and Gartner 2010). Fallah et al. (2013) have highlighted in their survey on indoor navigation systems, that many indoor navigation systems do not pay enough attention to the path planning aspect while localization becomes the main concern. The difficulty in locating the user with the limited presence of GPS signals in the indoors may be the main reason which draws attention towards positioning aspect of indoor navigation systems.

There are well established path planning methods commonly used in ETAs, which are mainly based on criteria such as travel distance and travel time. Dijkstra algorithm is used by four of the 12 ETAs analyzed by Fallah et al. (2013), in their survey on Indoor Navigation aids while the remaining eight have used A* algorithm. Minimizing the travel time is the goal of eight of them. However, when an ETA is aimed at people with VI, it is questionable whether the path calculated based on such criteria are actually useful for the intended user; paths suitable for people who use normal vision as the primary perception may have little relevance for people who have little or no vision. For example, maximizing safety may be more important than minimizing the travel time for a person with VI. The least hazard path (Helal et al. 2001), ease of travel (Koide and Kato 2005; Petrie et al. 1996) , obstacle and hazard avoidance combined with other criteria such as less turns (Ivanov 2012) are attempts to use parameters more suitable for people with VI.

Landmarks, when combined with route determination methods, can support establishing orientation while navigating. The environmental clues and landmarks implicitly picks up by people with normal vision might not be helpful for people with VI to establish the orientation. In the absence of, or having only lower level ability to use the vision clues as the main reference information they would use other perceptions such as hearing, touch and smell as identification of reference points for movements. Sound and smell become the main clues used by people with VI when navigating in a city (Afrooz et al. 2012). RSNAVI, an application where path planning is done based on multiple criteria, considers count of landmarks available in a route in path planning (Ivanov 2012). Building Navigator, which supports the orientation of users with voice description of building features within their immediate surrounding using a custom made building feature database, is an attempt to integrate visual landmarks in meaningful manner in an ETA (Kalia et al. 2010). A new algorithm is proposed by (Hua et al. 2007), which combines shortest path algorithm with multiple parameters namely user's speed, stride length and position of furniture to derive a visibility graph for path planning.

We propose to develop a novel path planning mechanism, which would address the limitations related to path planning suitable for people with VI by matching the navigation capabilities of them with the navigation support provided by structures and features of the indoor environment.

The study is being conducted in three stages, (1) recognize the path planning strategies, their success and limitations in available indoor navigation support systems for people with VI (2) Identify and classify contexts useful for determine user centric path planning (3) Develop a multi-criteria navigation model for VI people which can propose optimum paths based on contexts identified in (2) above, while negotiating safety and convenience factors.

Exploratory research, where features of an indoor environment important to the navigation by people with VI are to be investigated is designed. These experiments are being conducted in Western Australia and Sri Lanka currently, considering two variation of buildings (complex and simple) and two variations of user familiarity (already familiar, not familiar). Authors work closely with Guide Dogs WA and their Orientation & Mobility instructors and the clients with varying levels of visual abilities are providing input to this study. Interviewing and observational methods are being used to gather information.

In this work-in progress paper, the derivation of the initial idea of the proposed navigational model and the identification of the useful contexts to consider for path planning, namely (a) user and (b) the building environment are presented.

2. Design of the Proposed Model

2.1. The activities of a path planning component

The activities of a path planning component of an ETA for a VI person are defined as follows for this study.

1. Calculate the optimum path to travel from a known start location to known destination
2. Monitor the movements and provide orientation support while following the proposed path by the user
3. In the event of deviating from the path , identify the change and recalculate the path to reach the destination from the known re-start position
4. Identify that the user has reached the destination

The second activity, the orientation support, is an important aspect expected by an ETA as loss of sense of orientation is reported as a major concern of VI people when navigating inside a building. In order to monitor the user, the support of a Location component would be necessary.

2.2. Limitations of generic path planning

The proposed indoor navigation model for VI people would support path planning and orientation establishment based on a user centric approach, considering individual capabilities and limitations to negotiate with the environment. Instead of generalizing the notion of vision impairment, the possible differences between how individuals with different levels of vision loss perceive the environment and thereby selecting the most suitable path to travel is to be considered.

In a user centric approach, more research is needed to understanding how an individual user with VI would perform the activity of navigation in an indoor environment, negotiating with different entities. It is expected that the navigational capability and the cognitive load expected from a user to not exceed the facilities provided by the indoor environment(Gorwood 2014). For example, in a scenario where an individual with VI is having difficulty in identifying the steps of a staircase (and no aid is provided to support this identification) then it is not recommended for the individual to use the staircase; he may be better to get the support of another person or use an alternative means such as use of an escalator or a lift . However, the same staircase can be used safely by another person with vision impairment. This is due to the differences in capabilities of different VI people. Alternatively, if the individual is getting the support of a guide dog, as guide dogs do not like to travel using escalators, the choice of escalator may not be suitable. The proposed model combines the user centric approach with context awareness.

2.3. Selecting contexts affecting indoor navigation of people with VI

We assume that the optimum path should be a one comfortable and safe for the individual with VI and may vary for each user. In an indoor environment, the possible paths would be constituted of connection of routes between building structures. These structures and the features may act as landmarks for way finding as well. The suitability of the routes can be determined by the suitability of them (routes) to be used by people with different degree of vision loss. The proposed model assumes that the path suitable for indoor navigation of VI people would be better determined considering the,

1. Individual's capability to negotiate with the indoor environment. (individual user context)
2. The support and restrictions related to building structures and features within the indoor environment for navigation of people with VI.(building environment context)

The environmental factors such as lighting levels can affect both of the above parameters. Based on the individual's capability to perceive a name board placed in a corridor, that corridor can be a supportive or non-supportive structure for navigation. The same corridor can be less or more supportive depending on the corridor's lighting level. If more people are around or a temporary hording is there on the corridor, it can be non-supportive for many navigators with vision loss.

Therefore, with initial findings, we argue that the information for deciding the optimum path and orientation establishment for people with VI can be extracted from the following four main contextual domains;

- User characteristics (Eg: vision related attributes, use a white cane or not)
- Building structures (Eg: Corridors, light switches)
- Physical environment features (Eg: Tables, aisles in a supermarket)
- Ambient environment (Eg: Lighting, Noise).

The last three are sub domains of building environment context.

2.4. Overview of the proposed path planning model

The contexts identified above provide inputs to the navigation model. The perceptual information provided by building structures within it can vary with the properties of the ambient environment. Though the building structures and user characteristics remain relatively static over time, characteristics of ambient environment and the physical environment features vary with time; how this information is perceived by VI people and their benefits, costs and risks vary with user characteristics. If the relative benefits, costs and risks associated with individual segments of building structures contributing to navigation of people with VI is identified based on their point of view, a relative ranking for each building structure can be derived.

Accordingly, we would define a dynamic, multi-criteria ranking system for assessing building structures and sections under different environment conditions which can be matched against the requirements of the user with VI. Once applied on a building data set, this will provide orientation & mobility ranking (OMR) for individual structure and segments of a building. The path planning engine would use the OMR of building structures, which made routes , to match against user characteristics and derive a customized optimum path. This path would be integrated with orientation establishment support via visual and non-visual landmarks useful for vision impaired travelers.

The *Figure 1* shows the top level functional view of the proposed context aware navigational model.

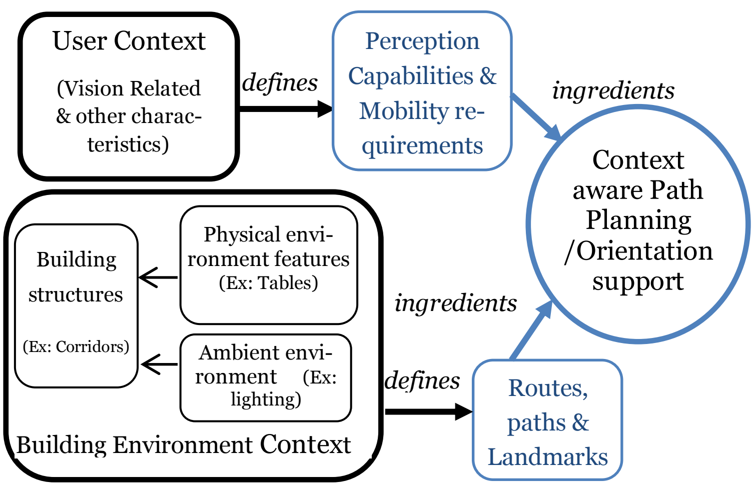

Figure 1. The overview of the functionality of the proposed navigation model

3. Analysis of Contexts considered

3.1. Indoor Environment Characteristics

Visual access, differentiation and layout complexity are identified as main environmental factors affecting way finding and navigation (Weisman 1981). As per Daniel and Corina (2006), these parameters can be defined as follows.

- Visual access: degree to which the building parts of a building are seen by a particular viewpoint.
- Differentiation: degree to which different parts of the environment look same or different. More differentiation with the environment supports greater mobility for users.
- Layout complexity: more complex layouts make way finding different; As per Daniel and Corina (2006) ,what increases the complexity of a layout needs further research.

"The effectiveness with which the vision can be used for safe travelling" is defined as visual accessibility (Legge,2010-as cited in (Kallie et al. 2012) and how easily and safely the objects in the spaces can be detectable by people with VI is a main issue related to visual accessibility. According to the same authors, distance, colour, height, shape of objects and interactions between illumination, colour, and shape contributes significantly to object identification by people with VI (Kallie et al. 2012). Further they conclude that the perception of distance, colour, shape and height are affected by the individual's degree of vision impairment (which is measured in term of visual acuity). The differentiation can be affected by the illumination and other factors as well. For people with VI, non-visual access also can be a major contributing factor. The presence of tactile objects and sound in the environment supports non-visual access. Therefore, not only the visual accessibility but non-visual accessibility also needed to be considered for safe traveling of people with poor vision. Presence of visual or non-visual landmarks would be an additional strength to support orientation and thereby navigating with confidence. The possibility of perceiving such landmarks would be affected by other parameters such as visual access and differentiation.

Accordingly, at this stage of our study, six parameters, visual access, differentiation, layout, lightning, non-visual access and presence of landmarks are identified as parameters affecting navigation support of a building structure. The last three parameters can be defined as follows.

- Lightning: the illumination level presence in the building structure.

- Non-visual access: the degree at which building structures and objects nearby can be perceived via non-visual perceptions such as hearing and touch.
- Presence of landmarks: the degree to which the visual and non-visual landmarks meaningful to people with VI are presented

The building structures and physical environment features (as described in section 2.3 above) are therefore suggested to be analysed for accessibility by people with VI and assign a rank for safe and comfortable travel for them. The basic set of parameters for orientation and mobility rank (OMR) for a building structure is summarized in *Figure 2*. The sub parameters and their interactions are to be further analysed. Whether the ranking can be quantified possibly with a scale is still open to explore.

The OMR value should be defined considering VI people's capabilities and with the understanding of the meaning of the parameters for them. Based on the different dimensions of vision impairment and other characteristics, the OMR ranking would indicate whether the structure is suitable for navigation by a particular user. For an example, a corridor may be ranked differently for individuals with different levels of visual field loss or contrast sensitivity.

3.2. Context of User: Individual characteristics

The individual characteristics of indoor navigators with VI can be defined in terms of vision impairment related and other characteristics (such as age, presence of hearing loss, use of a white cane etc.). Only the initial findings related to vision related characteristics are presented in this paper.

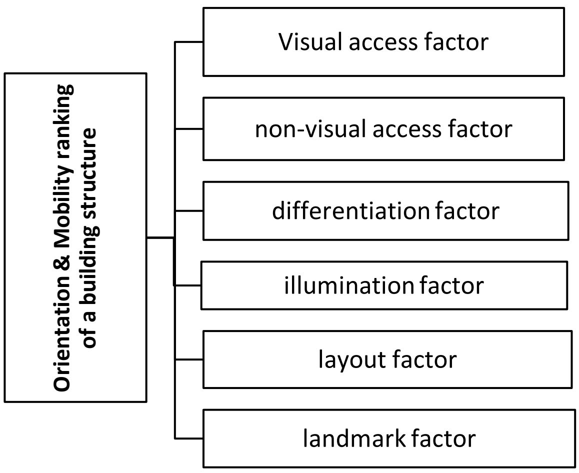

Figure 2: Summary of top two levels of parameters related to VI user characteristics

Vision Impairment Parameters

The Vision impairment, even though commonly generalized and simplified as to loss of vision in ETAs, is a complex phenomenon, affecting different visual capabilities and non-visual capabilities of the VI people. As per the ICD classification, vision impairment is defined based on levels of visual acuity (WHO 2010), which consider about far or near distance perception measurements. Merron and Baily (1982) shows visual acuity, however it is rarely related to functional vision required for mobility (as cited in Woods and Wood 1995). For functional vision assessments, combination of visual acuity and field view are commonly used (NIRE 2004; AIHW 2007). Visual field loss is a critical concern for independent travel (Freeman et al. 2007). The walking speed is declined and number of bumps increases with the decline in visual filed (Turano et al. 2004). Vision colour sensitivity is another concern for mobility (Murray 2008; Gorwood 2014). Contrast sensitivity, Glare sensitivity and analysis of actual tasks performed are suggested to use for better functional vision assessment in general(AIHW 2007).

The functional vision supporting navigation, the navigation vision, needs to assist in performing common tasks such as detection of nearby and far objects (Eg: steps, walls, wall edges, tables etc.) , recognizing signs (Eg: arrows, sign of cafeteria), reading large and small name boards and recognizing moving objects(people in a corridor), for safe and comfortable indoor navigation. The detection of objects and signs may be needed to be done around the immediate surrounding and not just directly towards heading direction. For an example, in an activity of walking along a corridor and the taking a turn towards a door at the left side, the door has to be detected while walking directly to not miss it and taking the correct turn. Central and peripheral vision contributes to this activity while vision colour loss or glare on the corridor may affect the correct detection. Therefore the degree and types of different vision impairments present is important for the indoor way finding. Accordingly, nine vision related parameters are identified. The parameters of the user context are summarized in the *Figure 3*.

Vision Conditions

The visual perceptions, in turn, would be affected by different vision diseases and issues. There is a wide spectrum of vision conditions which affect navigation vision. Seven conditions namely Age-related macular degeneration, cataract, Glaucoma, diabetic retinopathy, refractive errors, eye trauma and trachoma (in some remote areas) are the major contributing factors for vision loss cases in Australia (Dept.Of Health 2005). The first five of

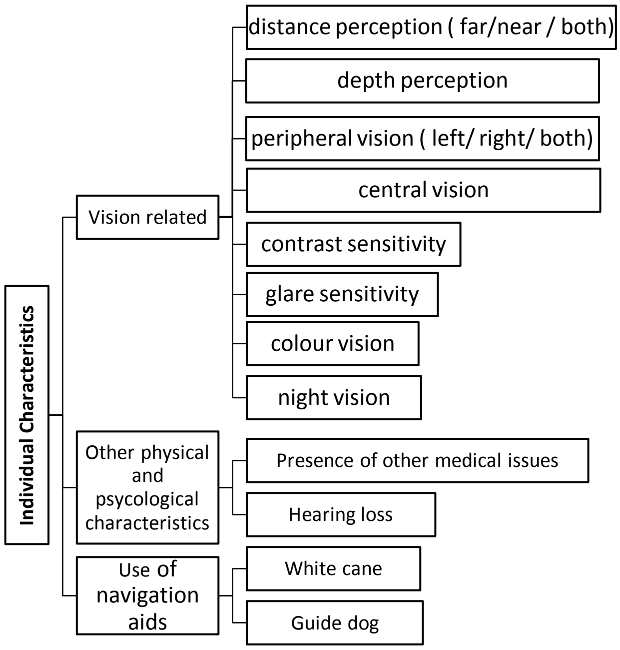

Figure 3: Summary of top two levels of parameters related to VI user characteristics

above conditions are considered as major issues commonly (Vision 2020 2014; Freeman et al. 2007; Gorwood 2014). Sample of analysis of how common vision conditions affect visual perceptions and thereby navigation abilities are presented in *Table 1*.The analysis is mainly performed based on the information provided by Retina Australia (2014), Vision Australia (2014) and Macular Disease Foundation (2014).

4. Future work & Conclusion

The sub parameters of the indoor environment context will be identified and a multi criteria ranking system for the different building components will be derived. The individual characteristics will also be analysed further to classify different vision impairment conditions in a meaningful manner related to indoor navigation. Input from above two steps will then be used to design a multi-criteria navigation model. The model would be independent from any implementation technologies of a particular ETA. Indoor Open Street Maps is considered as a possible tool to record and maintain the building feature information with OMR ranking data.

From this, a building environment ranking system for the navigation by people with VI and a multi-criteria path planning model will form this study's major contribution to indoor building navigation by VI people.

Main Causes of Vision Impairment	Affecting Capabilities	Links to vision parameters	Concerns related to Indoor Navigation
Age-related macular de-generation	loss, blurring or distortion of central vision,Reading, Writing, Looking at fine details , recognise fac-es,Dimming of colour vision	visual acuity, visual field (loss of central vision colour vision	Difficult/ cannot see what is in front, reading signs , name boards, size of an object may appear different for each eye, difficulty in differentiating two large objects(bus & a truck)
Glaucoma	Painless blurred vision, Loss of peripheral vision, Difficulty adjusting to low light	visual field, contrast sensitivity	Difficult in seeing sides, Where to turn may not be seen before a turn is taken
Diabetic Retinopathy	Low contrast sensitivi-ty,Blurred or distorted vision,Difficult to read standard print, watch television or see people's faces, Increased sensitivi-ty to glare ,Difficulty see-ing at night	Contrast sensitivi-ty,	Difficulty in seeing areas larger than few centimetres, Seriously affected seeing at near/ distance / direct/sides

Table 1: Sample of vision conditions and their effect on navigation

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Collaboratively collected geodata to support routing service for disabled people

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Abstract.

One of the main topics of cities is mobility. Nowadays, Mobile phones can provide navigation instructions in real-time, accessing wireless the Internet so routing and navigation applications on the Internet, in cars or on personal smartphones are everyday tools for many people. The purpose of i-SCOPE project was to deploy, based on new generation urban city model, a set of services to support the improvement of life quality on urban areas. One of these services was a personalized routing service for disabled people.

Pedestrians need a specific set of features to represent the environment and other information including barriers, sidewalks accessibility along the way, points of interest, and even services for disabled people. Unfortunately commercial geodata providers do not offer this detailed information; therefore there is a lack on this data from digital city maps, yellow pages and travel information data sets.

This paper will explore the potential for the VGI community to improve data access and services in the field of disable pedestrian mobility computing. This allows collecting information about a network to be used in route-planning, real-time navigation or for both, by providing detailed information about the “best” individual route based on the user’s limitations.

Keywords. VGI, OLS, routing, OSM, smart cities

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1. Introduction

Cities are the part of the world where there is the highest concentration of population. The United Nations estimates that at beginning of 2019, it is expected that more people will live in cities than in rural areas. This implies, a big effort for administrator, scientists and citizen improving the quality of life within cities.

The emerging trend is going towards a unified urban-scale ICT platform transforming a City into an open innovation platform called Smart-City. A core component of this approach is using communication and collaboration technologies to manage city information. However cities are a very complex system and, in several cases, it is difficult to collect and maintain this information without expensive surveys and instruments.

One of the main topics of cities is mobility. Nowadays, Mobile phones can provide navigation instructions in real-time, accessing wireless the Internet so routing and navigation applications on the Internet, in cars or on personal smartphones are everyday tools for many people.

A challenges faced on by Smart Cities is how to improve access to city space for wheelchair users and other disabled people. Of course this has to be realized, from the structural point of view, eliminating barriers and making city spaces available but even providing smart tools to support their mobility. Routing network data is suitable for motorized and (for selected cities) non-motorized path finding applications. However, content and granularity of the information requested by pedestrians with special needs has to be based on more specialized dataset, and cannot utilize the provided commercial geo-information and require highly detailed ground-truth data (Neis & Zielstra 2013). Pedestrians need a specific set of features to represent the environment and other information including barriers, sidewalks accessibility along the way, points of interest, and even services for disabled people.

Unfortunately commercial geodata providers do not offer this detailed information; therefore there is a lack on this data from digital city maps, yellow pages and travel information data sets. Furthermore the collection of this kind of information is extremely expensive and time consuming so municipalities and public body typically avoid inserting they into the survey and mapping updating.

Volunteered Geographic Information (VGI), or Geospatial crowd-sourcing, grouping all those activities in which citizens (volunteers) contribute to collect data and information about the earth and environment that is explicitly or implicitly georeferenced and then disseminated via collaborative projects. One of the most established projects in the context of VGI is OpenStreetMap[1] (OSM).

This paper will explore the potential for the VGI community to improve data access and services in the field of disable pedestrian mobility computing. This allows collecting information about a network to be used in route-planning, real-time navigation or for both, by providing detailed information about the "best" individual route based on the user's limitations.

The work described in this paper is part of the co-founded European project i-SCOPE[2] and consists on the definition of methodologies and workflow an to collect geometrical features supporting routing services for pedestrian disable people, in order to overcome the abovementioned information lack. Furthermore a multipurpose routing services to for disabled people with special navigation information will be described.

The remainder of this article is structured as follows: Section 2 presents some background information and related research in the field of routing networks and way finding for disabled people. In Section 3, the methodology including data preparation and the generation of the tailored routing network is described. Section 3 also contains detailed information about the requirements and parameters that the generated network should inherit and the routing algorithm should take into account when computing a route. The article concludes with a discussion of potential algorithm limitations, a summary of the findings and an outlook on future research.

2. Related works

Disabled people rely on very detailed information about potential obstacles in their neighbourhood, so although the efforts spent in developing navigation systems for pedestrians, many users with special needs are mostly excluded due to a lack of appropriate geographical data such as sidewalks, steps, surface conditions, or obstacles.

Several researches report application of GPS and GIS to developing navigation maps for individuals with disabilities (Sobek & Miller, 2006, Matthews et al., 2003). However these systems have limited capabilities to provide

[1] http://www.openstreetmap.org (accessed on 27 May 2014).

[2] www.iscopeproject.net

real time routing information or they are tailored on specific barriers free paths.

Other works focus on the different geodata requirements between non-motorized traffic, such as pedestrians, and applications tailored to motorized traffic. For example, Beale (2000) developed, tested, and applied a GIS for modelling access for wheelchair users in urban areas.

Geo-data source prerequisites for a potential navigation system for pedestrians has been studied in several researches (Gaisbauer & Frank, 2008, Matthews et. al. 2003). This kind of information is often very time consuming and expensive to be collected by the municipalities and the result are used into customized systems.

However in the last years new technologies have created opportunities for citizens to interact with each other, form collaborative groups, collect and disseminate information about their social networks and the world around them, in realtime (Budhathoki, & Haythornthwaite, 2013). This trend became popular under the term VGI (Goodchild, 2007) when the contributions tend to be more casual or Public Participation Geographic Information Systems (PPGIS) in which volunteers collect geodata for a particular purpose.

One of the most popular and most manifold projects for VGI is the OpenStreetMap (OSM) project (Neis et al., 2007). In recent years several studies demonstrated the potential of OSM in a variety of Location Based Services (LBS) applications (Schmitz et al., 2008). In a number of major cities the volunteers collect information about sidewalks, road surfaces, road slope, pedestrian crossings, and tactile paving. The classic approach is to collect data with a GPS receiver, which afterwards can be edited with one of the various freely available editors, such as Potlatch or JOSM. This information are fundamental when considering the creation of a suitable routing graph for disabled people, such as wheelchair users or elderly people.

Even if several studies about OSM demonstrate that urban areas are better mapped than rural counter parts or, only objects of certain types (e.g. roads) have descriptive measurements; other analyses by Neis, Zielstra et al. (2012) and Zielstra and Hochmair (2011b, 2012) have shown that the OSM provides a comprehensive network for pedestrians in comparison to commercial or governmental dataset distributors.

The work presented in this paper explores the potential for the VGI community and PPGIS to improve data to support disabled mobility. The methodology we present in this paper start from these data collection in order to deploy routing services tailored on disabled people.

3. Motivation

The purpose of i-SCOPE project was to deploy, based on new generation urban city model, a set of services to support the improvement of life quality on urban areas. One of these services was a personalized routing service for disabled people.

The first item to be investigated is the level of detail essential when considering the creation of a suitable routing graph for disabled people, such as wheelchair users or elderly people.

The methodology proposed in our work consists in these steps:

- Definition of the recommended parameters that need to be implemented to enrich the final dataset;
- Collection and editing of the information;
- Design and deploy of the routing services.

During the first step, ontology for datasets is needed as a formal specification of the data model, which is applied exemplary on the digital map of the city of Vienna and Cles (province of Trento). The ontology is based on the OSM tagging schema, which is increasingly being developed into a complex taxonomy of real-world feature classes and objects, this is a core part of the OSM initiative and is community-driven. Any member of the community can contribute to and update the schema by proposing new key=value pairs.

After the initial data preparation, the second step involves the creation of the disabled friendly routing network, utilizing all relevant information that was retrieved from original OSM dataset in addition to the collected ones.

The overall system proposed in this work includes smart phone application, web routing services, and OSM open source map editor.

3.1. Data model

In order to produce a useful services for disabled people, several consideration about the features taken in account have to be done. Generally routing service are based on graphs composed by geographic objects which are modelled through nodes, ways, and relations, where nodes are described through a location on earth using a coordinate pair and attributes. Considering vehicles mobility the graph is usually constituted by the road network where each ways and nodes have several attributes[3] such as max speed limit, number of lanes.

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[3] http://en.wikipedia.org/wiki/Geographic_Data_Files

Pedestrian mobility is more complex: pedestrian can move in in different spaces (sidewalks, roads, cycleway and pedestrian areas) and they can move from a space to another almost continuously so pedestrian routing geometrically has to consider many interconnected graphs. Furthermore the number of attributes to fully describe in particular disable people routing are very huge (curbs, slope, paving, width, crossing etc.).

Several data models have been developed to describe mobility and to support routing service: the already mentioned Geographic Data File (GDF) is mainly oriented to automotive segment, Graph Integration Platform (GIP) is another data model, primarily designed for outdoor environments. It provides the basis for traffic management, intermodal routing, and traffic modeling in Austria however is intermodal traffic graph core is rather complex.

CityGML data models is an emerging standard for modelling of buildings and landscapes in 3D, and i-SCOPE project bases its development on this standard for 3D buildings; however even if it is theoretically possible to extend the complex structure of the standard to support transport features, any implementation has been yet implemented and it is quite difficult to use it for practical implementation. Anyway a CityGML application domain extension for disabled routing has been implemented even if it will be not used for the technical implementation of the services.

The data model on the base of the i-SCOPE routing service has been developed on top of OSM data model. The OSM project has the goal to create a detailed map of the world based on VGI in vector data format. The information is collected by many participants, collated on a central database and distributed in multiple digital formats through the World Wide Web. Objects and their attributes are coded through tags in the form of key-value pairs, for example `highway = 'steps'` (object) and `step_count = '#_of_steps'` (attribute).

The spatial representation of the defined objects and structures is facilitated by matching the verbal descriptions of the i-SCOPE data model with the OSM based data model. Where possible existing OSM key-value pairs were used to describe the content of the catalog, otherwise In order to support disabled people routing an extension of the existing tags already developed in other similar projects[4] has been done..

[4] Wheelchair routing: http://wiki.openstreetmap.org/wiki/Wheelchair_routing#Sidewalks

Element	Type	Attributes
Road network	Line segments	Traffic barriers
		Width
		Number of lanes
		Longitudinal slope
		Direction
		Name
Sidewalk network	Line segments	Tactile paving
		Obstacles and their position
Pedestrian crossings	Line segments	Traffic lights and their type
Pedestrian network	Line segments	Tactile paving
		Type
		Obstacles and their position
		Longitudinal slope
		Name

Table 1 Example of data model routing features and related attributes.

Table 1 reports some feature already existing on OSM data model, some of the related attributes are an extension to this data model proposed by i-SCOPE. The data model includes some mandatory and optional attributes that are functional to the development of the routing service.

3.2. Data collection

Once defined the data model the main objective of the work was to collect the needed data within the pilot area. To due the complex nature of the required information the data collection task is very challenge and it has required an accurate study of the methodology. Also in this case the already existing initiative have gave to the project the right input in to find an feasible way to achieve the result.

The overall process could be schematized in four main steps:

- Awareness and motivation of volunteers;
- On-field survey;

- Data elaboration;
- Services deployment.

The first item is for sure the most challenge ones and moreover without a full involvement of volunteers it is impossible to achieve good results. Furthermore a good awareness of the volunteers lets to obtain useful data during the on-field survey and post processing elaboration.

In order to support the on-filed operation a mobile application has been developed. The application allows the user to collect the information about the features geo-localizing them directly on field, using the GPS embedded on the devices or, in case of bad GPS signal, to directly edit the feature on the map.

The app uses Wi-Fi where a wireless access point is available; in the field it uses mobile data access through 3G or 4G provided by the service provider. Web Services enable interaction between the smart phone and other components in the model. Web Map services (WMS) is consumed by the mobile app to display the OSM as background map. HTTP web service is used for user authentication, to send non-spatial attributes to the central repository. The non-spatial Database contains the information collected including images and info about the users.

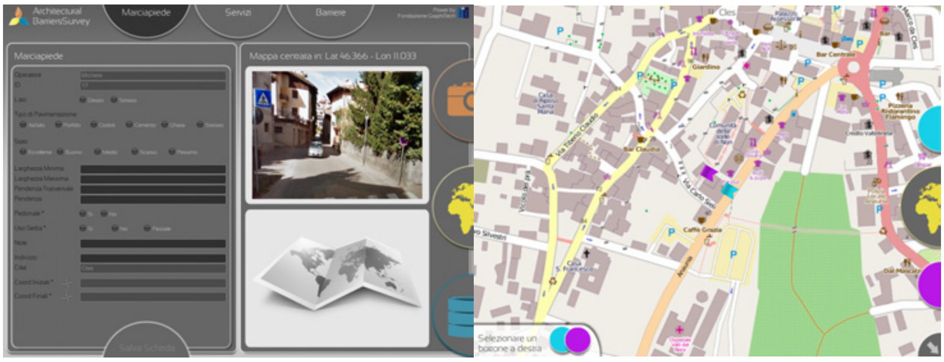

Figure 1 The interface of the mobile application for the architectural barrier[5] survey

Several application as been designed to collect geo-information directly on field increasing the crowd source data collection approach, however the main purpose of these application is to collect information which are typically modelled using a point of interest (PoI) approach.

Routing services on the other hand rely on very well geometrically structured graphs where node represents junction between two or more arcs. It

[5] https://play.google.com/store/apps/details?id=it.graphitech.iscopenew&hl=en

is obvious how it be impossible to obtain so well structured information using mobile application during the on-field campaign. For this reason the third phase is related to the post processing editing of the graph needed for the routing service purpose.

The rational behind the i-SCOPE routing data is to enrich the data model provided by OSM with the additional information coming from the specific volunteer surveys realized using the mobile application on field. This implies three main advantages: i) to exploit the existing information already existing on the OSM database, ii) to exploit the commitment of the OSM community in order to assess and verify the uploaded information, iii) to put within the loop additional information which can be reused from different users.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<osm version="0.6">
  <node id="143" lat="44.8356588646678" lon="11.6191821217" user="team01" visible="true" version="1" timestamp="14-04-2014 8:50:36"/>
  <node id="-143" lat="44.8358954324033" lon="11.6193430703011" user="team01" visible="true" version="1" timestamp="14-04-2014 8:50:36"/>
  <way id="12" user="team01" visible="true" version="1" timestamp="14-04-2014 8:50:36">
    <nd ref="143"/>
    <nd ref="-143"/>
    <tag k="name" v="corso martiri della liberta, ferrara"/>
    <tag k="highway" v="footway"/>
    <tag k="footway" v="sidewalk"/>
    <tag k="foot" v="yes"/>
    <tag k="surface" v="sett"/>
    <tag k="smoothness" v="good"/>
    <tag k="sidewalk" v="right"/>
    <tag k="est_width" v="0.5 m"/>
    <tag k="incline" v="0 %"/>
    <tag k="barrier" v="yes"/>
    <tag k="wheelchair" v="yes"/>
  </way>
```


Figure 2 Example of OSM file export from architectural barriers survey database ready for editing within JOSM.

The editing phase is realized within typical OSM editing tools (i.e. JOSM[6]); in order to facilitate the communication between the mobile application and the editing phase it is possible for the user to export the information from the central database directly in OSM format.

Once edited and saved on OSM the information can be downloaded from OSM website and imported on the i-SCOPE routing database for supporting disabled people routing requests.

3.3. Routing Services

The last component of the whole chain is the routing service engine. The disabled people routing service (or Inclusive Routing service) is a routing service aiming to serve people with disabilities and aid them move in urban environments. It is based on an existing OpenLS-compliant routing service,

[6] https://josm.openstreetmap.de/

and relies on OpenStreetMap data. Specifically it supports the following user categories:

- People with visually impairments
- Wheelchair users
- Pedestrians

The Inclusive Routing service also provides support for directions using and extending existing service technologies developed in the context of AmauroMap[7], which allows defining semantically-rich text-based description of environmental features based on vector GIS data.

The main important feature of this service is that, relying on OSM data enriched by the information collected through the volunteers campaign, it is able to provide instructions tailored on specific user behaviour. To achieve these results a number of factors have been identified in an urban environment facilitating or obstructing mobility for wheelchair users and visually impaired people. These factors have been modelled within the data model described on section 3.1.

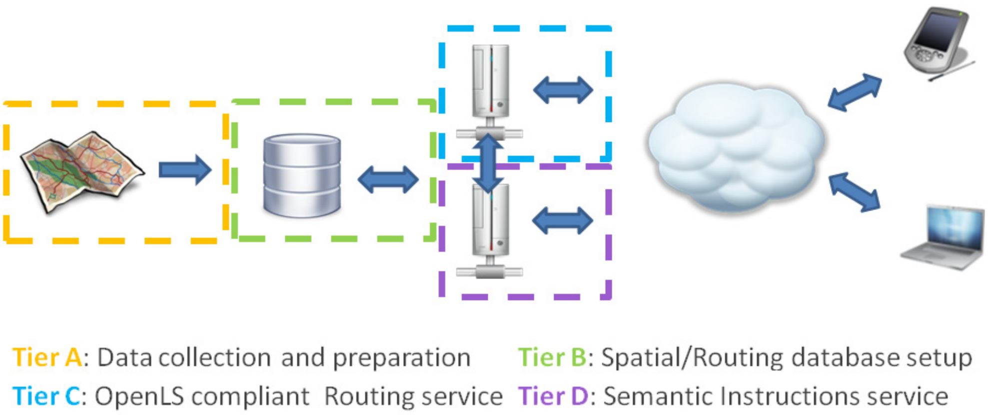

Figure 3 System Architecture

The global system architecture of the service is based on a typical three layer Service Oriented Architecture: at the bottom there is the data layer composed by the database containing the routing weighted networks and the POIs from the different pilot regions, the middleware is composed by a

[7] http://www.amauro.map.at/

OpenLs compliant service; and at the application layer there are a web and a mobile able to perform the request and visualize the output.

In order to cater with the Inclusive Routing services particularities the OpenLS schema was extended. For instance values `"Wheelchair"` and `"VisuallyImpaired"` are added as possible values (along with `“Shortest”`, `“Fastest”`, `“Pedestrian”`).

One of the main important element of the service are the weight assigned to the features in order to obtain the more appropriate path based on the different input parameters. The set-up of these weights is very complex because there are many parameters to take in account: length, slope, type, paving condition, presence of obstacles etc. At the moment we are in the testing phase where the users testing the services providing feedback on the output path, reporting strange behaviours due to the wrong weight assignment.

4. Conclusion

This paper report the results of the EU project i-SCOPE; in this project it has been deployed a routing service to support the pedestrian mobility of the diversely able people. The main characteristic of the work is that the whole chain starting from data collection to the services deployment has been considered.

Disabled people mobility indeed requires a lot of information about the path elements, and in many cases these are not available at all, in other they are not available in appropriate data model to support routing service.

Furthermore the collection of these information is very expensive and time consuming and the municipalities often have not enough resources to collect them. The work proposes methodologies and tools to collect and update the information using VGI approach.

Motivating specific groups of interest people and giving them appropriate instruments it is possible to collect a huge umber of information in a very short time. A specific mobile application for collecting information on field has been developed; through this application it is possible to survey the features to describe pedestrian mobility. The features are collected according to a data model, which extends the OSM data model. Then the data collected are edited in order to create a graph and used as base for the routing service.

The main difficult is related to the mobilisation of people for data collection; this is a very challenge topic and there is not an unique solution. In this project relying on OSM platform, data model, and community, we would to enlarge the audience and facilitate the operation for the data collection. Furthermore the possibility to reuse the collected information for other purpose outside the project through the open data format can put in contact different organization to the data collection.

Figure 4 Example of two different returned path based on different request, above shortest path below wheelchair path.

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RFID Based 3D Indoor Navigation System Integrated with Smart Phones

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Abstract. Nowadays there are a lot of high rise, complex and huge buildings in the cities especially in metropolises. These building are almost like a small city with their tens of floors, hundreds of corridors and rooms and passages. Sometimes people lost their way in these huge buildings. Due to size and complexity of these buildings, people need guidance to find their way to the destination in these buildings. In this study, a mobile application is developed to visualize pedestrian's indoor position as 3D in their smart phone. This mobile application has the characteristics of a prototype for indoor navigation system. While the pedestrian is walking on his/her way on the route, smart phone will guide the pedestrian by displaying the photos of indoor environment on the route. As a future plan, an RFID (Radio-Frequency Identification) device will be integrated to the system. The pedestrian will carry the RFID device during his/her tour in the building. The RFID device will send the position data to the server directly in every three seconds periodically. On the other side, the pedestrian will just select the destination point in the mobile application on smart phone and sent the destination point to the server. The shortest path from the pedestrian position to the destination point is found out by the script on the server. This script also sends the environment photo of the first node on the acquired shortest path to the client as an indoor navigation module.

Keywords. Indoor Navigation, Smart Phone, Android, RFID, Mobil

1. Introduction

Nowadays there are a lot of high rise, complex and huge buildings in the cities especially in metropolises. These building are almost like a small city with their tens of floors, hundreds of corridors and rooms and passages.

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Sometimes people lost their way in these huge buildings. Due to size and complexity of these buildings, people need guidance to find their way to the destination in these buildings. Although there are a lot of studies about indoor navigation on 2D (two dimensional) maps, pedestrians need more realistic navigation system that routes pedestrians in buildings as 3D (three dimensional) (Musliman et al., 2009).

In this study, a mobile application is developed to visualize pedestrian's indoor position as 3D in their smart phone. This mobile application has the characteristics of a prototype for indoor navigation system. User will define the route on smart phone in advance, by selecting the nodes, which will be passed through along his or her tour, in order. This mobile application uses client server architecture, the client side is represented by smart phone and server side is represented by a web server, which holds a spatial database. Within the scope of this study, indoor environment is taken photo in three-meter intervals between all nodes and photo-frame library is established. Every photo is processed separately to decrease the storage size without losing much image quality due to making data transfer faster. The spatial database is designed by relating the nodes on 3D node networks with the photo frame library. Thus, this keeps the database information of photo frame library belonging to the indoor points. Client (smart phone) connects to the web server on a wireless network connection and sends user defined route to the server. When the route information arrives to the server, a web service is activated to query database. The query is retrieving operation of photos on the route from photo frame library. The result of the query consisting of a group of photos is sent back to application on the smart phone using the wireless network connection. While the pedestrian is walking on his/her way on the route, smart phone will guide the pedestrian by displaying the photos of indoor environment on the route.

2. Tools

The application is aimed at Android Mobile Operating System that has a widespread user and developer groups on the world (Dimarzio, 2008). Since the Android Application is generally developed based on Java programming language, Eclipse Interactive Development Environment (IDE) is used as a development environment. This mobile application is coded to able be run on all versions of Android from Android 2.2 (API Level 8) to Android 4.4 (API Level 19) http://developer.android.com. Script on the web server to query on the database is coded in PHP (Hypertext Preprocessor) web based programming language. Oracle Database 11g Database is used on the web server as database management system to keep all information (nodes, links, the paths of photos, extra definition about points and so forth) about the mobile application. The results of query on the server is formatted as JSON (JavaScript Object Notation) to make a lightweight data transfer from the server to the smart phone www.json.org.

Figure 6. Architecture of the mobile application.

3. Mobile Application

This study is realized in three basic steps. In the first step, the database of the application is designed and provided a sample indoor environment's data. In the second step, the Android mobile application that works on client (smart phone) is developed. At the last step, a web based script is coded to connect to the database and to retrieve the photos on the route of pedestrian from the database on the server.

3.1. Database Design

In the database design, two different tables that are related to each others are created. The first table (link table) keeps the information of links between nodes in the building. In this table, every link has a specific identification number, a different start node and a different end node. The second table (photo table) keeps the name of the environment photo that belongs to each point in every link in the building. The second table also keeps extra information to specify the location of every points in the links. Therefore, every link in the first table has at least two related records (points) in the second table. The number of records that belongs to a link is calculated by considering the link length. If the link length is longer than three meters, then the link has more than two records in the second table for the reason that the indoor environment is taken photo in three-meter intervals between all nodes as mentioned before.

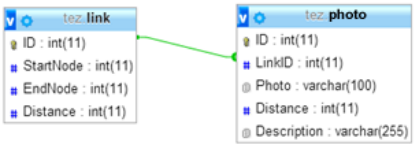

Figure 7. ER diagram of spatial database.

3.2. Development of Mobile Application

In the development of mobile application step, a graphical user interface is designed for pedestrian on the smart phone. There are two drop down boxes on the screen, one is for specifying the start node and another is for specifying end node. In this way, the pedestrian will define and add all links on his/her way. The pedestrian clicks on the send button on the screen just before he/she starts the tour. Then the mobile application sends the list of nodes, which pedestrian will visit along the tour, to the server in order. The application connects to the server by using http protocol. The script on the server will run and send the photo frames back to the smart phone. Thus, the indoor photos will be loaded to the smart phone in every three seconds, periodically. The period for loading the indoor photos to smart phone is defined as three seconds why a normal pedestrian would probably walk three meters in three seconds. Therefore, every point in the pedestrian's route will be displayed on the smart phone.

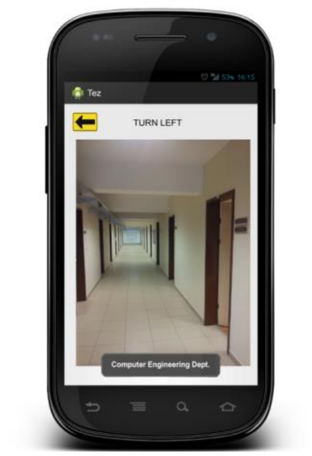

Figure 8. Mobile Application.

3.3. Development of Web Script

In the last step of the study, a PHP script is developed running on an Apache web server. The script takes the node list as argument coming from Android application. The script parses the node list and forms pairs of the nodes. Every pair of nodes corresponds to a record in the link table. Thus, the script reveals the links on the pedestrian's route and retrieves all the photos of these links from photo table. The script converts the retrieved photos JSON format data uses http protocol to send it back to the client.

4. Future Plan

As a future plan, an RFID (Radio-Frequency Identification) device will be integrated to the system. The pedestrian will carry the RFID device during his/her tour in the building. RFID device will be used to determine the exact position of the pedestrian in indoor environments whose all floors, corridors, passages and rooms are equipped with RFID tags. The RFID device, handed by the pedestrian, will read the tags and find out pedestrian's 3D position in the building. The RFID device will send this position data to the server directly in every three seconds periodically. On the other side, the pedestrian will just select the destination point in the mobile application on smart phone and sent only the destination point to the server. As soon as the script on the server gets the position data from RFID device and destination points from the smart phone, then it will find out the shortest path from the pedestrian position to the destination point. The environment photo of the first node on the acquired shortest path will be sent to the client by the server script. The script will also send visual and voiced navigation information to the client to inform the pedestrian on his/her way. So the pedestrian will get a real indoor navigation module that is running on smart phone.

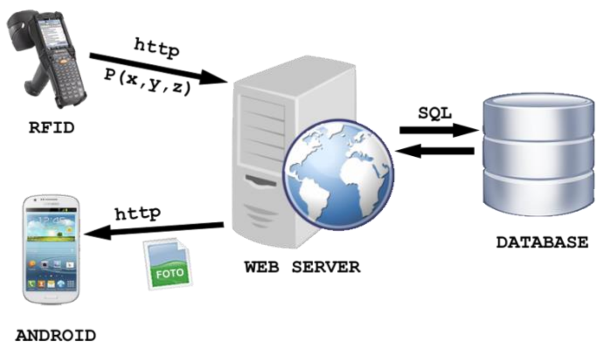

Figure 9. RFID device integrated navigation module.

5. Acknowledgement

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Privacy Preserving Aggregation of Distributed Mobility Data Streams

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Abstract. Proliferation of pervasive devices capturing sensible data streams, e.g. mobility records, raise concerns on individual privacy. Even if the data is aggregated at a central server, location data may identify a particular person. Thus, the transmitted data must be guarded against re-identification and an un-trusted server. This paper overcomes limitations of previous works and provides a privacy preserving aggregation framework for distributed data streams. Individual location data is obfuscated to the server and just aggregates of k persons can be processed. This is ensured by use of Pailler's homomorphic encryption framework and Shamir's secret sharing procedure. In result we obtain anonymous unification of the data streams in an un-trusted environment.

Keywords. Privacy Preserving Big Data Collection, Mobility Analysis, Distributed Monitoring, Stream Data

1. Introduction

Smartphones became a convenient way to communicate and access information. With the integration of GPS sensors mobility mining was pushed forward (Giannotti & Pedreschi, 2008). The mobility information of multiple devices is usually stored on a server which performs analysis in order to extract knowledge on the movement behavior. In the easiest case this is the number of visitors to dedicated places, compare Figure 1.

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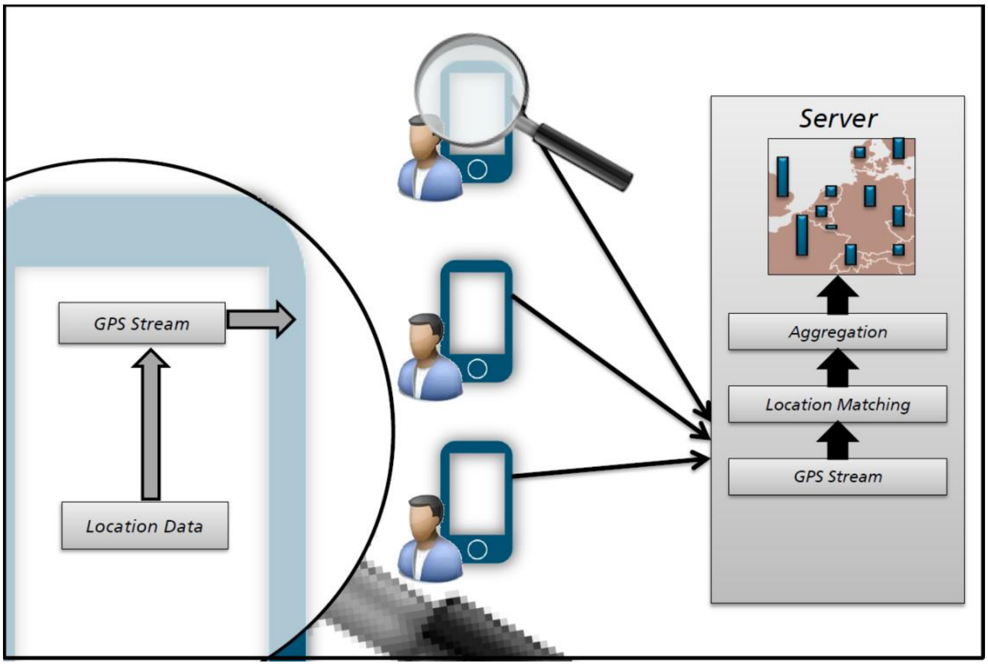

Figure 1: Centralized Mobility Data Analysis

The processing of the data streams became infeasible for large use cases, where millions of people are monitored, and massive data streams have to be processed. In this Big Data scenarios, the expensive computation (matching and counting in individual, continuous GPS streams) is split among the parties and just the aggregation step remains in the server. Thus, the continuous movement records (GPS) are reduced to episodic movement data (Andrienko et. al. 2012) consisting of geo-referenced events and their aggregates: number of people visiting a certain location, number of people moving from one location to another one, and so on. The preprocessing of the GPS data streams is then locally embedded in the location based devices and the aggregation is subject to crowd sourcing. Recent work focuses on in-situ analysis to monitor location based events (*visits* (Kopp et. al. 2012), *moves* (Hoh et. al. 2012)) or even more complex *movement patterns* (Florescu et. al. 2012) in GPS streams. In all cases a database with the locations or patterns of interest is provided in advance, and the mobile device computes event-histograms for succeeding time-slices. These histograms are much smaller and may be aggregated by the server in order to achieve knowledge on current movement behavior, compare Figure 2.

However, the transmission of these individual movement behaviors still poses privacy risks. The devices monitor daily behavior and thus reveal working place and hours, the place where we spent the night and other locations indicating information on sensitive subjects as health, religion, political opinions, sexual orientation, etc. Thus, the transferred episodic movement data may even lead to re-identifications.

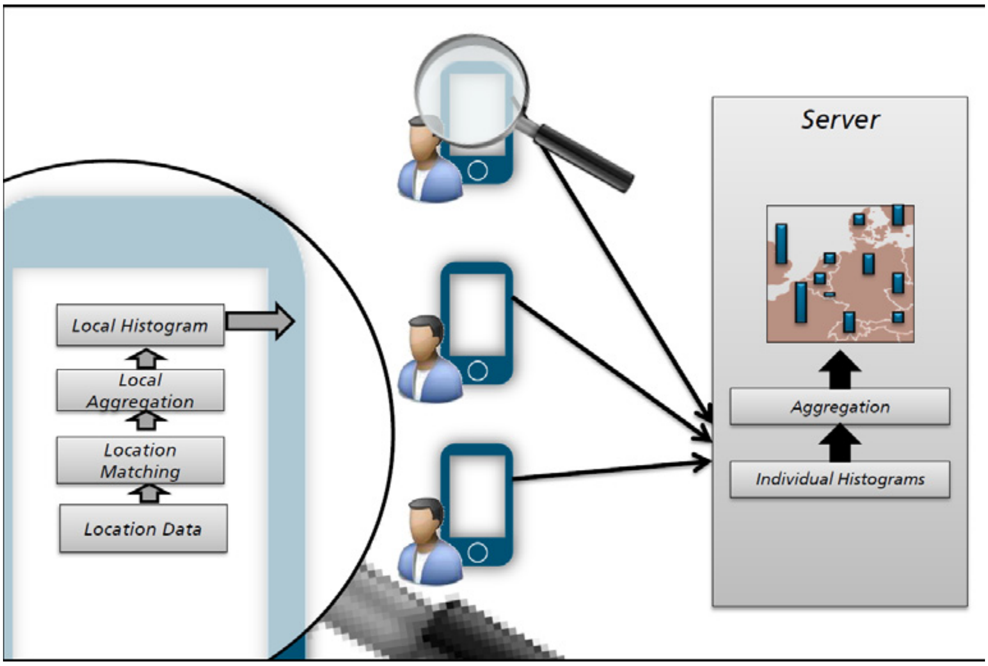

Figure 2: Aggregation of Distributed mobility Data Streams

The problem we thus focus is the protection of the individual histogram in such a data stream of locally aggregated mobility events. The adversary model is a corrupted server that utilizes the received individual histogram for inferences on the identities and other sensitive data.

Existing methods either act on the network layer (Kopp et. al. 2012) or inspired by the differential privacy paradigm they add random noise (Monreale et. al. 2013). The work in (Clifton et. al . 2004) denotes a protocol for secure aggregation among multiple parties, but their algorithm requires extensive communication among the parties and is infeasible in the considered crowd sourcing (i.e. single server) scenario, also their encryption can be broken after several computation cycles.

In contrast, our approach bases on homomorphic crypto systems (Paillier, 1999). These are systems where the decryption of several multiplied encrypted values reveals the sum of the original messages. Similarly to the RSA algorithm (Rivest et. al. 1983), the system, based on (Damgard & Jurik, 2001), uses one-way encryption functions to protect the messages. Thus a public key is used for encryption and a secret private key will be used for decryption. We share the secret key among the clients in the network using hamir's secret sharing scheme (Shamir, 1979). The temporal entanglement of the messages is prevented using a one-way hash as in (Lamport, 1981).

The paper proceeds with a detailed discussion of latest work that tackle the described problem. Afterwards our approach is presented in conjunction with preliminaries on crypto systems. However, our approach poses new requirements to the architecture from Figure 2, which are briefly discussed afterwards. We conclude with a discussion of our achievements and an outlook on future research.

2. Related Work

The problem to protect individual privacy in a distributed scenario with an untrusted server receives increasing importance with the spread of Big Data architectures and the wide availability of massive mobility data streams. Thus, the problem is subject of many recent publications.

The work in (Abul et. Al. 2008) computes k-anonymity and assumes a trusted server. The work from (Kopp et. al. 2012) tries to solve the untrusted server problem by introduction of an obfuscation layer in the network communication, see Figure 3. But individual location data is identifying, even if it is aggregated in space-time compounds (Monreale et. al. 2010). Therefore, this work still delivers the vulnerable data to the server. Recently, differential privacy was applied to the problem in (Monreale et. al. 2013). Originated in database theory, differential privacy implies that adding or deleting a single record to a database does not significantly affect the answer to a query (Dwork et. al. 2006). The work in (Monreale et. al. 2013) follows the common method to achieve differential privacy by adding Laplace noise (with the probability density function $(\mu, \lambda) = p(x|\mu, \lambda) = \frac{1}{2\lambda} e^{-\frac{|x-\mu|}{\lambda}}$, where μ is set to zero and λ=1/ε) to every flow value in the vector, as proposed in (Dwork et. al. 2006), compare Figure 4.However, for cell counts differential privacy is known to provide strange behavior, especially if a large number of cells are zero (Muralidhar & Sarathy, 2011).

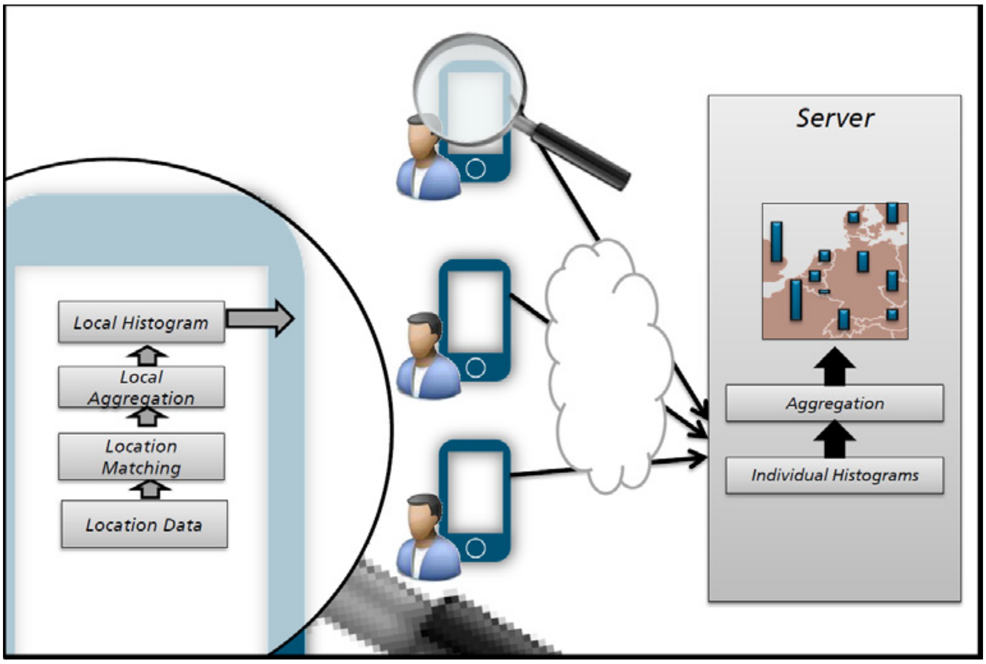

Figure 3: Obfuscated Communication

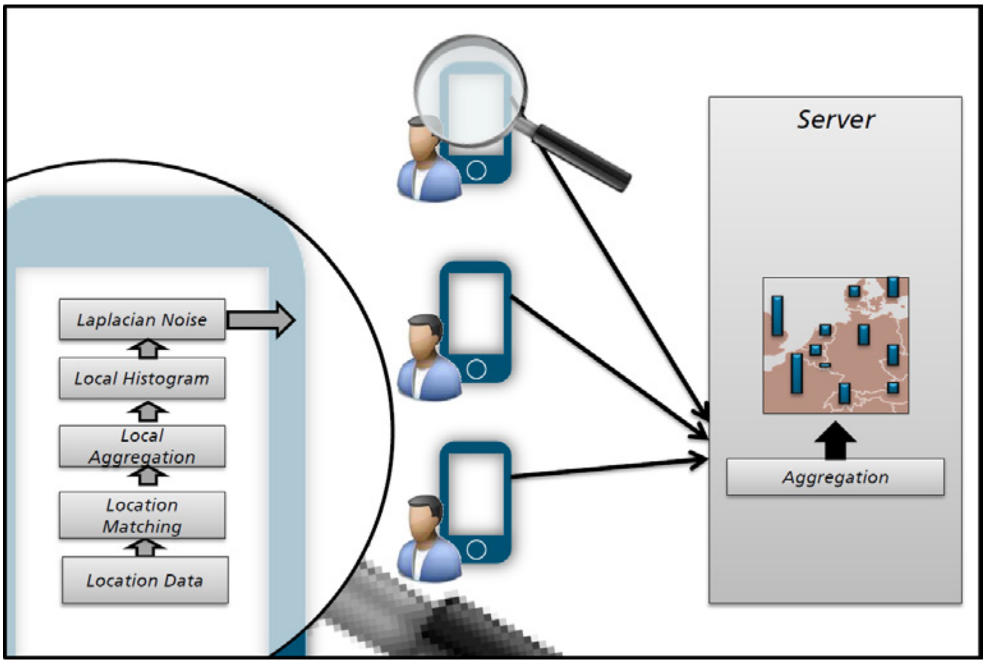

Figure 4: Differential Privacy

Moreover, movement often is a routine behavior and within their considered time interval most likely similar counts are produced for every person, this offers a chance to extract the mean and thus the correct value of the distribution within a stream environment (Duan, 2009) as the noise is sampled from $Lap(0, 1/\varepsilon)$ instead of sampling from $Lap(0, m/\varepsilon)$, where m denotes the expected number of queries. Additionally, movement is not random, and thus the frequencies in the vector are not independent, but correlate (Liebig et. al. 2008, Liebig et. al. 2009). Thus, combination of various noisy replies may be utilized to reveal the true distributions.

In contrast, our approach based on homomorphic cryptology in conjunction with a shared key ensures that individual data may not be accessed by the server but only aggregates of at least k people can be used, Since k may equal the number of clients, no data on the individual persons need to be revealed.

3. Proposed Cryptographic Approach

In contrast to previously described approaches our method (1) encrypts the values of the histogram, (2) communicates these ciphertexts to the server, (3) aggregates the ciphertexts and finally (4) decrypts the result, see an overview in Figure 5. The process utilizes asymmetric cryptography methods using two separate keys: one for encryption and another one for decryption. The utilization of a homomorphic crypto system in conjunction with Shamir's secret sharing guarantees that the individual messages cannot be restored, but their sum.

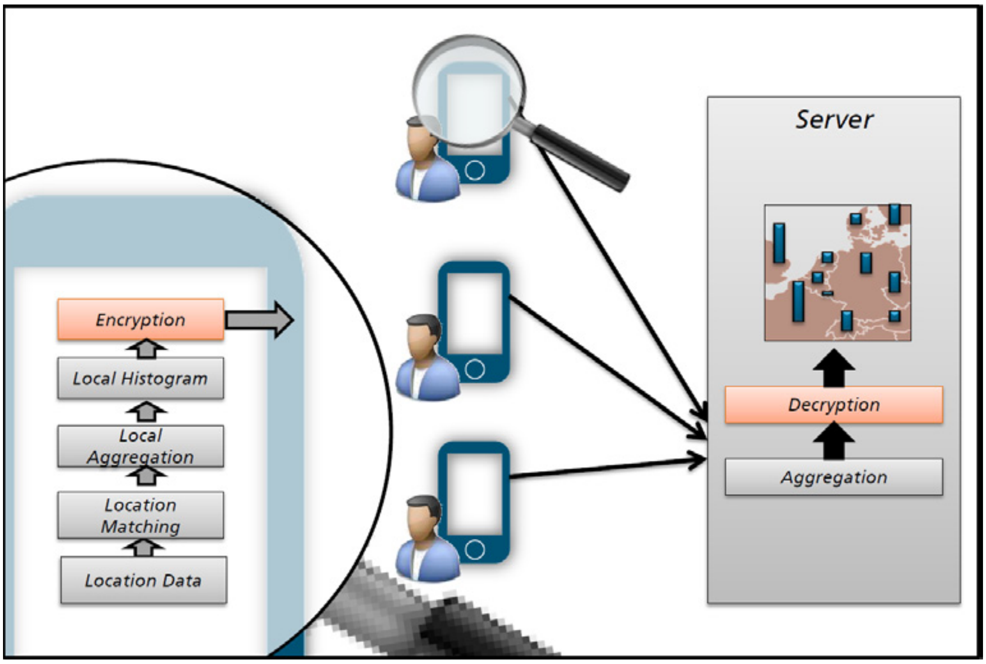

Figure 5: Proposed Cryptographic Approach for Privacy Preserving Aggregation of Distributed Mobility Data Streams

As our method bases on the RSA-method (Rivest et. al. 1983), homomorphic crypto systems (Paillier, 1999), (Damgaard & Jurik, 2001), Shamir's secret sharing (Shamir, 1979) and the work on hash chains, described in (Lamport, 1981), we proceed with a brief primer and describe our method afterwards.

The RSA-algorithm (Rivest et. al. 1983) is an asymmetric crypto system. The system bases on two keys, a *private key* which is used for decryption and a *public key* used for encryption. Whilst the public key can be shared with multiple parties, the private key is the secret of the receiver, and may hardly be computed from the public key.

3.1. RSA Algorithm

The RSA method uses one-way functions. These are functions which are easy to compute in one direction but difficult to reverse. A simple metaphor of this function is a phone book: While it is easy to derive the call number of a particular person, it is hard to look up the name given a phone number.

Preliminary for understanding is the notion of multiplicative inverse b of a number a, which is defined as $a \cdot b = 1 \bmod m$. This inverse just exists, if m and a are co-prime, i.e. $gcd(m, a) = 1$.

Consider a communication among the client who wants to send a message to the server. In this case, the system works as follows. In a key generation process, the server chooses two different primes p and q and computes $n = pq$ and $m = (p-1)(q-1)$. Furthermore, the server chooses a number a which is co-prime to m. The public key, created by the server, then denotes as $pk = (n, a)$. The server computes the multiplicative inverse $b = a^{-1} \bmod m$ of a, which is the secret private key.

Encryption

The client has a message x, with $x < m$. He sends the ciphertext c, computed as $E(x, pk) = x^\wedge a \bmod n$.

Decryption:

The server decrypts the message and restores the plaintext by computing

$x = D(c) = c^\wedge b \bmod n$.

The system is secure, as knowledge of n does not reveal p and q, since factorization is in NP (Johnson, 1984).

3.2. Homomorphic Crypto Systems

A public key encryption scheme (E, D), where E and D are algorithms for encryption and decryption, is homomorphic when it meets the condition $D(E(m_1) \cdot E(m_2)) = m_1 + m_2$.

Our approach bases on the generalisation of Paillier's public-key system (Paillier, 1999), introduced in (Damgaard & Jurik, 2001). Their crypto system uses computations modulo $n^\wedge(s+1)$, with n being the RSA modulus and s a natural number. By setting $s = 1$ Paillier's scheme is a special case (Paillier, 1999). If $n = pq$ with p and q being odd primes, then the multiplicative group $\mathbb{Z}^*_{n^{(s+1)}}$ is a direct product of $\mathcal{G} \times \mathcal{H}$, where $\mathcal{G}$ is of cyclic order n^s and $\mathcal{H}$ is isomorphic to $\mathbb{Z}^*_n$. Thus, $\overline{\mathcal{G}}$=$\mathbb{Z}^*_{n^{(s+1)}}/\mathcal{H}$ is cyclic of order n^s.

For an arbitrary element $a \in \mathbb{Z}^*_{n^{(s+1)}}$, a=$\overline{a}$=a$\mathcal{H}$ denotes the element represented by a in the factor group $\overline{\mathcal{G}}$.

Choose $g \in \mathbb{Z}^*_{n^{(s+1)}}$ such that $g = (1+n)^{jx} \bmod n^{s+1}$ for known j relatively prime to n and $x \in \mathcal{H}$. Let λ be the least common multiplier of $p-1$ and $q-1$, $\lambda := lcm(p-1, q-1)$. Choose d by the Chinese Remainder Theorem, such that $d \bmod n \in \mathbb{Z}^*_n$ and $d = 0 \bmod \lambda$. The public key then is n, g whilst the secret key is d.

Encryption:

The plaintext m is element of $\mathbb{Z}^*_{n^s}$. With a plaintext m we choose at random r in $\mathbb{Z}^*_{n^{(s+1)}}$. The ciphertext $E(m, r)$ computes as:

$E(m,r) = g^\wedge m\, r^{n^s} \bmod n^\wedge(s+1)$.

Decryption:

For the ciphertext c compute $c^\wedge d$ mod $n^\wedge(s+1)$. If $c = E(m,r)$ this results in

$$\begin{aligned} c^d &= \left(g^m r^{n^s}\right)^d = E(m,r)^d \\ &= \left((1+n)^{\{jm\}} x^i r^{\{n^s\}}\right)^d \\ &= (1+n)^{jmd \bmod n^s} \left(x^m r^{\{n^s\}}\right)^{\{d \bmod \lambda\}} \\ &= (1+n)^\wedge(jmd \bmod n^s) . \end{aligned}$$

In (Damgaard & Jurik, 2001) an algorithm is proposed to compute $jmd \bmod n^s$. Their method bases on a function $L(b) = (b-1)/n$ which ensures that

$$L(1+n)^i \bmod n^{\{s+1\}} = \left(i + \backslash\binom{i}{2} n + \cdots + \binom{i}{s} n^{\{s+1\}}\right) \bmod n^s .$$

The basic idea of their algorithm is to compute the value iteratively in a loop For convenience, their algorithm is cited in Algorithm 1.

With the same method computed for g instead of c the value $jd \bmod n^s$ is computed. The plaintext then is:

$$(jmd) \cdot (jd)^{-1} = m \bmod n^s .$$

$i := 0$

For $j := 1$ to s

$t_1 := L(a \bmod n^\wedge(j+1))$

  $t_2 = i$

  For $k := 2$ to j

    $i := i - 1$

    $t_2 := t_2 \cdot i \bmod n^j$

    $t_1 := t_1 - \frac{\{t_2 \cdot n^{\{k-1\}}\}}{k!} \bmod n^j$

  ENDFOR

  $i := t_1$

ENDFOR

Algorithm 1: Damgard Jurik Algorithm (Damgaard & Jurik, 2001)

The crypto system is additively homomorphic. As example consider two messages m_1 and m_2 which are encrypted using the same public key pk such that $c_1 = E(s,pk)(m_1,r_1)$ and $c_2 = E(s,pk)(m_2,r_2)$ then $c_1c_2 = g^{m_1}g^{m_2}r_1^{n^s}r_2^{\{n^s\}} = g^{(m_1+m_2)}r^{n^s}$ so $c_1c_2 = E(s,pk)(m_1 + m_2,r)$.

3.3. Shamir's Secret Sharing

The work presented in (Shamir, 1979) discusses how to distribute a secret value d among n parties, such that at least k parties are required for restoring the secret.

The idea utilizes a polynomial function $f(x) = \sum_{i=0}^{k-1} a_i x^i$,with $a_0 = d$, and distributes the values $f(i)$ to the parties.

In case k of these values are commonly known, the polynomial $f(0)$ can be restored.

The advantage of this method is that the shared parts are not larger than the original data. By some deploying strategies of the parts hierarchical encryption protocols are also possible.

3.4. Hash Chain

The work in (Lamport, 1981) describes a method for authentication with temporally changing password messages. The passwords series are created in advance using a cryptographic hash function which is a one-way function $F(x)$. They are created as follows $F^n(x) = F\left(F^{(n-1)}(x)\right)$, where x is a password seed. The passwords are used in reversed order. Thus, the server stores the last value that the client sent, $F^n(x)$, and proves correctness of the new value $F^{n-1}(x)$ by verification of $F^n(x) = F(F^{n-1}(x))$. Afterwards the server stores the latest received value for the next check. As $F(\cdot)$ is a one-way function, the server may not pre-compute next password.

3.5. Putting Things Together

Our cryptographic system follows the protocol of the homomorphic crypto system in (Damgaard & Jurik, 2001). Consider communication among w clients with a single server. Similar to (Damgaard & Jurik, 2001) key generation starts with two primes p and q which are composed as $p = 2p' + 1$ and $q = 2q' + 1$, where p' and q' are also primes but different from p and q. The RSA modulus n is set to $n = pq$ and $m = p'q'$. With some decision for $s > 0$ the plaintext space becomes $\mathbb{Z}_{n^s}$. Next, d is chosen such that $d = 0 \bmod m$ and $d = 1 \bmod n^s$. Now, we use Shamir's secret sharing scheme (Shamir, 1979) to generate the private key shares of d to be divided among the clients. Thus, we apply the polynomial $f(X) = \sum_{i=0}^{w} a_i X^i \bmod l$, by picking a_i for $0 < i \leq w$ as random values from $0, \ldots, l$ and $a_0 = d$, l is a prime with $n^{s+1} < l$. We choose g as $g = n + 1$. The secret share of d for the i'th client will be $s_i = f(i)$. A verification key $v_i = v^{\{\Delta\, s_i\} \bmod} n^{s+1}$ is associated with each client i. The public key then becomes (n, s, l) and $(s_1, \dots, s_w)$ is a set of private key shares.

Encryption:

The plaintext of the ith client m'_i is multiplied with the one-way hash function $F^n = F(F^{n-1}(a))$ of a commonly known seed a. Thus the plaintext for the encryption results as $m_i := m'_i F^n$. Given this plaintext m_i we choose at random $r \in \mathbb{Z}^*_{n^{s+1}}$. The ciphertext $E(m_i, r)$ computes as:

$E(m_i, r) = g^{m_i}\ r\text{^}(n^s) \bmod\ n^{s+1}$.

The client i then communicates $c_i^{2\Delta s_i}$, with $\Delta = l!$ (Damgaard & Jurik, 2001).

Decryption:

The server can verify that the client raised s_i in the encryption step by testing for $log_{c_i^4}(c_i^2) = log_v(v_i)$. After the required k number of shares S arrived. They can be combined to (Damgaard & Jurik, 2001):

$c' = \prod_{i\ in\ S} c_i^{2\lambda_{0,i}^S}\ \bmod\ n^{s+1}$, where

$\lambda_{0,i}^S = \Delta \prod_{i'\ in\ S \setminus i} \frac{-i}{i-i'}$.

Thus, the value of c' has the form $c' = (\prod_{i\ in\ S} c_i)^{4\Delta^2 f(0)} = (\prod_{i\ in\ S} c_i)^{4\Delta^2 d}$. As $4\Delta^2 d = 0 \bmod \lambda$ and $4\Delta^2 d = 4\Delta^2 \bmod n^s$, $c' = (1+n)^{4\Delta^2 \sum_{i\ in\ S} m_i} \bmod n^{s+1}$. The desired plaintext $\sum_{i\ in\ S} m_i$ can be obtained by previously introduced algorithm and succeeding multiplication with $(4\Delta^2)^{-1}\ mod\ n^s$. The original plaintext can be computed by dividing the resulting sum by F^n. This ensures that previous messages may not be used for analysis of current messages. The homomorphic property of the system is directly used, and bases on the work presented in (Damgaard & Jurik, 2001).

Security:

The security of the crypto system is based on the *decisional composite residuosity assumption* already used by (Paillier, 1999). The assumption states that given a composite n and an integer z it is hard to decide whether z is a n-residue (i.e. a n-th power) modulo n^2, i.e. whether it exists an y with $z = y^n \bmod\ n^2$.

4. Consequences for the Architecture

As a consequence of our method the keys need to be distributed among the communicating parties: the clients and the server. This may not be done by the server, but has to be performed by a (commonly) trusted authority (TA).

Once the keys are distributed, the communication channel to this TA can be closed. Thus, no vulnerable data reaches this third party.

5. Discussion

The hereby presented method overcomes limitations of related work. In addition, our approach may be combined with the methods presented in (Monreale et. al. 2013). Thus, the transmitted histograms can be obfuscated by Laplacian noise (Monreale et. al. 2013). On the other hand transmission may not be obscured by anonymous messages (Kopp et. al. 2012) since the identifier of the clients is required for verification of the transmitted messages and reconstruction of the aggregated plaintext.

However, our method assumes that the space covered by individual movements overlaps. If this assumption does not hold, e.g. with persons from different cities, the privacy of each individual is not guaranteed (Abul et. al. 2008). An approach to overcome this limitation is by sending messages to the server just if the according entry in the histogram is at least once (i.e. the person was at least once at this location or used at least once the movement pattern). This ensures that the server may just decode the aggregated histogram if a sufficient number of people sent their messages and thus have been there. On the other hand, then the transmission of the message itself contains information on a person's movement behaviour. Thus, future studies should find a message encoding of a zero which does not allow to compute the aggregated sum but passes all verification steps of the server.

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Data Models for Moving Objects in Road Networks - Implementation and Experiences

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Abstract. Paper deals with the specific LBS scenario – Fleet management (FM) and more specifically with systems for Automatic vehicle location (AVL). Well designed and implemented spatial data model for moving objects is one of the most significant elements of any AVL system. In practical applications the results of the latest scientific research are seldom applied, despite the fact that this area has been developing intensively for more than 20 years. The reasons for this are analysed in the paper. Short analysis of functionality of these systems is presented considering the impact of these functionalities on the implemented data model for moving objects and more specifically their impact on spatio-temporal component of the model. The paper especially reviews the possibility of using road networks as a basis for the representation of moving objects data models and a fact that these models are rarely used in practical applications. A solution overcoming this situation is proposed. The solution assumes transition from the system that is not based on road network to the system that is based on network. There are quite few research papers dealing with OSM data models. Therefore, a significant space in this paper is dedicated to the description of these models since OSM data can be valuable for this type of applications.

Keywords. Moving objects data model, road networks, fleet management, vehicle tracking

1. Introduction

One of the most significant elements of any Automatic vehicle location (AVL) system is a well conceived data model for moving objects. Research

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on these models started more than two decades ago. However, results of the research are seldom fully implemented in practical applications. A basic reason for this is a fact that it is quite possible to develop and implement FM AVL that is applicable in many practical application scenarios simply by using standard RDBMS tables without spatial extensions, standard SQL language and services available from industry content providers.

This and other reasons for this situation are briefly analysed in the paper. Short analysis of AVL systems in terms of their functionality requirements is given in the paper. Implications that these requirements have on data models and spatio-temporal analysis aspect of using these models are especially analysed.

Another very important aspect for the specific FM AVL application is availability of the high quality road network data. There are quite few research papers dealing with OSM data models. Therefore, a significant space in this paper is dedicated to the description of these models. Classification of these models according to their application domain has been introduced and some typical models have been described. Quality of the data is also analysed.

Special consideration is given to the aspect of using road network as a basis for implementing data model for moving objects and the fact that these models are rarely used in practical applications. Paper reviews reasons, i.e. objective circumstances that influenced such a situation. All the circumstances were analysed, starting from current models of GPS/GPRS devices for vehicle positioning and data acquisition, through telecommunication networks status and possibilities of applying international and industrial standards in this area.

A solution overcoming this situation is proposed. The solution assumes transition from the system that is not based on road network to the system that is based on such a network.

2. FM AVL Scenario

FM AVL is one of the typical LBS scenarios. It is a mixture of management and tracking scenarios (*Figure 1*).

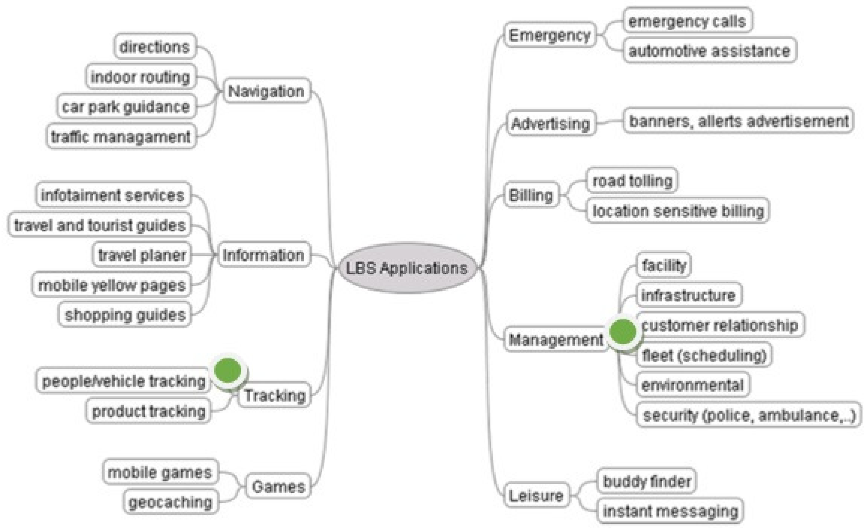


Figure 1. LBS application categories / Foundations of LBS (Steiniger et al. 2006)

Specifics of this scenario can be summarized through LBS components used by the system (*Figure 2*):

Communication network – GSM network is used predominantly; network is well developed with high stability in data transfer; data transfer rates are sufficient to enable efficient transfer of all the data (except for maybe video files in real time); very affordable prices of data transfer enabled that large data quantities can be transmitted in real time; new EU legislations in the area of telecommunications provided that state borders are rendered as irrelevant in terms of data flow through telecommunication networks, so it is possible to implement vehicle tracking in real time at very affordable pricing;

Positioning – GNSS (GPS and GLONASS positioning); very high quality of positioning is provided; in the last year large number of companies, in addition to GPS, enabled utilization of GLONASS satellites; this provided higher data accuracy and reliability but also better availability of positioning devices; prices of positioning devices are quite affordable, so it is possible to purchase devices with basic functionalities for about 50 EUR, devices with medium functionalities for about 80 EUR and devices that can be used for implementation of complicated application scenarios can be purchased for about 100 EUR;

Mobile devices - GNSS/data devices; in the last year a large number of devices supporting GLONASS positioning emerged, providing increase in quality, accuracy and reliability of positioning; manufacturers provided modules enabling data readout from internal vehicle buses (CAN, LV-CAN, K-line and others); therefore, number and quantity of telemetric data are signifficantly increased.

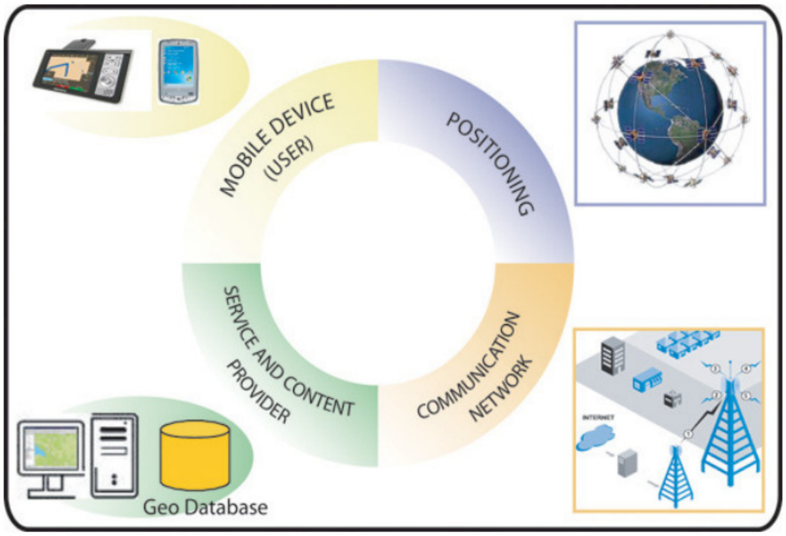


Figure 2. The basic components of LBS (Steiniger et al. 2006)

Service Provider and Content Provider – there are global data providers (Google, Microsoft), data providers offering data content highly relevant for FM scenarios (for example, Teleatlas offers navigation and traffic data) and Open Source providers (OSM data); global, regional and local leaders have been distinguished on the market (Insight 2012); customers' demands and the market shaped typical services offered by providers; therefore, almost all providers offer few standardized service packages.

Specifics of this scenario can be described through the following aspects: types of data that are collected, functionalities that are required and users' requirements regarding temporal aspects of the vehicle movement.

1. Types of data that are collected:

- Geospatial data (positions acquired by using GNSS method),
- Data based on GNSS measurements (speed, acceleration, azimuth, etc.),
- Telemetric data (fuel consumption and fuel level).

In addition to basic data, a large number of telemetric data containing additional information on vehicle is collected (fuel consumption, temperature, number of engine rotations per minute, door opening control, alarm, etc.).

Therefore, in addition to location tracking, the whole series of additional parameters is the subject of interest to users.

Besides online tracking, users also demand for reports based on collected parameters – driving style (harsh braking, harsh acceleration and harsh cornering), data on driver (driver's id, sending working orders to driver, communication with driver, etc.).

2. Functionalities that are required:

- Vehicle location display,
- Display of the vehicle track,
- Reports,
- Alarms,
- Route optimization.
- etc.

3. Users' requirements regarding temporal aspects are the following:

- Current vehicle location and status of all the parameters that are tracked,
- Vehicle locastions and status of all the parameters that are tracked in the past,
- Prediction of the vehicle location and status of all the parameters that are tracked in the future.

Official status of the collected data is very important aspect that has to be considered for these systems. This is especially related to the following data:

- **Position and time** - positional data are obtained with CEP=3m accuracy and time accuracy is expressed as RMS=1sec; this means that objects that have been tracked can be located with accuracy that is satisfying for most users; users also have demands regarding reports based on these source data;
- **Speed** - GNSS method is currently one of the best and one of the most common methods for vehicle speed measurement; speed is determined with RMS=1km/h accuracy; users also usually have demands regarding reports based on these data;

- **Mileage -** data on mileage are obtained using the following ways: from the vehicle, by calculating it from vehicle locations, and from odometer of the GNSS/GPRS device; accuracy of the mileage obtained from the vehicle is usually very unsatisfying because it depends on many external factors that are related to vehicle condition; accuracy of the mileage that is calculated from vehicle locations depends largely on the data resolution; accuracy of the mileage that is obtained from odometer is very good and it is better than 1% of the mileage, which usually satisfies users' requirements.

3. Models for Moving Objects

Beginning of the research on data models for moving objects (mobile objects is also an expression that can be used with the same meaning) is continuation of the research efforts from late eighties and early nineties of the last century (Tanse et al. 1993). Theories related to the spatio-temporal and geospatial data bases from the middle of nineties gave significant contribution to the development of these models (Sistla et al. 1997). Since 2000, international and industrial standards in GIS and LBS, i.e. OGC / ISO TC 2011 have very important influence on the development of these models (Stojanovic & Djordjevic-Kajan 2003, Macedo et al. 2008).

Characteristics that can be used to describe these models are the following: application of object oriented data models, availability of past, current or/and future object's positions and its trajectory, mobile geometry data types are supported or not, possibility of performing spatio-temporal operations and availability of the query language that has been developed for implementation of these spatio-temporal operations.

According to the basic concept these models can be regarded as:

- Location management,
- Spatio-temporal databases.

This classification actually corresponds to the classification that can be made in yet another way – according to the way that we want to track our object through time:

- Modelling of object's movement in present time and eventually in near future,
- Modelling of object's movement as it was in the past.

The first one is focused on providing answers to questions regarding actual positions of moving objects, and possibly regarding their predicted evolutions in near future.

The second approach takes into consideration a complete history of moving objects' movements (Cotelo et al. 2003, Güting et al. 2006). This is definitely more challenging requirement. A complete evolution of the moving object can be given as an attribute in a database.

According to the type of movement of moving objects the models can be classified as:

- Models based on free movement (moving objects move freely in space),
- Models based on movement in network (moving objects move on network).

In addition to models of moving objects, algorithms and languages supporting database management (queries) with spatio-temporal information have been subject of the research (Wolfson et al. 1998, Vazirgiannis & Wolfson 2001, Cotelo et al. 2001.).

3.1. Models for Moving Objects Moving Freely in Space

Even though vehicle moves continuously through predefined network infrastructure (mainly roads), this fact is usually disregarded. During the late nineties and early years of the twenty first century researches were especially focused on the problem of modelling and indexing moving objects (Wolfson et al. 1999, Saltenis et al. 2000, Porkaew et al. 2001, Güting et al. 2000.). Common characteristic of these researches is that they were based on the free movement of objects (moving objects moving freely in space).

These models are frequently used in practical applications. The reason for this is that implementation and use of the models that are based on objects movement on network are more complicated, but also due to the fact that the data required for the network model implementation are usually unavailable.

3.2. Models for Moving Objects on Network

It can be stated that research foundations in this area has been set by Güting (Güting et al. 2006.). He defined networks taking into consideration the importance of the routes (routes correspond to roads from real life and they can be represented as paths in a graph) from the following reasons:

- Roads are relevant conceptual entities from the real life; roads have names instead of crossroads or road segments between crossroads; address systems are also linked to roads or streets; model should reflect these facts;
- Using lines to describe paths, i.e. using them as means for referencing is in widespread use as a concept applied in GIS; this also indicates that

positions should be described in respect to roads and not in respect to graph edges;

- Maybe the most practical reason for this is that representation of the moving object is as small as possible; for example, if vehicle goes along the highway using a constant velocity, if its position is to be described by an edge, than a change of that description should be done on every exit/crossroad, because identification of edges is also changed; however if a position is linked to a road, than description would have to be changed only if the vehicle changes a highway.

Güting defined network as a set of routes accompanied with a set of crossroads between routes.

Using these assumptions as a foundation he built a model based on the following principles (Güting et al. 2006.):

- Definitions of the spatial network, network locations and network regions are given; model offers paths through network of graphs as a basic concept called route; route enables to make a difference between simple and dual routes, as well as to describe possible transitions of object movement (for example vehicles on crossroads);
- Networks are available through network data type; interface for relational environment is made enabling creation of network from relations, but also creation of relations from the network;
- Two data types are created gpoint and gline; gpoint type represents a position in given network gline type represents a region in the network; these data types are integrated within a system that has been defined earlier (Güting et al. 2000.), so that time-dependant constructors moving (gpoint) and moving (gline) can be applied on them; these four data types makes the core of the concept;
- Operations are also defined in order to enable interaction between gpoint and gline objects, on one side, and the network and spatial data, on the other side; some of the specific operations are defined for moving (gpoint) and moving (gline) data types, as well as for the network data type (for example, shortest path and trip).

Comparative analysis of moving objects models is given in the *Table 1*.

Source/model	Object based	Trajectory	Mobile geometries	Mobile data types	Movement on network	Spatio-temporal operations	Query language
MOST	-	Current, future	Point	No	No	No	FTL
Güting, 2000	Yes	Last	Point, region	mreal, mboolean	No	Yes	SQL extension
Brinkohoff	-	Last	Point	No	Yes	No	No
Mouza	-	Current	Point	No	Yes	No	No
Vaziriannis	-	Current, future	Point	No	No	Yes	SQL extension
Stojanović	Yes	Last, future	Point, polyline, polygon	Mobile boolean, number, string, object	Yes	Yes	SQL extension
Güting 2006	Yes	Current, future	Point, region	Mreal	Yes	Yes	SQL extension

Table 1. Models for moving objects (modified from Stojanović 2004)

4. OSM Data Model

In the last few years quality of network data has been improved significantly. Various global trends contributed to this. Maps and spatial data have become one of the most significant sources of information and both Google and Microsoft showed enormous interest for such data. Open Source community also has a great influence. Quantity of information is increased on a daily basis and there is a large number of online services offering such data.

OSM data model (Wiki OpenStreetMap 2014) is a powerful way of presenting geographic information. OSM uses topological data structure where elements (primitives) are basic components of the data content. Elements that model the physical world are the following:

- Nodes – defined points in space,
- Ways – defined linear objects and borders of areas,
- Relations – explain how elements are related to each other.

Each of these elements can have one or more tags describing the meaning of the element.

Node represents a point on the Earth surface defined by its coordinates, latitude and longitude (in WGS 84 coordinate system). Each point at least contains ID number and a pair of coordinates. Nodes are used for the definition of independent point features (for example, bench in the park, drinking-fountain, traffic light, mountain peak, etc.), but it can be also used for the definition of the shape of ways.

Way is ordered list containing 2 or more points (up to 2000) defining a polyline. They are used for the representation of linear objects such as: rivers, roads, streets, etc. They can be used to represent polygon (area) borders such as: buildings, forests, lakes, etc.

Relation is ordered structure describing link between two or more elements (nodes, ways, relations). For example, relation for turn restriction states that it is not allowed to turn from one way to another way. Relation contains a list of elements and they are calld relation's members. Each relation's member can optionally has the role in relation. For example, for turn restriction relation members can have roles *from* and *to* which describe from which way it is forbidden to turn to which way.

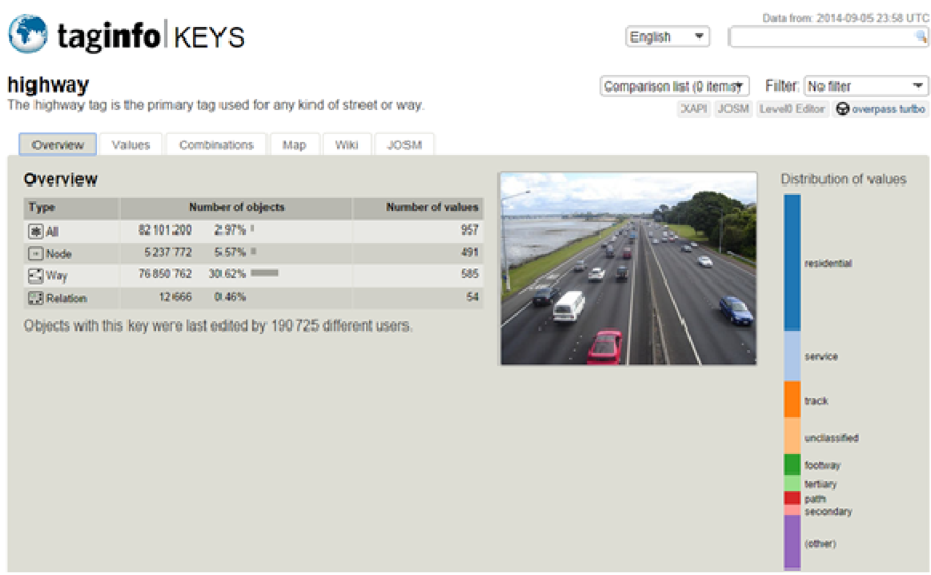


Figure 3. Frequency of using tags (OpenStreetMap Tags, Web links)

Each of elements can have tags describing the meaning of that element, i.e. they represent elements' metadata. Tags are comprised of two text fields, key and value and each of them consists of 255 characters. For example, *highway=pedestrian* denotes pedestrian path. There is no fixed list of tags and a user can create his own tags. However, there is a convention to use tags that are already defined. Also, there is a web page http://taginfo.openstreetmap.org/ (*Figure 3*) where it can be seen for any tag how often it is used and with what value, in which element, and so on.

There are also some common attributes that are stored for nodes, ways and relations. These attributes are listed in *Table 1*.

Name	Value type	Description
id	integer	Unique id of element for certain type (for example, node and way can have the same id)
user	string	Name of the user who was the last one to make a change on the element. User can change his name.
uid	integer	Unique id of the user who was the last one to make a change on the element. This id is always the same for certain user.
timestamp	W3C Date and Time Formats (YYYY-MM-DDThh:mm:ssZ)	Time of the last update of the element.
visible	Boolean (“true”, “false”)	Indicates whether element is deleted or not in OSM database
version	integer	Element’s version. Newly created element has value of 1 and this value incrementaly increases.
changeset	integer	Set of changes that containing element update.

Table 2. Common attributes for all OSM elements (OpenStreetMap Tags 2014)

4.1. OSM Tags Important for Road Network

Tags related to the road network are only a fraction of the complete list of tags. According to application *osm2pgrouting* which is used for OSM data import into database, for import of ways representing road network only four tags are used:

- Highway,
- Cycleway,
- Tracktype,
- Junction.

These four tags can have a lot of different values. However, only key-value pairs from *Table 2* (only one tag specific for certain grup is listed) are used for road networks.

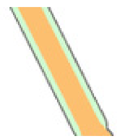
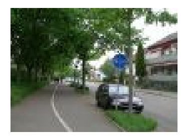
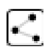
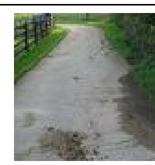
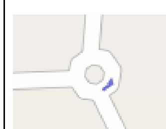
Key	Value	Element	Description	Map display	Photo
highway	motorway		A restricted access major divided highway, normally with 2 or more running lanes plus emergency hard shoulder. Equivalent to the Freeway, Autobahn, etc...		
cycleway	lane		A lane is a route that lies within the roadway.		
tracktype	grade1		Solid. Usually a paved or heavily compacted hardcore surface.		
junction	roundabout		Roundabout. This automatically implies oneway=yes, the oneway direction is defined by the sequential ordering of nodes within the Way.		

Table 3. Some of OSM tags important for road networks (Wiki OpenStreetMap 2014)

4.2. OSM Data Providers

There are many providers offering OSM data files in various data formats. OSM files for certain territories can be downloaded from internet pages of these providers.

A single OSM file for the whole planet Earth (Planet.osm file) can be downloaded from the site: http://planet.openstreetmap.org/ in .pbf and .osm.bz2 format. This site also offers a possibility to download files with daily, hourly and minute changes (.osc). Other OSM data providers are listed in *Table 4*.

WEB address	Update
ftp://ftp.spline.de/pub/openstreetmap/	Weekly
http://ftp.osuosl.org/pub/openstreetmap/	Weekly
http://ftp.snt.utwente.nl/pub/misc/openstreetmap/	Weekly
http://ftp.heanet.ie/mirrors/openstreetmap.org/	Weekly with 10 hour delay
http://ftp5.gwdg.de/pub/misc/openstreetmap/planet.openstreetmap.org/	Daily
ftp://ftp.pucpr.br/osm/mirror/	Daily
http://download.bbbike.org/osm/planet/	Weekly

Table 4. OSM data providers and their data update rate

4.3. Road Network Data Models Based on OSM Data

OSM data can be stored in PostgreSQL, i.e. PostGIS database so that they can be used for moving object modelling and routing. There are dozens of applications that have been developed to facilitate storage of PSM data into PostGIS database. Therefore, there is approximately the same number of data models used for storing OSM data within PostGIS. Some of these applications were developed exactly to meet the requirements of routing, so they build a data model that is suitable for that purpose, whereas other applications aim at displaying OSM maps, facilitating OSM data maintenance, etc.

Applications that are most frequently used are the following:

- *osm2pgrouting*,
- *osm2po*,
- *osm2pgsql*,
- *osmosis*.

Depending on what kind of data models these applications build, they can be classified into following groups:

1. Those that are appropriate for routing (*osm2pgrouting* and *osm2po*),
2. Those that are appropriate for OSM map display (*osm2pgsql*),
3. Those that are appropriate for OSM data update (*osmosis*).

4.3.1. Models suitable for routing

The routing in this paper will be discussed in the context of using *pgRouting* library (open-source library facilitating routing for the data kept in PostGIS database). However, it can be extended easily to routing using some other tool as well, so whenever in this paper some model is evaluated as suitable or not for *pgRouting* library, it certainly means that the model is also suitable or not for routing in general.

The development of *pgRouting* library also initiated the development of applications for the storage of OSM data for routing into PostGIS database. Two open-source applications that are used for this purpose are *osm2pgrouting* and *osm2po*.

OSM data are kept within a database in the following data tables:

- *types* – road types (types of segments/ways);
- *classes* – classes (subtypes) of the road;
- *nodes* – all points from the OSM file (road network points and points outside of the network);
- *relations* – relations related to the road network;
- *relation_ways* –relations between ways/segments (within road network and outside of the network);
- *ways* – segments of the road network (from node to node);
- *way_tag* – tags of road network segments;
- *ways_vertices_pgr* – road network nodes that have been created by *pgRouting* function *pgr_createtopology*.

The following diagram (*Figure 3*) depicts all tables, their attributes and their relationships.

Attribute *osm_id* of the table *ways* represents id of the segment from OSM file and attribute *gid* represents a unique identifier of the segment. The reason for having *gid* attribute is that more than one segments can have the same *osm_id*, because one OSM segment can be divided into several segments connecting network nodes. If new data set is imported again for the same area, the same OSM segments would not get the same *gid*.

Good characteristic of this model is that the table *ways* is modelled in such way that *pgRouting* functions can be called and executed for this table and attributes *length* (representing cost) and *reverse_cost* have been created to respect one-way streets (if some segment is one-way street and if that segment is oriented in one-way street direction, its cost will be equal to the street length, whereas its *reverse_cost* will be 1000000 times larger). This table also contains maximum allowed speed in both directions (attributes *maxspeed_forward* and *maxspeed_backward*) which is very important if it is required to calculate time to travel through some segment or route, as well as street names (attribute *name*).

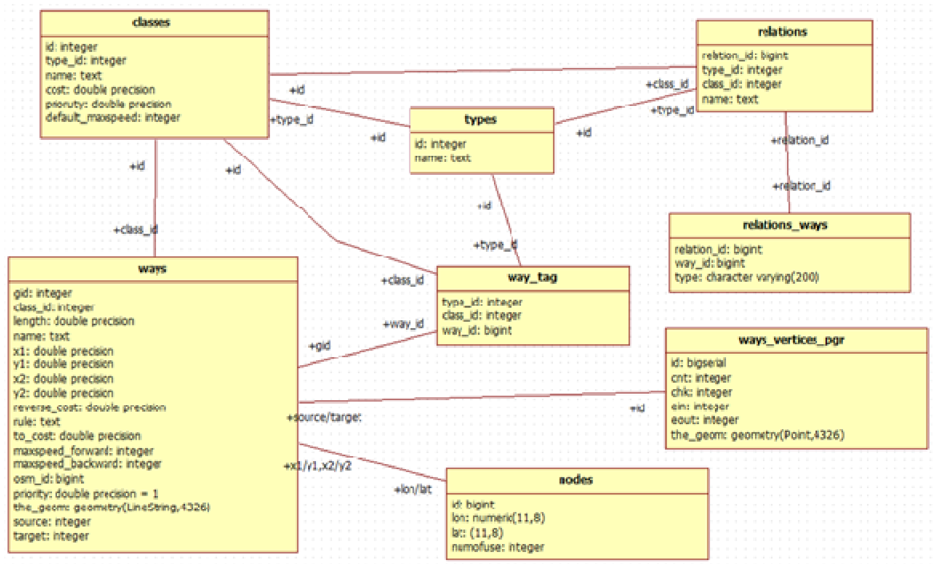


Figure 4. *pgRouting* data model

The raw OSM data contain much more data and information than it is needed for routing and that makes this tool very suitable for simple routing systems. However, there is a problem if the tool is used within routing systems where additional information such as street names, respecting of turns restrictions, etc. is needed. Currently, this model does not provide support for additional pieces of information on *nodes*, *ways* and relations that are stored as tags of OSM file. The table *way_tag* is probably designated for the segments. However it only contains type and class of the road. These pieces of information already exist in the table way.

Another big problem related to this application is that it does not support update of OSM data. If it is required to update the database containing OSM data, than new data set has to be imported again from the scratch and that will change *gid*s of the segments. However, this is not convenient if history of data changes is to be maintained.

4.3.2. Models Suitable for OSM Maps Rendering

As the title already suggests, models suitable for OSM maps rendering are developed to store OSM data in a way that would be the best for data rendering. The best known application from this group of applications is *osm2pgsql*.

The database created using this application and its model is primarily to be used for data rendering data by using Mapnik software. As such, it is not suitable for *pgRouting* functions. History of changes is also unavailable. Good side of this model is that most of the tags are stored in their own columns of the four basic tables.

Update is facilitated by the application called *osmosis*. This application reads OSC file and after that *osm2pgsql* application is used to store the data into the database.

4.3.3. Models Suitable for OSM Data Update

The best known application that builds these models is *osmosis*. In addition to update, this application provides the data model that facilitates history of OSM data changes maintenance. The model created by *osm2pgsql* application can be maintained by using the combination of applications *osmosis* and *osm2pgsql*. However, primarily function of this application is rendering of the OSM data.

Osmosis (Wiki OpenStreetMap 2014) is JAVA application for processing OSM data. This tool contains a lot of components that can be combined in order to perform more complicated operations such as: processing/reading of OSM file, database update, data sorting and indexing, etc. Some of the tasks that this application successfully performs are the following:

- creation of OSM file using the data from the database;
- OSM file data import into the database;
- creation of OSS file using history tables;
- database update;
- comparison of two OSM files and creation of OSS file;
- OSM file data sorting;
- reading of the data enclosed by the specified bounding box.

By using this application, OSM data can be imported into PostgreSQL/PostGIS database. This can be done by using one of three available data models (schema):

- Simple schema,
- Snapshot schema,
- OSM API schema.

Simple Schema, as its name suggests, is a simple schema that facilitates storage of OSM data. This is older schema type where tags for nodes, segments and relations are stored in separate tables.

It is possible to update OSM data, but this schema does not store history of data changes. The update is done by using the same code that is also used for the initial data import. The difference is that, instead of the parameter --*write-pgsimp*, a parameter --*write-pgsimp-change* is used. Also, OSS file is used, instead of using OSM file.

This model does not facilitate usage of *pgRouting* functions. Therefore, come changes are required in order to facilitate this usage.

Snapshot Schema is basically the same as a Simple Schema with additional improvement facilitating usage of *hstore* columns. This column enables that set of key/value pairs can be stored in a single field of an entity. This is very applicable for OSM data and elements' tags. This provide for memory savings.

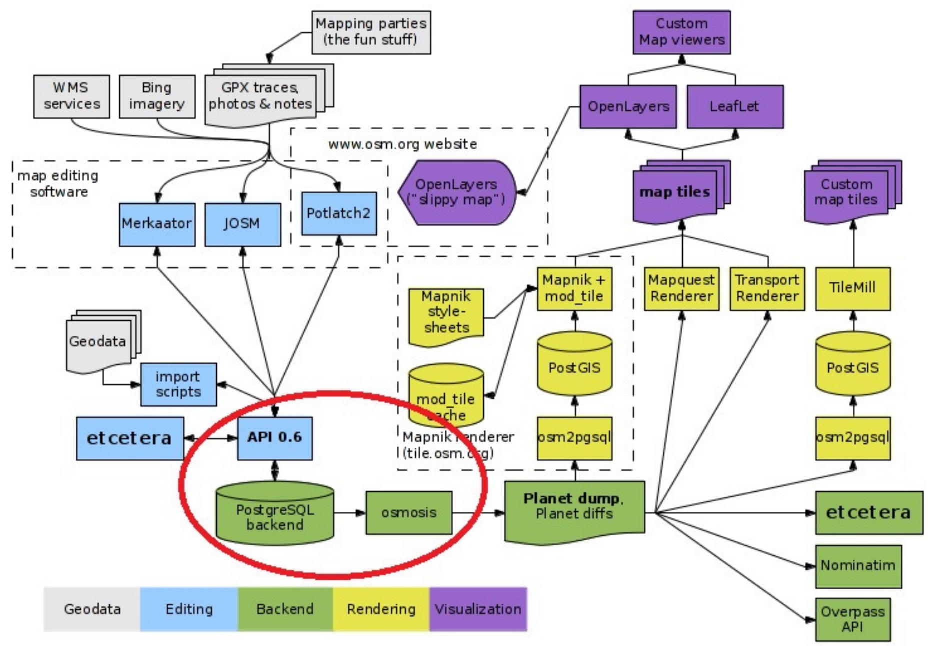


Figure 5. OSM model appropriate for data update (Wiki OpenStreetMap, 2014)

OSM API Schema represents a schema that is in the background of OSM API, i.e. it represents a complete OSM database. The purpose of this database is to answer to all OSM API requests and to render OSM maps.

OSM system model is depicted in *Figure 5*. It can be seen that this schema is used in the background and that *osmosis* is to be used for serving OSM and OSS files that are used by *osm2pgsql* application to create models for data rendering. This model contains 39 tables.

The data stored using this model can be updated in the same way as in the cases of using the previous two models. In addition to update, this model facilitates the maintenance of history of changes.

This model is also unsuitable for using *pgRouting* functions. However, this model is the most complete one when compared with all the previous models. It enables data update, history of changes maintenance. Also, all pieces of information from OSM file are stored within the database, so they are immediately available if they are needed for some reason. With minor modifications this model could be suitable for modelling movements of moving objects as well as for *pgRouting* functions and as such it would be the best solution for more complex systems for routing and moving objects movement modelling.

For moving objects movement modelling it is especially important that this model provides data versioning. This could be very important if history of vehicle movement is to be maintained.

4.4. OSM Data Quality

OpenStreetMap is open-source project enabling people all over world to collect data for their territory. Users use different data sources such as satellite images, terrain maps, GPS devices and so-called local knowledge to collect data that is precise and updated as much as possible.

In practical applications it very important that the data completely and without gaps covers the whole relevant territory and that the data is at the same time complete and consistent.

The same applies to routing applications. It is necessary that road network is complete and consistent. Otherwise, incorrect information is obtained and the routing itself loses its basic purpose – savings in time and resources. The modelling of moving objects movement is also very demanding task because insufficient accuracy of the data can undermine the whole concept and meaning of the model that is based on such data.

Since OSM data have been collected by interested people, based on their own initiative and from different data sources it is reasonable to ask a question regarding accuracy and suitability of OSM data for the modelling of moving objects and for the routing applications.

The methodology for quality assessment is perhaps best described by Oort (2006) and Hackley (2010). The methodology involves the following aspects, i.e. data quality elements: lineage, positional accuracy, attribute accuracy, logical consistency, completeness, semantic accuracy, usage, purpose and constraints, and temporal quality.

Description of these data quality elements and their relevance (grades from 1 to 5) for the modelling of moving objects and for the routing applications is given in the *Table 5*.

Aspect	Modelling	Routing
Lineage	1 - Less important aspect.	1 - Less important aspect.
Positional accuracy	5 - Very important aspect.	3 - Medium important aspect. It is good if positional accuracy is high, but topological consistency is more important than positional accuracy.
Attribute accuracy	3 - Important aspect. It is good if attributes are accurate, but it is not vital for the proposed model.	4 - Very important aspect, especially for the routing which takes into consideration various types restrictions.
Logical consistency	3 - Important aspect. It is good if attributes are logically consistent, but it is not vital for the proposed model.	5 - Very important aspect.
Completeness	5 - Very important aspect.	5 - Very important aspect.
Semantic accuracy	3 - Important aspect. It is good if semantic accuracy is high, but it is not vital for the proposed model.	4 - Very important aspect, especially for the routing which takes into consideration various types restrictions.
Usage, purpose and constraints	3 - Important aspect.	4 - Very important aspect, especially for the routing which takes into consideration various types restrictions.
Temporal quality	5 - Very important aspect.	5 - Very important aspect.

Table 5. Data quality elements and their relevance for the modelling of moving objects and for the routing applications

Haklay (2010) performed a spatial analysis of the quality of OSM street network representations in the UK. Girres and Touya (2010) performed a spatial analysis of the quality of OSM for France. Both authors use a comparison to ground-truth data obtained from the corresponding national mapping agency. Both studies have proved that the data quality is good to a great extent, but the quality is not uniform for the whole study area.

The research conducted by Neis et al. (2012) where the quality of the OSM street network was evaluated for the different regions of Germany, for the period 2007–2011 is also interesting. Neis found that, on the average, the OSM street network representation exceeds the information contained in a proprietary dataset by more than 20%.

Corcoran et al. (2013) analysed the growth of OpenStreetMap networks. They noticed that the complete road network for the USA was imported into OSM from the TIGER dataset in 2007 and 2008.

A statistical data were collected during this research showing how many new OSM elements have been added every day (*Table 6*). Statistical data have been produced using 5 updates by using OSS file (one file for each day) to update OSM data stored in API OSM data model.

	Serbia	Hamburg	Luxemburg	Slovenia
current_nodes	4255	531.6	413	3333
current_relations	0.4	2.6	0.4	2.6
current_ways	331.8	114.8	66.6	204.2

Table 6. Average number of elements added to OSM data every day for different territories

It can be noticed from the statistical data (*Table 6*) that the extent of changes (number of new nodes and ways) for the Serbia is the largest in comparison to the other areas. As far as the other areas are concerned, Slovenia has somewhat larger number of changes, whereas Hamburg (Germany) and Luxemburg already have well established road network and therefore it is reasonable that less new elements are added to OSM database on a daily basis for these territories.

The map has been published on OSM forum depicting the level of changes (increase in road network total length) during the period of 2009-2012 (*Figure 6*). A number for some region (state) on the figure, divided by 100, denote how many times is the length of the OSM road network for that region larger in 2012 in respect to corresponding length in 2009. For example, for Serbia length of the road network in 2012 is 4,33 times the length of that network in 2009. This is the biggest increase in road network length (changes in OSM data) in Europe. The lowest increase is registered for Netherland (1,21).

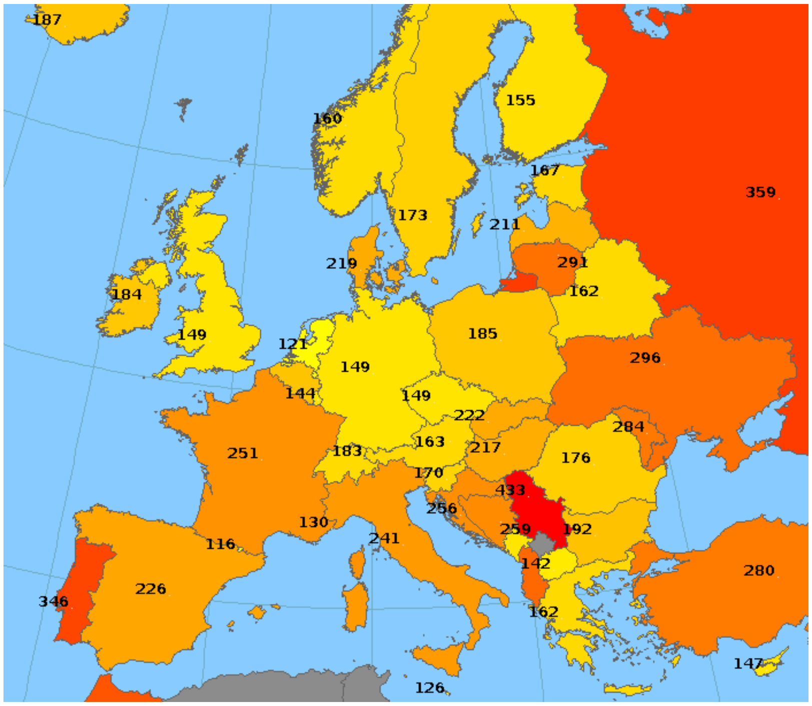


Figure 6. Changes for the road network for the period 2009-2012 (OpenStreetMap Forum, Web link)

All these studies revealed the following:

- There is a huge quantity of OSM data on a global level;
- Quality of OSM data is highly heterogeneous;
- For many application scenarios (for example, using maps as background in some GIS application or for data visualization) OSM data have immense value and they are highly useful;
- Application scenarios where OSM data, especially the data on road network, are to be used for the modelling of moving objects movement and the routing are very demanding;
- Quality of OSM data that are required for the modelling of moving objects movement and the routing is varying to a great extent for different regions in the world and in many regions the data are almost useless.

5. Models for Moving Objects Based on OSM Road Network

Even though this area has been developing for more than 15 years, models for moving objects moving on road network (MORN) are rarely used in practical applications. The reasons for this are the following:

- In addition to spatial data, a large quantity of telemetric data is collected; users require the whole range of functionalities that do not directly depends on location; therefore, models that provide very fast results are used, so system designers usually opt for models that do not take into consideration movement through road network (moving object moving freely in space - MOFS);
- Implementation of models based on road network is more complicated in comparison to implementation of models considering that object move freely in space (there is no network that constrains object movement);
- A proper network model and updated data have to be available for practical applications;
- Model implementation is directly linked to road network objects; therefore, the implementation process directly depends on the quality and up-to-dateness of the road network data; in cases where road network data model is available, but the data are not updated, the process of implementation is possible, but very difficult.

Model	Advantage	Disadvantage
Raw data	The simplest model. The easiest for the implementation. The smallest amount of information is stored. Fast queries providing data/results that can have official status (*Section 2*).	Either more spatial information is stored due to expected geometry queries than needed or spatial queries are too costly (in terms of time) because some additional on-the-fly calculations have to be made. Limitations and much lower performances for spatial queries based on road network and routing (it this functionality is provided by using external services).
Moving objects move freely in space (MOFS)	Simpler model. Easier for the implementation. Fast queries providing data/results that can have official status (*Section 2*).	Much more spatial information is stored. Limitations and much lower performances for spatial queries based on road network and routing.
Moving objects move on	Enables fast spatial queries. Enables fast and powerful queries based	The most complicated data model. The most complicated for the implementation. Requires availability of additional resources

Model	Advantage	Disadvantage
road network (MORN)	on road network data model. Enables routing.	– road network data. Much lower performances for spatial queries related to the original data providing results that are officially valid.

Table 7. Comparison of different models for moving object movement

The analysis provided in *Table 7* indicates that each of the listed models has some advantages and disadvantages. Therefore, it seems that combination of two approaches might be the best solution that would meet the users' requirements.

5.1. Requirements for the Model of Moving Objects

Factors that affect the model design are the following:

- Functional requirements (described in *Section 2* of this paper),
- Possibility of using road network model.

In order to develop and implement a model of moving object movement that is based on road network, it is required that resource that can be consumed quite fast and that is based on high quality and updated road network data is available. Additional request is the necessity that the link between the model of moving object movement and the road network model (resource) is established via data that have a permanent identification. Considering that very important aspect for FM AVL applications is also tracking of vehicle movement in the past, presence and eventually in the future, it is clear that it is of vital importance to provide maintenance of the history of changes in the database, i.e. the versioning of the road network data model has to be provided as well.

OSM data and the development of models based on these data opens possibilities that OSM data can be used as one of the resources supporting models of moving objects movement. This can be accomplished either by building a special model for this purpose or by modification of some existing data model.

The models of moving objects movement that is to be used for FM AVL scenario has to provide management with object in the past, presence and eventually in the near future (*Section 3*).

5.2. Starting Assumptions

Figure 7 depicts typical data acquisition process (registration of vehicle positions) for some FM AVL scenario. Vehicle positions are registered as blue dots. Of course, additional data on vehicle condition are also registered and linked to these positions.

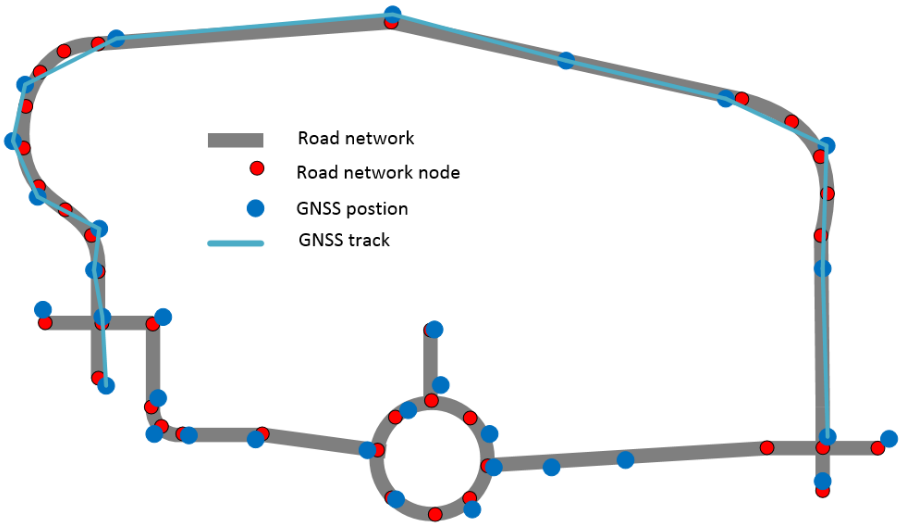


Figure 7. Registration of vehicle positions in respect to the road network in a typical FM AVL scenario

The devices used for this process have one important characteristic – they can be set to collect data by using algorithm that tracks changes in object movement (if object change its current direction of movement for an angle that is larger then defined treshold). It has already become standard that three parameters (time, distance, angle) are used to make a decision on data registration. Additional data registration can be triggered by any other event as well. For example, if value of any of the monitored parameters (*Section 2*) reaches some threshold.

In *Figure 7*, red colour indicates nodes of the road network model. These nodes are usually generated by using Douglas-Peucker algorithm.

FM AVL devices in vehicles are usually programmed to collect data according to the following principles:

- Travel distance: 200-500m;
- Travel time: 1 minute;
- Direction angle: 20-30 degrees.

Considering these facts, it can be stated that two paths depicted in *Figure 8*, i.e. the road network path (as given in the road network data model) and the vehicle movement path (as a result of data registration by GNSS/GPRS device) closely match each other.

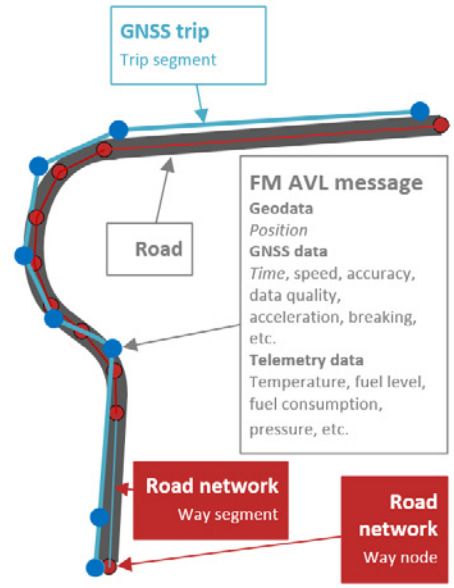


Figure 8. Data that are being registered in FM AVL system and key OSM road network data

Interesting information for this consideration is that average length for OSM road network segments in Europe is about 150m. Average lengths for OSM road network segments for some regions are given in *Table 8*.

Region	Serbia	Hamburg	Luxemburg	Slovenia
Average road network segments [m]	257.59	58.60	120.77	172.43

Table 8. Average length for OSM road network segments

If, in terms of informatics, one treats a road segment as a basic spatial unit for which information is to be linked to, than it can be concluded that OSM road network data have good spatial resolution and as such it can be used to store the information generated by FM AVL devices.

5.3. The Proposed Model for Moving Objects on Road Network (MORN)

Authors of this paper do not have any knowledge on the existence of some open-source data model that could be used in a way that all the requirements for FM AVL scenario could be satisfied. Two models (*osmosis* and *pgRouting*) have been used in the research described in this paper. These models have been modified to facilitate the modelling of moving object movement.

Figure 9 depicts FM AVL system architecture and its relationship with the system for the production of OSM data and maps.

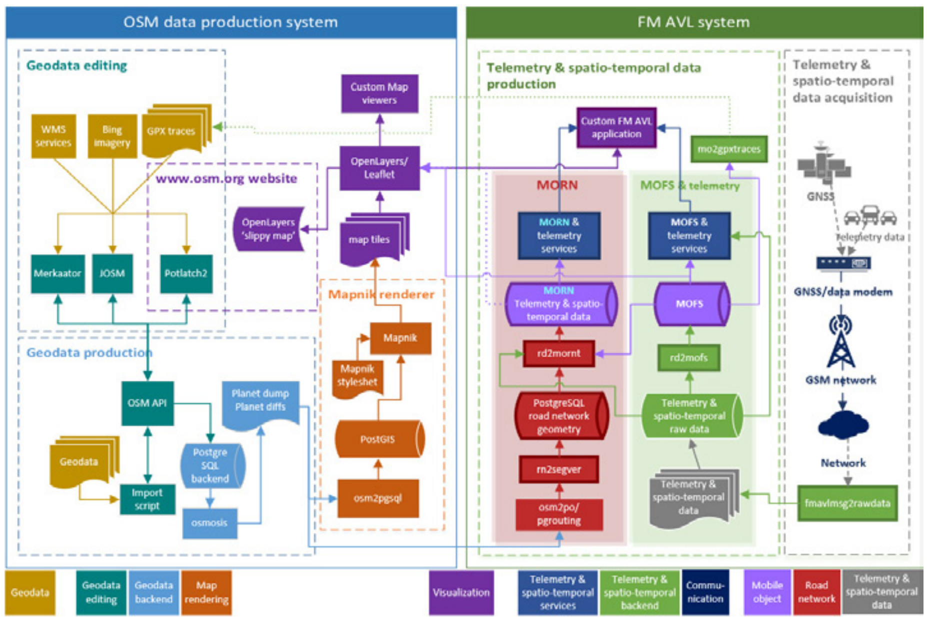


Figure 9. FM AVL system architecture and its relationship with the system for the production of OSM data and maps

Part of the FM AVL system is responsible for the acquisition of spatio-temporal and telemetric data. Process *fmavlmsg2rawdata* enables parsing of messages coming from GNSS/data devices. Usually, this component is implemented by using the TCP/IP or UDP server that translates binary messages coming through the network as streams into messages that are stored within the database.

Process *rd2mofs* translates the data that are stored within the database as a raw data into the moving objects' geometries. These objects move freely in space (MOFS), i.e. their movement is not constrained by the network. ISO/OGC geometries are used for this purpose.

Application services that are based on MOFS data (stored in the database) and on telemetric and spatio-temporal data (also stored in the database) contain all the functionalities (reports, alarms, graphics, etc.) that are consumed in custom FM AVL application.

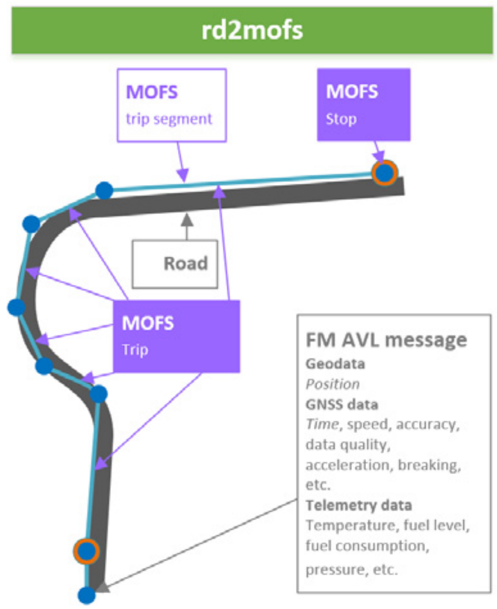


Figure 10. Process *rd2mofs* (transformation from the raw data to the moving objects' geometries (objects move freely in space - MOFS)

These components all together comprise MOFS telemetry, i.e. FM AVL system which is, in terms of the model of moving objects movement, based on telemetric data.

OSM data production system has important role during the process of building a MORN system. OSM data production system, in addition to classical maps (map tiles) and subsystems for data visualization (Open Layers and Leaflet), provides OSM data (via Planet dump data), as well as the road network geometry that is stored in the database. Very important role here plays the process *osmosis* that facilitates the data versioning.

Data model that is suitable for routing is provided by the process *pgrouting*. The process *rn2segver* is responsible for the preparation of the data in a format that is suitable for data modelling based on road network, i.e. road segments, as well as for providing the data versioning which is very important for this model.

The process *rd2mornt* reresents a component that is used to build a model of moving objects movement which is based on road network. Input pieces of information (*Figure 11*) for this process are the following: road network (segments/ways and nodes of the road network), messages from the FM AVL system and trip segments from MOFS system that is based on movement of moving objects freely in space.

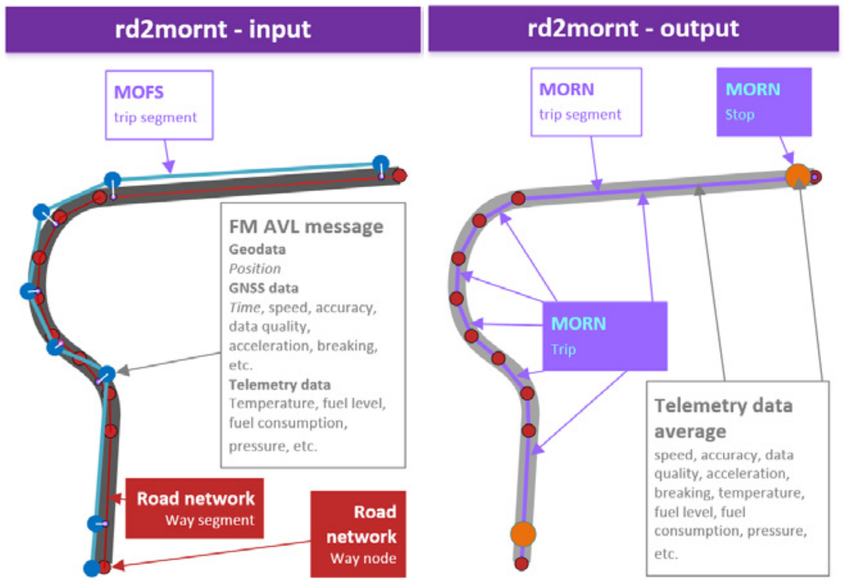


Figure 11. Process *rd2mornt* (transformation of the raw data to the moving objects road network data) – input data (left), output data (right)

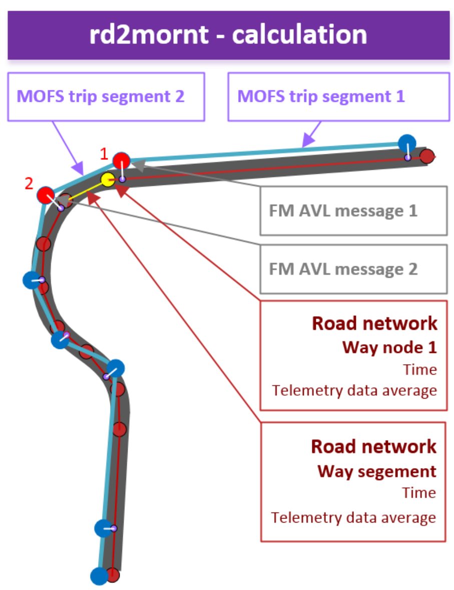


Figure 12. Process *rd2mornt* (transformation of the raw data to the moving objects model based on road network) - calculation

Algorithm for calculation is depicted in *Figure 12*. All the FM-AVL messages are sequentially processed. When message 1 and message 2 come for the processing, corresponding segments of the MOFS, i.e. trip segments 1 and 2 are assigned to these messages. These segments are taken to provide spatial context and to determine the closest corresponding segment of the Road network. After that, positions of message 1 and message 2 are projected onto OSM road network segments/ways. These projections and vehicle speed values for points 1 and 2 are used for calculation of estimated moment in time when vehicle passed through the point Way node 1. Similar principle is used for the calculation of average values of telemetric readings/parameters and all of these data are linked to the trip segment of the road network.

Figure 13 depicts the data comprising models MOFS and MORN.

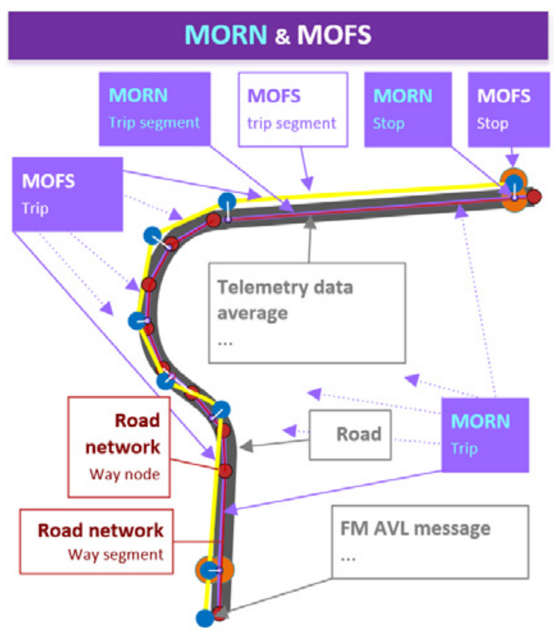


Figure 13. Basic elements of the moving objects models MORN and MOFS

Figure 9 shows the relationship between these two systems (MORN and MOFS). Planet dump files containing the latest version of OSM data which, due to the processing by *osmosis* procedures, also respect versioning are basis for building the road network geometry and topology. FM AVL system also uses Open Layers. Because of the cases where some parts of the network have insufficient data quality, an option is provided which facilitates conversion of the data from MOFS by using *mo2gpxtraces* process into GPX files suitable for processing by Geodata editing procedures.

5.4. Implementation of the MORN Model

Implementation of this model is still in the development stage. MobTrack:24 FM AVL system is used as an application framework (Vojinović et al. 2011, *Figure 14*). The system has been developed since 2006 and it has been in commercial use since 2008.

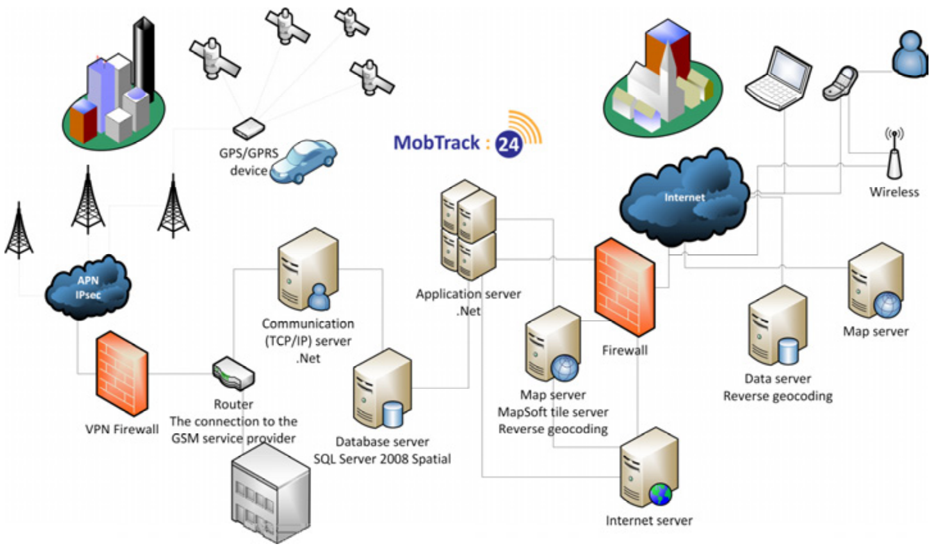


Figure 14. MobTrack:24 system architecture

System was working with raw data during the period 2008-2011. Since 2011 system uses MOFS data. Implementation of the model that is proposed within this paper has been going for several months.

OSM data for the whole Europe has been imported into the system. The procedure for data update has been implemented. The system has been implemented using the described MOFS conceptual model (*Figure 9*). The existing MOFS model, whose implementation is depicted in *Figure 15,* has been extended using concepts given in *Section 5.3*.

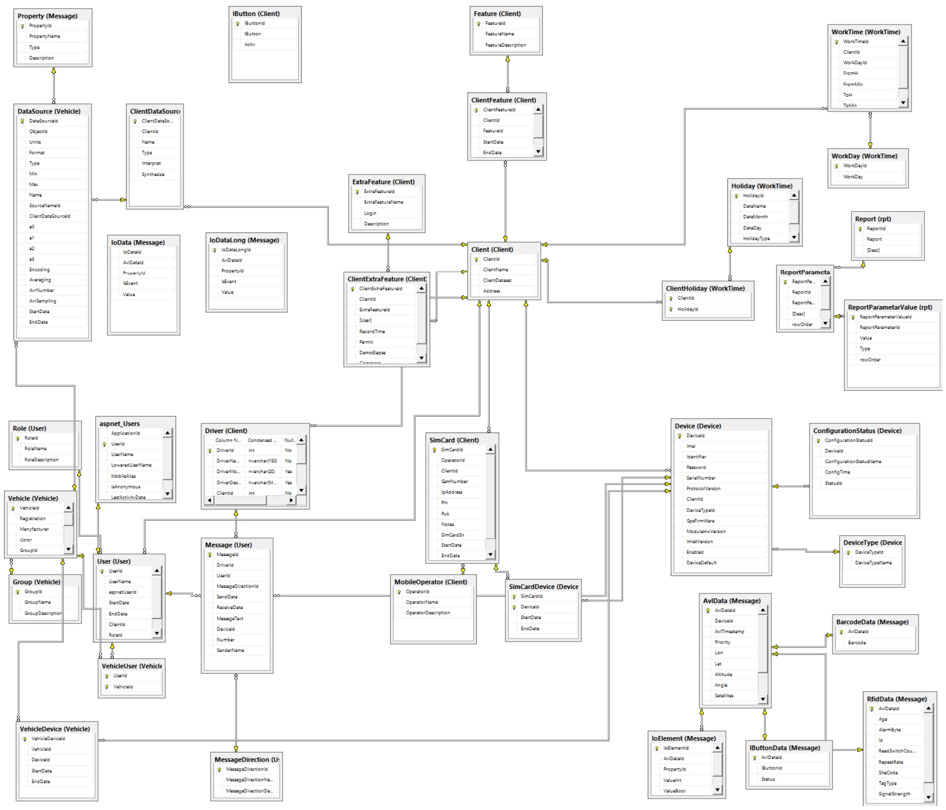


Figure 15. MOFS database design before MORN implementation

The implementation of MO Trip segment, MO Trip and MO Stop classes has been done in RDBMS. It can be seen from *Figure 16* how these classes have been implemented as database tables.

In the *Figure 16*, as well as in other figures, red colour indicates tables that implement OSM Road Network classes, grey colour indicates Raw Data tables/classes and purple colour indicates classes that belong to the moving objects model (white text denotes MOFS classes, blue text denotes MORN classes).

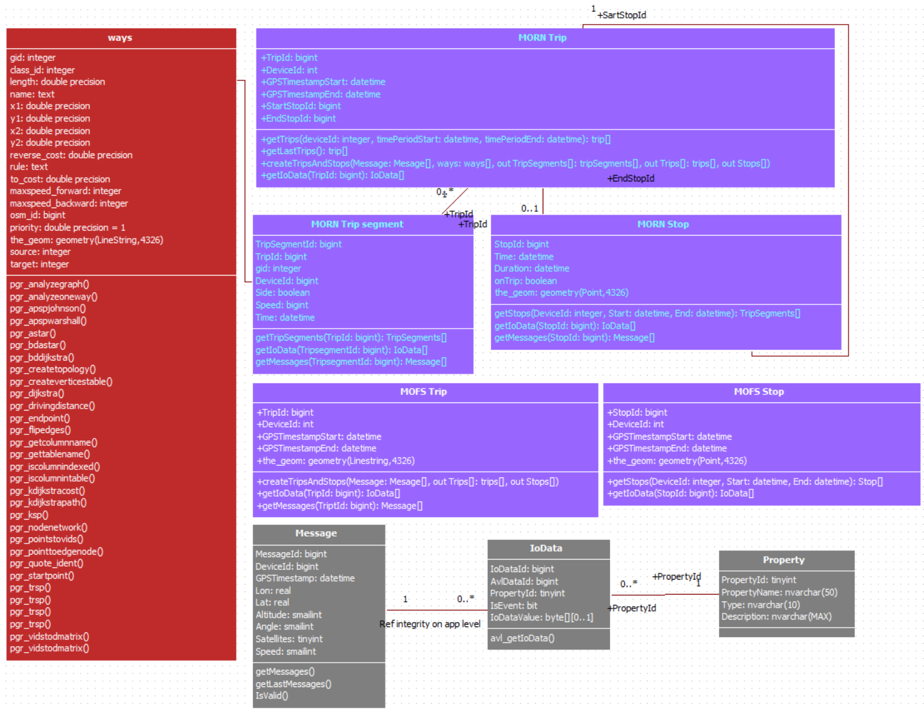


Figure 16. The MORN model obtained by extending existing MOFS model by using concepts proposed in this paper

The first results indicate the expected outcomes. One of them is that mobilisation of additional hardware resources was required in order to support work with the new data and the new data model. However, some of the functionalities are significantly improved in terms of execution time (display of vehicle movement, routing, etc.). The main problem that has been noticed is the quality of OSM data which is rather heterogeneous.

Some concrete indicators of the proposed FM AVL system capabilities and performances will be available in the next few months. What seems to be a conclusion is that, due to the insufficient quality of the data, system which is based on MORN in FM AVL scenario cannot be used as the proper solution for the model of moving objects movement, at least for the time being. Therefore, a back-up option has to be provided in case that MOFS model has to be used to answer the user's requests. However, the existing trend in the development and data quality increase indicates that systems based on the road network will have its use for FM AVL applications in the very near future.

6. Conclusions

One of the main reasons in implementation of models based on network is that data with sufficient quality were unavailable until recently. Even though the situation is not ideal nowadays, utilization of OSM data is certainly an interesting possibility.

There are various models using OSM data for different applications. Those which are suitable for moving objects movement modelling have to support object identification and to facilitate data versioning and routing. In order to provide efficient import of OSM Road Network data into the proposed models for moving objects movement, *osmosis* and *pgRouting* open-source libraries are used. Also, additional procedures have been proposed to obtain the proposed model which is suitable for modelling moving objects movement and for routing.

Based on collected statistical data related to road network geometry that are generated by FM AVL (GNSS/data) devices in standard FM AVL scenario it has been concluded that path geometries of moving objects roughly correspond to road network geometry. Density of the OSM road network and lengths of ways/segments comprising this network are such that they can be used as spatial reference for modelling and storing data generating by FM AVL devices. The whole concept of the proposed model for moving objects movement on network (MORN) is based on this assumption.

Implementation of the proposed model is done within a commercial FM AVL system. The system uses a model that is based on moving objects movement in free space (MOFS). Therefore, existing MOFS model is extended and modified according to proposed principles to implement the proposed MORN model. First experiences indicates that system which is based on MORN, due to the insufficient quality of the data, in FM AVL scenario cannot be used as the proper solution for the model of moving objects movement, at least for the time being. First test indicate that back-up option has to be provided when vehicle is located in a region without high quality road network. In that case, existing MOFS model has to be used.

Current research on OSM data quality indicates that there is a trend in data quality improvement. Therefore, moving objects movement models based on OSM road network are likely to be used in near future.

Model for tracking moving objects that is based on road network as well as the model that is not based on road network are equally significant and have to be supported for vehicle tracking application scenario due to required functionalities. Therefore, approach for testing these models will be designed and implemented using a commercial system for tracking vehicles - MobTrack:24. Procedures that will be designed and implemented within the system will enable utilization of the proposed models. These procedures will be designed to respect all the specifics and limitations of both implemented solutions. The results of these experiments might be very useful, because they might be significant in cases where the transition from models and systems that are not based on road network towards the systems and models that are based on road network is considered. It is expected that valuable practical experiences obtained from using these solutions within the MobTrack:24 FM AVL system will be obtained and analysed in terms of their performances.

The research is still in progress and it is going to be continued. The research done so far was mainly aiming at modelling moving objects movement on network. In future, the research will be also focused on routing. It is planned that two variants of AVL system for routing are to be implemented and tested in real applications. The first solution is based on using publicly available routing services such as Google and Open Street Maps and the second one is based on using *pgRouting* open-source solution for routing. Comparative analysis of the two implemented solutions will be conducted. The first solution is based on online services and that provides some advantages such as: updated spatial data, no need for the storage and maintenance of large quantity of data within proprietary system etc., but there are also some disadvantages such as limited availability, reduced system performances (in terms of system responsiveness and processing speed), price for using the services, etc. The second solution requires significant resources for the development and implementation of system for routing, investment in system installation, maintenance of the system and data etc., but, on the other side, this approach provides working autonomy and better system performances and responsiveness.

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Speed-Up Heuristics for Traffic Flow Estimation with Gaussian Process Regression

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Extended Abstract

Traffic volume estimation is a natural task in macroscopic street based traffic analysis systems and has important applications, e.g., quality-of-service evaluation, location evaluation or risk analysis. Nowadays, intelligent transportation systems rely on stationary sensors, which provide traffic volume measurements at predefined locations (Kinane et. al., 2014). However, imputation of the unobserved traffic flow values and short term-predictions are highly important research topics (Schnitzler et. al., 2014).

Application of Gaussian Processes is an appealing state-of-the-art method that outperforms recent methods (Liebig et. al., 2013). The method bases on a covariance matrix that denotes the correlations among the traffic flux values at various locations. Due to the computational complexity of Gaussian Process Regression, application to urban areas were restricted either to small sites or a sample of locations (Artikis et. al., 2014). This paper introduces and discusses the application of a speed-up heuristic to Gaussian process regression for the traffic flow estimation problem.

The computational complexity results from the kernel inversion which is part of the Gaussian Process Regression. We relax this global function to a focal one which incorporates not all data at once, but iteratively incorporates the data of the neighborhood. The neighborhood, however, has to be defined in advance. This neighborhood definition should be consistent to the correlation expressed by the kernel function. I.e., if a kernel models correlation based on the spatial closeness, the spatial closest neighbors are most likely the important locations for estimation of the unknown neighbor. Intuitively, this heuristic introduces a Markov assumption, whereas the traffic flow at one location is fully defined by the flow situation of its neighbors. Furthermore, as we want the Gaussian Process Regression to be applicable we may want to fix the kernel size and thereof the number of neighbors being incorporated for traffic flow prediction. This step seems to be

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similar to the k-Nearest Neighbor method. Indeed, with usage of a linear kernel the methods are identical. In general the Markov assumption does not hold (Liebig et. al. 2008, Liebig et. al. 2009) thus appropriate decision on the neighborhood is crucial in this heuristic.

With this heuristic, we expect the Gaussian Process Regression to perform well in smart city applications. We will apply the heuristic in the city of Dublin using traffic loop data of about 620 fixed stationary sensors, compare Figure 1. One smart-city application of this heuristic is the integration in the situation aware tripplanner, we presented in (Liebig et. al. 2014).

Figure 1. Visualization of the traffic loop sensors in Dublin City (red dots) and sketch of the heuristic to use closest neighbors for traffic flow imputation.

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Towards Machine-based Matching of Addresses Expressed in Natural Languages

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Abstract. Address matching is frequently used in everyday life. It is an essential prerequisite for many of the functionalities provided by location-based services (e.g. car navigation). The procedure is simply parsing an address expressed in a pre-defined standard format to its components, and then matching these components with their corresponding features on the map. If such standards are absent however, the parsing and, consequently, the matching usually fail; thus human intervention is needed. As one of such cases, this paper presents the initial results of an ongoing research on developing a machine-based matching for addresses expressed in natural languages. As the first step, we show how such addresses can be parsed through formal expression of their combination rules. The implementation result for a case study is presented.

Keywords. Address matching, Addressing standards, Natural languages, Parsing, Location-based services, BNF

1. Introduction

Address matching (also called *geocoding*) is an applied spatial analysis which is frequently used in everyday life. Almost all desktop (e.g. ArcGIS) and web-based (e.g. Googlemaps) GIS environments are equipped with a module to match the addresses expressed in pre-defined standard formats on the map. It is an essential prerequisite for many of the functionalities provided by location-based services (e.g. car navigation). ERSI defines address matching as "a process that compares an address or a table of addresses to the address attributes of a reference dataset to determine wheth-

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er a particular address falls within an address range associated with a feature in the reference dataset. If an address falls within a feature's address range, it is considered a match and a location can be returned" (ESRI's GIS Dictionary on Address Matching). Several methods have been proposed for address matching which assume a standard format for the components of the address, and propose solutions for matching the known address components to map components (O'Reagan & United States. Bureau of the Census. Statistical Research 1987; Yu 1996; Yang et al. 2004; Goldberg et al. 2007; Goldberg 2011; Eckman & English 2012; Qin et al. 2013).

Address matching is composed of four main steps: (1) Text parsing, (2) Standardization, (3) Correction, and (4) Matching (Yang et al. 2004). Although address matching may be considered a straightforward, well-studied issue, there are still many questions to be answered. Surfing the web, you encounter practical questions such as: "the same address may be referred to in multiple ways: 110 Test St, 110 Test St., 110 Test Street, etc.", where different notations are used for "street". A more complex situation is: "the addresses could be written in all different ways: 1345 135th St NE, 1345 NE 135th St, etc.", in which the order of components may change. Such problems may be partially solved by designing a comprehensive parser (step 1) that captures all of the above addressing formats. The parsed address is then standardized (step 2) and corrected (steps 3) before performing the final matching (step 4). However, unmatched addresses may still remain (30% on average), which then require user intervention (Yang et al. 2004).

In both of the above examples the components of the addresses are fixed, and only the symbols (the first example) or the order (the second example) differ. The situation is much more complicated when there is no addressing standard present whatsoever, and addresses are expressed in natural languages (hereafter called *textual addresses*). An interesting example is Iran, where people express addresses as a sequence of spatial elements (e.g. streets, squares, landmarks, etc.), starting from a known element. For example, in *Figure 1* the address of point **A** based on route #1 is "Tehran, Shariati Ave., Gholhak, Pabarja St., Ayeneh Blvd., West corner of Gol-e-yakh Alley, No. 2, Unit 9". Even worse, the same place could also be referred to in completely different ways because different starting points or spatial elements may be used by another person. For example, based on route #2 in *Figure 1*, point **A** is referred to as "Tehran, Daroos, Shahrzad Blvd., Pabarja St., Ayeneh Blvd., West corner of Gol-e-yakh Alley, No. 2, Unit 9". Note that in the first address, "Gholhak" is an old famous name for the point shown on the map; and in the second address, "Daroos" is an old name for this area, which is not even shown on the map!

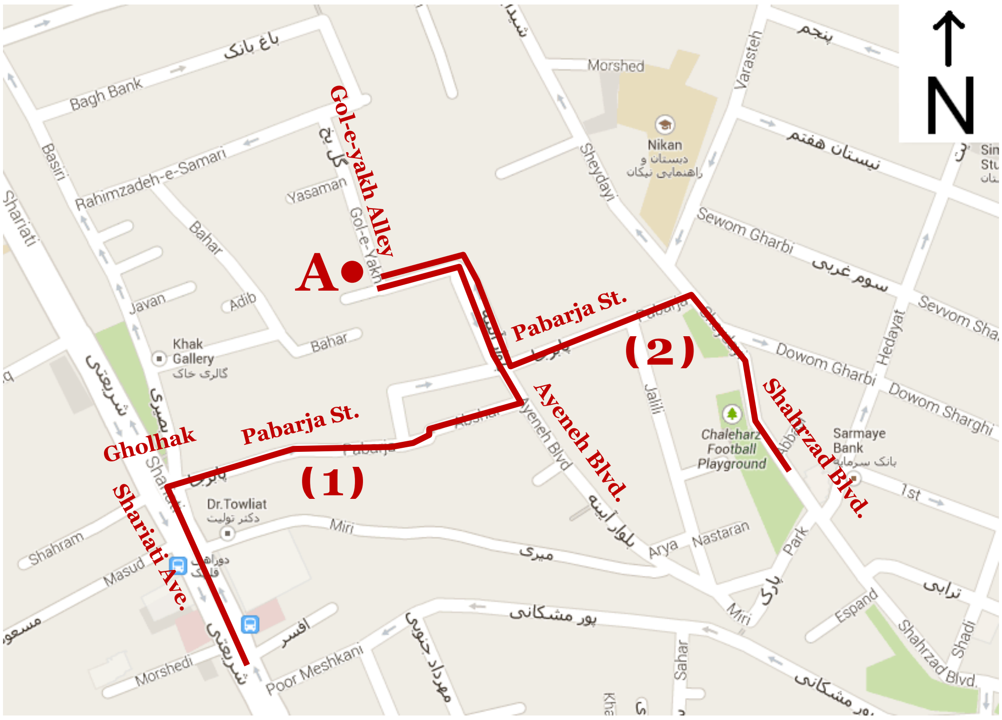

Figure 1. Point **A** is referred to in two different ways using different stating points and spatial elements.

Although this method of addressing may seem very unpleasant at first, it is very efficient, because:

- It not only specifies the destination, but it also tells how to reach it. In other words, you do not need any map, navigation system, etc. to find the destination. Instead, you can reach the known starting point and then look for the next components, step-by-step. Compare this with "Bräuhausgasse 64/7, 1050 Vienna", which only tells you that your destination is located in the 5th district of Vienna, but you will need to look all over the 5th district on the map for Bräuhausgasse, or search for it in your navigation system.
- This way, you will inevitably be exposed to the environment and its spatial elements, which helps you in building up your cognitive map. Again, compare it with having a navigation system that tells you how to reach Bräuhausgasse. In this case, you rely on the navigation system and do not necessarily have any connection to the environment.

Nevertheless, even if, as we claim, this method of addressing is efficient, it prevents many of the location-based services that require address matching to be (efficiently) used. A simple practical example is car navigation systems: even if you know your destination, you have to find it and point to it on the map through zooming and panning; very difficult to do for unknown destinations!

This paper presents the initial results of an ongoing research on developing a machine-based matching for addresses expressed in natural languages. We believe that text parsing is the most critical step in this regards. Such non-standard addresses are expressed in natural languages (Chomsky 1956; Ginsburg 1975; Bolc & Carbonell 1987; Allen 1995; Chomsky 2002; Gómez-Rodríguez 2010; Biemann 2012; Pustejovsky & Stubbs 2013) and based on the user's spatial cognition (Lynch 1960; Coventry et al. 2009; Frank 2010; Goodchild 2011; Hirtle 2011; Karimipour & Niroo 2013; Khazravi & Karimipour 2012). Therefore, the elements of spatial cognition, as well as linguistic structures must be considered in order to efficiently parse such textual addresses. The attempts to deploy the machine-based natural language processing (NLP) in address-matching has reached limited successes. The main reason is the complexity of natural language structures, which caused an address to be unmatched even if there is a partial error in its parsing.

Language is conceptually connected to human cognition. Twaroch & Frank (2003) combined language and space for better understanding of spatial cognition and urban environments. Shusterman et al. (2011) studied the role of language in development of spatial cognition. There are other studies on connections between space and language (Talmy 1983; Bloom 1999).

In this paper, we propose a simple formal language to parse the addresses expressed in natural languages. Section 2 describes how formal languages may be used to formally express the combination rules of natural languages. This results in a simple formal language to parse the textual addresses expressed in natural languages, which is presented and tested for a case study in Section 3. Lastly, Section 4 concludes the paper and introduces future research directions.

2. Formal Expression of Combination Rules of Natural Languages

A *formal language* consists of a set of *symbols* (equivalent to words in natural languages) and a set of rules for their combination, called *syntax* (roughly equivalent to grammar in natural languages). A valid combination of symbols is called a *well-formed construction*, which can be parsed and interpreted using the combination rules.

Although natural languages do not obey such strict combination rules, still a level of regularity can be considered, and thus the parsing methods used for formal languages may be applied (Chomsky 1980). In particular, an address expressed in a natural language may be automatically parsed to its components by defining a set of combination rules, i.e. grammar.

Grammar is a set of rules to combine the symbols (vocabularies) of a natural language (Frank 2006). The symbols are classified into (*Figure 2*):

- A set of *terminal symbols*, which cannot be further simplified. Terminal symbols may be *constants* or *variables*.
- A set of *non-terminal symbols*, which must be eventually simplified to the terminal symbols by repeated application of combination rules.
- A special non-terminal symbol *S*, which is called the *start symbol.*

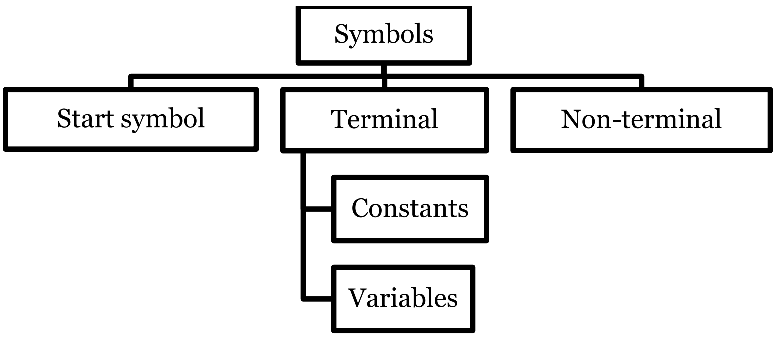

Figure 2. Classification of symbols of a language.

The combination rules are usually expressed in Backus-Naur Form (BNF), which is a formal meta-language to define other languages (Frank 2006). *Table 1* illustrates the main symbols used in the BNF.

:=	is replaced by or produces
|	or
[]	optional
{}	any number
()	grouping
“”	enclose terminal symbols

Table 1. The main symbols of the BNF.

For example, the grammar of a simple natural language may be defined using the BNF as follows:

1. S:=NP VP
2. NP:= M1 N M2
3. VP:= V NP
4. M1:= article | quantifier | N | demonstration | superlation
5. M2:= appositive | relative clause

where NP, VP, M1 and M2 stands respectively for “Noun Phrase”, “Verb Phrase”, “Modifier type 1” and “Modifier type 2”. Figure 3 illustrates how a well-formed construction in this language is parsed using the specified grammar.

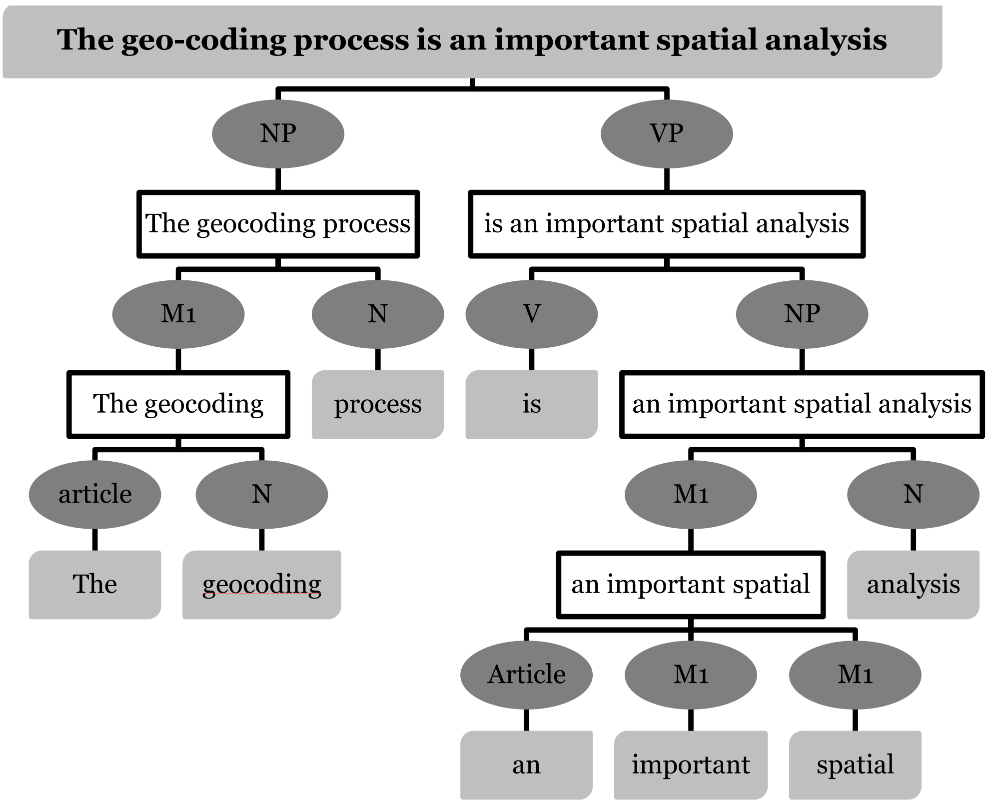

Figure 3. Parsing a well-formed construction using the specified grammar.

3. A Language to Parse Textual Addresses: A Small Example

As discussed, in order to parse textual addresses a formal language including valid grammar and vocabularies must be defined. As textual addresses are expressed in natural languages, the grammar must be as flexible as possible in order to optimally capture irregularities.

A textual address may consist of two *spatial groups (SG)* of terminal symbols:

1. *Geo-names (GN)*
   1.1. *Constant geo-names (cGN)*: avenue, street, alley, etc.
   1.2. *Variable geo-names (vGN)*: names of the constant geo-names
2. *Spatial relations (SR)*: after, before, etc.

Therefore, the combination rules of such a language may be defined as:

1. S := {SG, #41}
2. SG := [SR] GN
3. GN := cGN vGN | vGN cGN
4. cGN := “avenue” | “ave.” | “street” | “st.” | “alley” | “number” | “unit”
5. SR := “after” | “before” | “in front of” | “left of” | “right of”

Figure 5 illustrates the parsing of a sample textual address, whose position is shown in *Figure 4*, using the language defined.

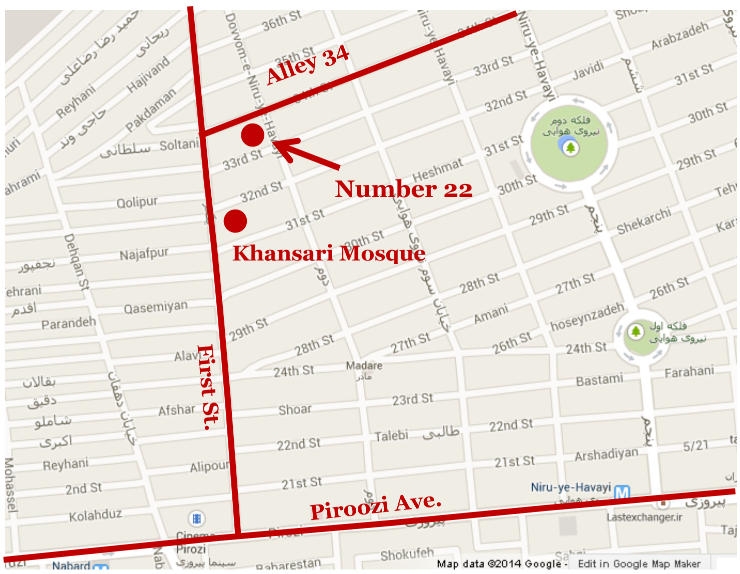

Figure 4. Position of the sample textual address on the map.

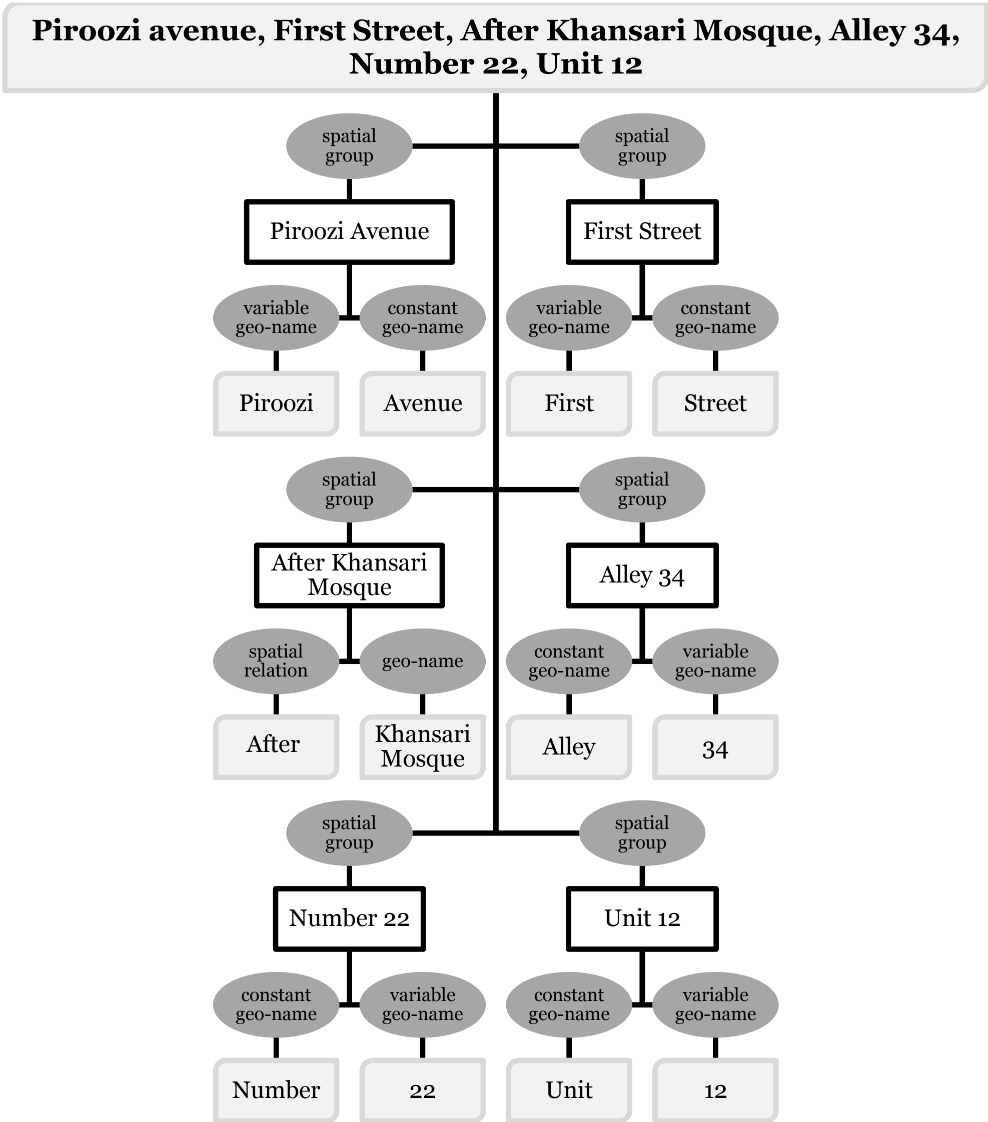

Figure 5. Pasring of a sample textual address using the language defined.

The proposed approach was implemented as a simple software (*Figure 6*), programmed in Microsoft Visual Studio C#.net. The user can introduce the geo-names and spatial relations (left). Then, any textual address that contains those geo-names and spatial relations is parsed to its components (right), which can be used by the next address matching steps.

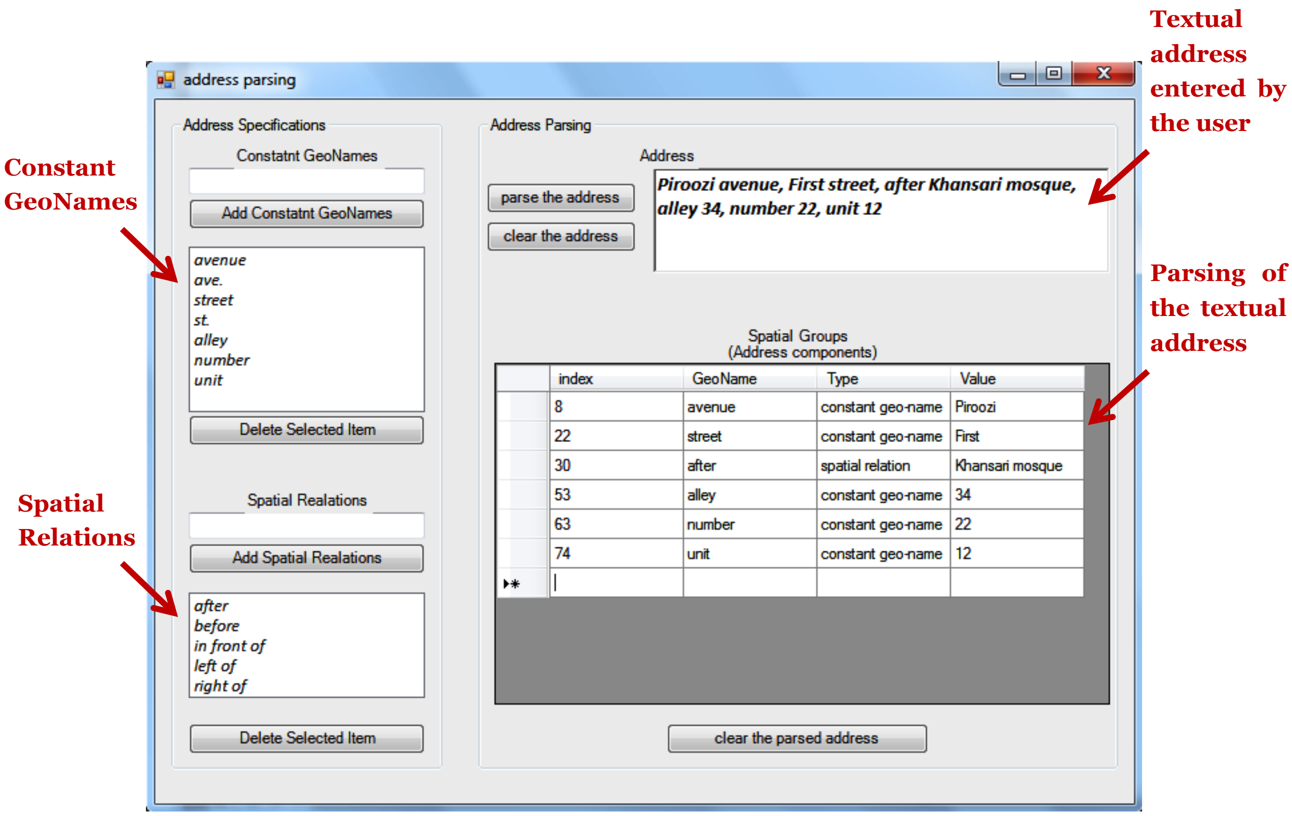

Figure 6. Implementation of the proposed approach of the paper: The textual address (top right) is parsed (bottom right) based on the geo-names (top left) and spatial relations (bottom left) introduced by the user.

4. Conclusions and Future Work

This paper discussed the initial results of an ongoing research on developing machine-based matching for addresses expressed in natural languages. As the first step, we defined a formal language - including symbols and combination rules - to parse such textual addresses. The implementation result seems promising, as we could parse a sample address to its components. However, it is still a long way to practically developing the desired address matching. The most problematic issue is that natural languages do not completely obey the rules provided by formal languages. We are currently working on enriching the proposed language with more symbols and combination rules in order to capture as many irregularities as possible.

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A localized avalanche risk assessment strategy assisted by on-site user-generated data

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Extended Abstract

Avalanche accident prevention and risk reduction consists of the following three main factors (Harvey et al. 2012):

(a) Equipment including: maps, orientation devices and emergency equipment

(b) Knowledge and experience in alpine surroundings

(c) Information about various environmental factors including: terrain, weather, the avalanche bulletin and human interactions

Some parts of these factors need to be learned, some experienced or bought while others need to be made available by experts. Combining as many of these elements would greatly improve the daily routine of winter sports enthusiasts who plan to go outside of patrolled areas.

Since the beginning of avalanche bulletins (ca. 1945 in Switzerland), the accuracy and up-to-dateness has increased from weekly to semi-daily updates and from general warnings to internationally recognized warning levels (1-5). Avalanche risk maps published by avalanche bulletin providers combine large, homogenous areas (usually mountain ranges) with related weather patterns. These providers issue avalanche bulletins generated by experienced forecasters with specific knowledge for evaluating the situation (Schweitzer et al. 2005).

There are two ways to evaluate avalanche risk: (a) by assessing known avalanche triggering factors (Mair 2012) and (b) through the rules of physics – meaning shear, drag, friction and other forces. Bulletin providers and experienced snow sports enthusiasts rely on the first option as there is no way of measuring all forces for any slope (Schweitzer at al. 2005).

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Bulletins usually consist of a map with a classification depending on risk level (1 to 5), exposition (8 directions – each 45 degree) and diurnal variation of the hazard (morning vs. afternoon), as well as a written report. Bulletins in most countries are available through websites or read out loud on hotlines. Written reports contain more information and valuable insights into a specific situation while maps display information in a spatial context (LWD Steiermark 2014).

An application already available in this sector is called “White Risk” by SLF (WSL Institute for Snow and Avalanche Research at Davos), providing a daily avalanche bulletin as a static map along with a written report. It also includes a parameterizable simulator for risk assessment. The bulletin is available only in Switzerland while the simulator may be used anywhere.

In addition to the bulletin, a skilled winter sports enthusiast needs to be informed about past weather events or reports by other sportsmen. This information is available in online forums (Styria’s avalanche warning service “Lawinenwarndienst Steiermark” operates „Touren Forum“). To gather all information, a user has to access various sources offering information for different topics (past weather events and forecasts, terrain analysis, et cetera).

The complexity of assessing all possible input parameters resulted in a variety of risk-reducing strategies, e.g. „at danger level 3 do not go any steeper than 30°.“ (Munter 2013, Larcher 2012). Attempts have been made to transfer these rules into smartphone applications for sportsmen. Modification (e.g. decreasing the slope by 5° for example) might lead to a reduced risk, but users may ignore threats resulting from other factors than slope and danger level. There is no model available yet to automatically take into account all relevant information to reflect the real world situation. Avalanche prediction still doesn’t have any scientific way to create forecasts (Harvey et al. 2012). Additionally, after talking to „Lawinenwarndienst Steiermark“, a conclusion was drawn: a singular number or word describing the situation or danger-level at a specific situation would be unwise.

Users outside of permanently controlled skiing areas either need to know how to judge the report depending on situation they are in, or be overchallenged, so they don’t make a lightheaded decision. To enhance the avalanche bulletin, all information needs to be available and tailored to a skilled and well-informed user (Schweitzer et al. 2005). Within this system, the user should be able to find all information needed easily and on-location. Furthermore, a user should have the opportunity to upload and share experiences and sightings, therefore turning into a “prosumer” (providing and consuming information).

The system focuses on time- and position-relevant information, made available by a location based service on a mobile device. In return, users should be motivated to upload their experiences in order to create information valuable for other users and avalanche service providers. With all necessary information provided, further assessment is left to the user.

The presented system is a prototype currently under development, to test and evaluate its strengths and weaknesses. It is designed as a web-application to allow access by different mobile devices with various operating systems.

Mobile component

The mobile part consists of two main features: the first provides viable information to the user, while the other allows users to upload specific „events", separated by categories. Displaying information is realized with a combination of jQuery mobile for usability on mobile devices (pinch zoom, swipe and other specific commands), OpenLayers 3, and HTML 5 APIs. Displayed information consists of the following layers:

- basemaps
- user position and attitude
- pre-calculated avalanche bulletin map
- weather stations
- user-generated data („event" layers)

Displaying the current position is essential for user orientation and information immediately relevant to the location. In addition, exposition and slope are important factors for avalanche assessment retrieved from the mobile device's GPS and inertial sensors by the HTML 5 Geolocation and Device Orientation API. A pre-calculated avalanche bulletin map provided by a WMS will show a general warning level for the selected area.

Weather stations and user-generated events are shown as different symbols on the map: current meteorological information is selectable on click and queryable for past meteorological events (e.g. snowfall from three days ago). User generated events are shown depending on their age in respect to their category.

Events do not only include visible phenomena such as avalanches and incidents, but also those that can only be sensed (e.g. sounds that happen when snow cover settles under its own weight, causing a structural weakening). Another example is surface hoar (LWD Tirol 2014) which occurs only during specific weather conditions and when snowed onto becomes invisible or hard to find even if looking at a snowprofile. Events are registered with their respective location, attitude and timestamp. Along with a personal assessment of the risk level given by the user, the official avalanche risk level issued by the avalanche bulletin provider is recorded. Depending on the type of event, users have to fill in a dynamically modified HTML form. Then the data is processed and sent to a database.

Server component

Data is stored in a PostgreSQL/PostGIS databases with a distinction between raster data (used to create the avalanche risk map) and vector data including user-generated events as well as weather information. Published avalanche risk maps are aggregated on a large-scale basis, therefore not being qualified as a basemap. Creating a useful basemap is currently under research. Experts of the avalanche service providers should enter daily risk assessments into an online-form. Upon upload, a function will be triggered to analyze the given information and render a new basemap, available via WMS.

Meteorological data and user-generated events are stored in the database, published by a GeoServer WFS instance in GeoJSON-format and implemented in an OpenLayers map. Attribute information is included and can be used for further information and rule-based styling.

Future approaches and benefits

Currently, no avalanche bulletin provider offers the chance for public users to upload their localized sightings and experiences yet (Entweder Currently oder yet!?). Putting effort in the upload-part and raising its usability could increase the systems acceptance. In the future avalanche service providers such as the „Lawinenwarndienst Steiermark“ could profit from additional information. At present they have to go outside and check the situation during questionable conditions. Since staff is limited and the area covered by each service provider in Austria is large, they could plan outdoor inspections accordingly and use information created by users.

Including additional data layers such as CORINE landcover, high quality ALS digital elevation models or vector layers for crests, spines and other terrain features, might help to further distinguish the risk map.

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Reverse Service Area Analysis of Styrian Hospitals Based on OpenStreetMap Data

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Extended Abstract

This study tests a new approach to analyze the accessibility of Styrian state hospitals based on open data. The entire geoprocessing toolchain is described, from data acquisition to analysis and visualization – all based on free or open-source software. The aim of this project is to find and calculate the best facility for emergency and hospital treatment for each municipal territory in Styria. A four steps strategy is applied: After acquiring necessary (geographical) data from open data stores, creating a topological network capable of routing and performing various routing algorithms, the results are visualized in a proper way eventually. A future goal is to implement a location-based service for mobile and desktop browser applications to show and navigate to the nearest hospital.

Proprietary GIS software, such as ArcGIS (Network Analyst), Intergraph or Smallworld, offers network analysis tools for road or, more general, infrastructure optimizations. Open-source software packages provide an even larger number of tools to model networks and solve related problems. In our research, we use the PostgreSQL database management system (DMBS) with a spatial extension, called PostGIS. This extension enables the DBMS to handle geographic features including spatial reference and projections. Geometric features are stored using the OGC Simple Feature Model, which supports points, lines and polygons with their respective multigeometrical appearances as well as collections of geometries. Another extension for PostgreSQL, pgRouting, provides geospatial routing functionality.

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Study Area

Styria is the second largest state in Austria, comprising an area of some 16,000 km². In the northern half, the terrain is determined by the mountain ranges of the Northern Calcareous Alps and Central Alps. The Eastern Alps in Styria are divided by longitudinal valleys in an east-west direction (Enns, Mur, Palten-Liesing valleys). The southern parts have lower relief energy with a basin opening southwards from the capital, Graz. A relief representation and the Styrian road network are illustrated in *Figure 1*.

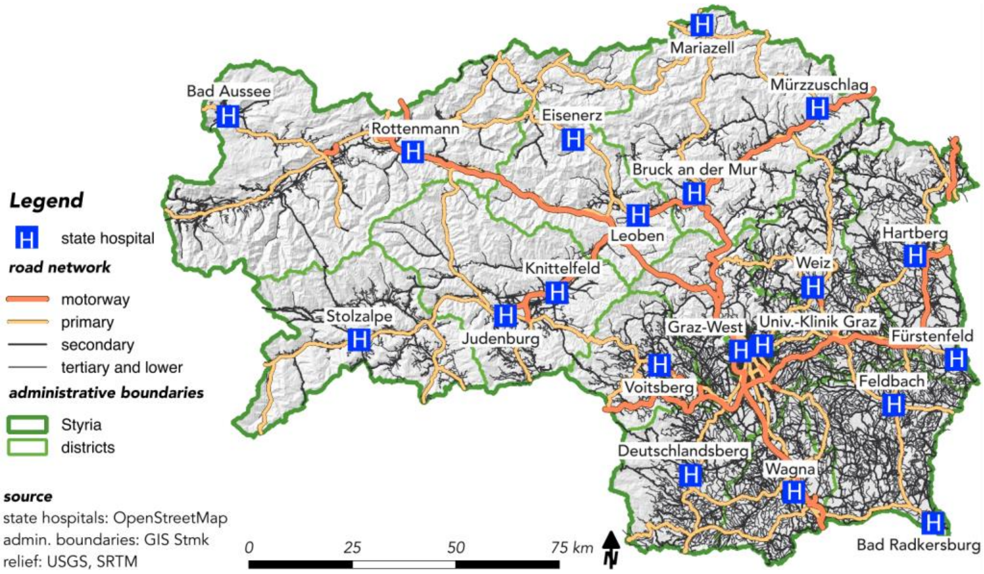

Figure 1. Map of the Styrian road network (highways, primary and secondary roads) including state hospital sites.

Data Acquisitions from OpenStreetMap

As a first step, locations of all state hospitals in Styria are queried from the OpenStreetMap (OSM) database. OSM is a free map of the world, collaboratively maintained by more than 1.8 million users as of October 2014 around the world (OSM Statistics, 2014). More than that, it is a queryable (geographic and semantic) data store, describing the mapped information and visualizing it in various ways. Querying OSM can be done via the Overpass Application Programming Interface (API): To acquire geocoded information, data is filtered by attributes using key-value pairs (e.g. “amenity” = “hospital”) or by location, defining spatial / topological restrictions (e.g. bounding boxes, maximum distance). For the sake of simplicity and comprehensibility, the reachability analysis will only cover public state hospitals.

For network analysis, street data has to be obtained from OSM. Osm2po is a java-based toolkit to download and parse both geometric entities and its street information for a specific country in a topologically correct format (Osm2po, 2014). Results are written to a SQL file and then loaded into the PostgreSQL/PostGIS database. pgRouting is an extension of the PostreSQL/PostGIS database management system and provides geospatial routing functionality. Various routing algorithms are implemented, such as functions for Dijkstra's, A*, Travelling Salesman or Driving Distance. In a first processing step, a routable topology has to be created from the topologically correct input data. After that, routing functions may be applied and results are given as cost-path-datasets including identifiers for nodes and edges of the corresponding line segments.

Reverse Service Area Analysis

The strategy is a combination of two typical network analysis scenarios: closest facility and service areas. The first one tries to find the nearest facility (in our case hospitals) to a specific point location (accidents, emergencies) where support / assistance of the mentioned facility is needed. "Closest" can also be seen as "best", not only in a minimization of distance, but also in terms of traveling costs or other factors (road surface and slope), limiting the accessibility of road vehicles. The second analysis tool estimates the area, for which a certain point location can provide its service within a specified timeframe. A classic example could be the area consisting of all network nodes within a distance from a hospital that can be covered in 5-, 10-, 15-minutes and therefore can be serviced by this medical facility.

After data retrieval from OSM, the discussed combined strategy is applied to the dataset: First, a stored procedure written in pl/pgSQL-Code iterates over all (n) hospitals in the database, implementing a Dijkstra-algorithm. For this operation, a hospital is set as the start location for routing. Considering that hospitals, as well as other larger scale facilities are stored as polygons, a further refinement has to be implemented: by calculating a representative point location for the respective areas. This location is matched to the closest topological network node.

An infinite (or very high) maximum cost value allows us to calculate cost factors for all other nodes in the network. In particular, reverse costs of edges are used, describing the travel time from each node to the given hospital. In the resulting dataset, a node has n (virtual) layers, containing traversing costs to the hospitals respectively. Up next is the aggregation on a 1x1 km raster grid or by municipal area: Nodes are selected by location and the average cost per raster cell or municipality respectively is calculated for each hospital. The best (closest) hospital for each administrative boundary is represented by the layer with the least estimated costs.

A subsequent application is a public location based service on mobile devices, helping citizens to find the nearest physician (on duty) for a medical specialty. Considering this application not only state hospitals, but all facilities for medical treatment should be included in a future analysis.

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Animated Cartographic Visualisation of Networks on Mobile Devices

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Extended Abstract

The presentation of networks on maps helps the user to explore, analyse and interpret relations between objects concerning a certain set of facts. Cartographic visualisation must consider several different types of networks with varying complexity. Typical scopes of application are schematic metro maps, street networks or power supply grids.

Visualisation of more or less complex network maps on (desktop) computer screens often becomes a demanding issue, because those screens are offering a rather limited viewport. Although screen size and resolution have increased during the last years, it is still a problem for the user to recognize all details and keep a good overview of the whole network at the same time.

Nowadays presentations on computer screens often are realized by means of web based mapping solutions as shown in *Figure 1*, which allow interactivity like panning and zooming or selecting and filtering the information shown on the map. Here, zooming helps to get detailed information of a certain part of the map. On the other hand, showing only subsections of the network makes it hard to get an overview about the whole set of facts and may lead to misinterpretations. If additional screen space is available, a medium sized conventional overview map can be supportive. A sophisticated approach for the cartographic visualisation of complex commuter relationships between German municipalities is described by Hanewinkel & Specht (2010).

Mobile devices, especially smartphones like in *Figure 2*, are only offering an even smaller viewport. Thus, the task is to find an appropriate compromise between mobility and the ability to show as much information as needed or even possible.

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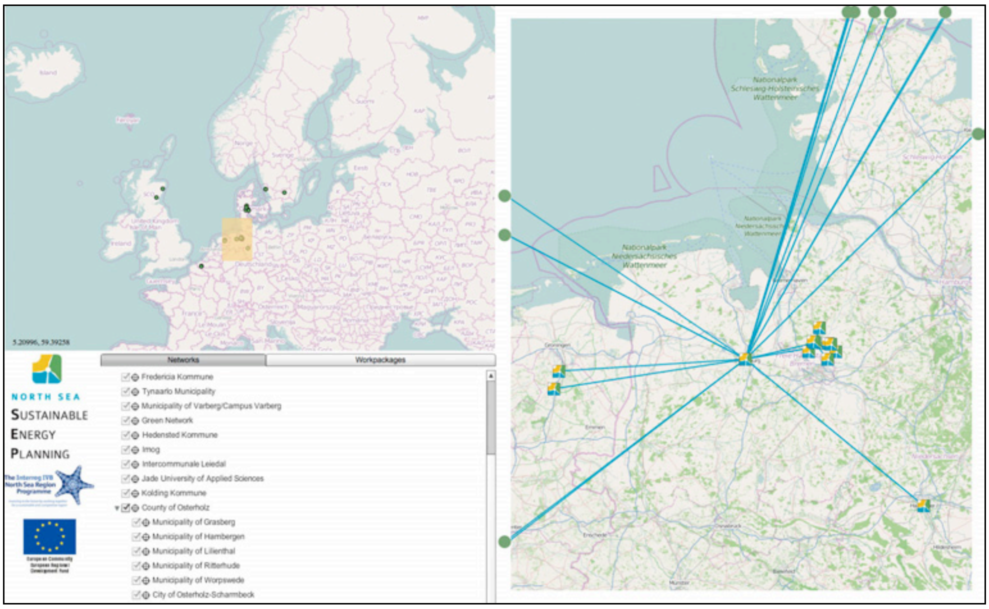

Figure 1. Web mapping application visualising the relations of the member organisations of a research network using the “fringe”. An additional overview map helps with the orientation. (Gollenstede A, 2011).

For the correct interpretation of the network or its subject it is often necessary to get information about qualities or quantities, which can be found outside of the current viewport.

A first approach to a solution is to use a part of the viewport frame border to show graphical objects, which represent the actually invisible objects or the invisible network parts – herein called the “fringe” cf. *Figures 1 - 3*. In the simplest case the fringe can be used to show where the next objects of the network are located and so it can support the user to pan into the right direction. But the fringe can also be used to give information about the number of objects or quantities outside the viewport. Therefore the graphical objects of the fringe can vary in size or colour or both. In the end all the traditional methods of cartography to visualise different kinds of quantities can be used here.

Different techniques for the visualisation of off-screen objects have already been introduced. A typical solution is to use space at the screen border, similar to the “fringe”, to display information about the objects outside the actual viewport.

Baudisch & Rosenholtz (2003) proposed a technique of indicating off-screen objects by using a visual effect named “halo”. Based on this work Gustafson et. al. (2008) introduced a technique called “wedge”. They developed an algorithm for a clutter-free screen border displaying multiple off-screen objects. At the same time also usability aspects on mobile devices have been taken into account. Hanewinkel & Specht (2010) concentrated on aspects of high quality cartographic output. Here, the indicator has been named "orbit" and is used on desktop and web based applications.

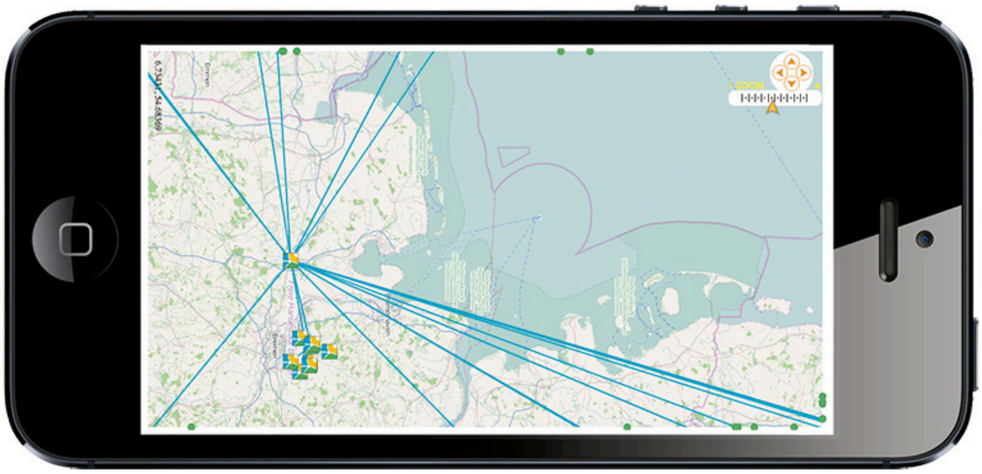

Figure 2. Mobile application visualising the network shown in *Figure 1* (Gollenstede A, 2014)

Panning and zooming require a constant actualisation of the fringe. The fringe objects constantly move and change size and colour when necessary. Depending on the complexity of the network data a large amount of calculations need to be executed on the mobile client to animate the fringe.

In addition to the fringe other types of animation can be used to support the user and to give an easy access to the network, e. g. showing animations of the edges, which are interconnecting the nodes of the network.

If objects related to the network vary in time and place, a "live" animation of the network elements and the fringe is required. Representations like moving buses on a street map or a schematic metro map require a continuous update and animation of almost all elements on the mobile screen. Then, the fringe can additionally contain information about the expected arrival of the next bus, as illustrated in *Figure 3*, or the stations still to go for the passengers.

Another possibility to avoid overcrowded small screens and to ease the interpretation of networks is the simultaneous use of different levels of generalisation on the map screen. Then, the degree of generalisation should be small in the centre of the viewport and increase to the border of the viewport.

Alternatively, Wolff (2013) mentions different deformation methods of the map centre e. g. the fisheye view, which can help to dissolve overcrowded areas. Similar approaches are well known from printed city maps of the German publishing house Falk.

When geometric networks have to be visualised, graph drawing and cartography are combined (Wolff 2013). In this case certain visualisation tasks, like generalisation of the network, can be solved with algorithms of graph theory.

Figure 3. Sketch of a mobile application visualising a schematic public transportation network. The fringe displays the expected arrival of the next buses to come for two selected routes. The background shows parts of the off-screen network. (Gollenstede A, 2014; map: http://www.vwg.de)

Current work in progress at Jade University does not focus on the development of new algorithms, e. g. in the field of graph theory. Instead the main emphasis lies on increasing the quality of the cartographic visualisation of networks on mobile devices.

In a first step different basic approaches are currently implemented and will be optimised for a proper cartographic presentation on mobile terminals. For these devices, especially the limited viewports are taken into account.

As a second step the development and test of more sophisticated methods of visualisation and animation of networks on mobile devices will be tackled. Cartographic variables are to be analysed systematically in order to improve the functionality of the fringe as well as enhancing the comprehensibility.

Furthermore, the project analyses, whether the used algorithms are suitable on mobile devices with regard to the still limited performance compared to desktop applications.

Finally empirical test beds are planned to evaluate how users deal with those different ways of presentation.

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Cartographic Symbols for 3D Visualization in Facility Management Domain

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Extended Abstract

This paper describes possibilities of 3D visualization in the areas of *Facility Management* (FM) and *Building Information Modelling* (BIM). 3D models and their utilization in location based services allow better orientation in distribution systems and in facilities.

Pilot study has been made based on data from Building and Technology Passport, summary referred as Building Documentation System. Since 2004, the Facility Management Division of the University Campus at Masaryk University has collected digital spatial data of the real-estate property of the Masaryk University. Building passport contains information about buildings, floors, rooms and stairs, elevators and windows, their ground plan's shape and attributes. In 2007, shortly after the Building Passport, the Technology Passport started – technologies in buildings and rooms including location of all electronic devices, air-conditioning system, fire equipment, water distribution system or heat distribution system. Building Documentation System is primarily 2D, because DWG files and ESRI geodatabases are utilized for storing spatial information (Herman et al. 2015). Technology Passport and especially Building Passport are used as a base data in various gradually formed positioning and navigation services. Such service is the application “Building MU“, which has been developed by Facility Management Division.

Usage of 2D cartographic visualization in case of technological passports and facility management domain is limited. Frequent overlaps of individual objects in the classical 2D visualization (in both, plain or side view) are main limitation. This situation is also described in Du & Zlatanova (2006). Overlaps occur especially in rooms with high density of objects (e.g. boiler rooms). There is also required height information for precise localization of

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technical devices (e.g. valve). So, 3D view is preferred for visualization of indoor utility networks. Within the technology documentation is primarily the resolution of individual technologies and equipment, with regard to cartographic methods it is visualization of qualitative characteristics.

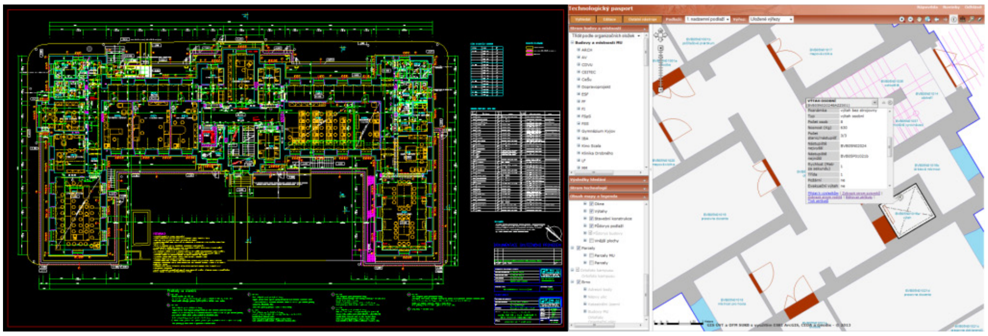

Figure 1. Data from Building Documentation System – DWG file and ESRI geodatabases.

Robinson et al. (1995) divides symbols for qualitative data on the basis of their localization to space of cartographical visualization into: point (figurative) symbols, linear symbols and areal symbols. In 3D visualization, it is necessary to deal with volume symbols. However, it should be emphasized that the differences between the volume characteristics and the other three groups are relatively fuzzy. Symbols localized as points can be full 3D (with nonzero volume) or only 2D, which are in field of computer graphics called as billboards. Billboards consist of 2D images, which are applied as a texture on a simple polygon, usually a rectangle. The underlying polygons are transparent. The position of billboards rotates in such way, that the symbols (billboards) are still vertically oriented to the virtual camera and users.

In scope of the practical testing were created 3D interior models of rooms from two buildings in campus of Faculty of Science. Processed rooms were classroom and boiler room. All technologies have been mapped in these rooms according to methodology used by Facility Management Division of the University Campus.

Various classes of utilities were differenced by colour in map legend (e.g. water, gas, heavy current or weak current). Shape or inner structure was used for representation of concrete devices. Two variants of cartographic symbols were created, tested and compared for point symbols. First variant were billboards and second variant were 3D volume symbols. Billboards were adapted from 2D map symbols, which were originally designed by Farkasova (2013). 3D symbols have been designed and created anew.

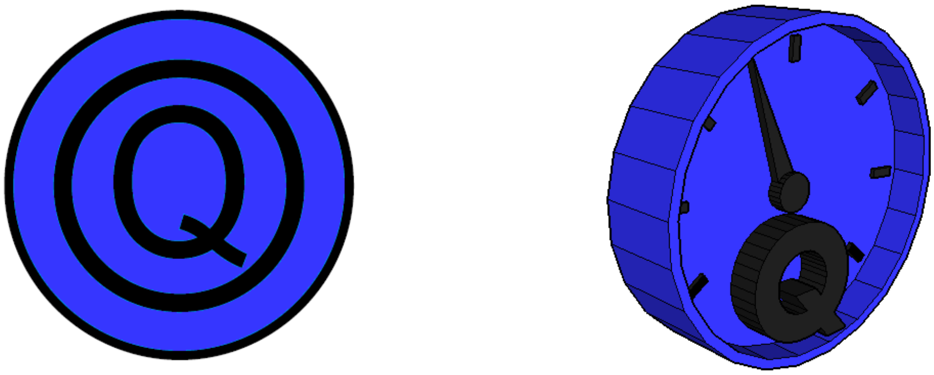

Figure 2. Two proposed map symbols for flowmeter (2D variant is on the left, 3D is on the right).

Volume symbols were used for larger devices (bigger than 10 x 10 x 10 cm). They were made automatically from 2D lines or polygons stored in source database. ArcGIS software (version 10.1 with 3D Analyst extension) was employed for automatic processing, it was 3D Buffer tool for creating volume pipelines from lines and Extrude tool for creating volume objects (e.g. radiators) from their plan view.

Comparison of size and speed of rendering was made in ArcGIS (in ArcScene module) as representative of desktop software and in X3DOM library as example of web technologies running directly in usual web browser. Combination of 3D symbols with 3D model of whole building (made from Building Passport) was tested as well. Verification of the technical parameters of symbols should is followed by testing of user cognition. This testing will be carried out by using the software MUTEP (*Multivariate TEsting Programme*), which is designed and utilized for this purpose in cooperation of cartographers and psychologists (Sterba et al. 2014).

3D symbols can be utilized in virtual reality, but also in mixed or augmented reality as well. Cartographic principles that should be followed when using the cartographic symbols describe Stanek & Friedmannova (2010). 3D symbols that have been proposed in our study could be applied in future in location based services in the field of facility management. Such services could be used for example by repairman for orientation in complicated piping or for precise localization of fault location in pipes and devices.

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Too Simple Maps

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Abstract. During their existence, maps have had many various roles. They have been used as works of arts, educational materials, object of propaganda expressing power (visualizing controlled and claimed territories) or results of research (e.g. various thematic maps). But the orientation and way findings have been considered the one of key and the most important role of maps and similar cartographic products. This role interconnects all main functions of maps - cognitive, communication, decision support and social functions.

The various maps in map clients, mobile applications for tourism and navigations systems using GNSS represent the contemporary version of maps focused on orientation or way finding. These products are very frequently criticized by cartographers that they do not respect cartographic rules and principles which have been developed and used for many centuries. Above-mentioned maps do not usually contain essential compositional element (e.g. scale or legend) or they use these elements in any unconventional way.

The paper introduces the research (work in progress) focused on cartographic evaluation of successful product exploiting maps (e.g. maps in browser, products of data journalism, mobile applications for tourism or navigation systems). The goal of our research is to find an answer (or answers) on the question “Why are above mentioned products successful (within the meaning of business and number of users), even though they usually do not respect essential cartographic rules and principles”.

The particular sections of this paper are focused mainly on finding, description and comparison of historical parallels of map simplification. In history, there were eras with important changes of map composition and content in history, which are usually related to elimination of redundant map components (e.g. reduction of decorative map symbols). Authors want to show that contemporary map simplification does not represent any exceptional

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changes or threat for cartography, but it is in compliance with the evolution of cartography and maps.

The maps used for orientation or way finding are emphasized because they usually were more simple than other cartographic products in all historical eras.

But there are also mentioned changes connected with a commencement of positioning devices, small-display devices and multi-layered maps (using background maps), because these factors have also contributed to map changes and simplification.

Keywords. Map, simplification, history of cartography, navigation system, web map.

Research on Holographic Location Map Cartographic Model

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Abstract. With the widely application of mobile internet, map becomes an important portal of location-based services. This article introduces a new kind of map named Holographic location map (Ho-lo map). Firstly, the concept and characteristics of Ho-lo map are given. Secondly, this article gives emphasis to the cartographic model of Ho-lo map. The algebraic form of this model is explained. And the context model, relationship computational model and representation model being parts of cartographic model are expatiated then. As the basis of cartographic model, the knowledge database of Ho-Lo map is presented. Finally, the cartographic process of Ho-Lo map is analyzed. An example of Ho-Lo map in the context of airport is showed. Compared with traditional map, Ho-Lo map has significant differences in drawing objects, drawing main body, drawing patterns and drawing technology. The cartographic mode will change from static to dynamic, and then to real-time. This will lead to many changes in cartographic techniques.

Key words. Holographic location map, Cartographic model, Context model, Relationship computational model, Representation model, Semantic similarity

I. Introduction

Along with technology of internet, mobile communication, mobile positioning, and the widespread use of smart mobile devices,

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Location-based Service (LBS) has become an important infrastructure of maintaining national security, improving military execution ability, constructing smart city, and realizing intelligent transportation. Especially, it has become necessary foundation of human dealing with natural disasters and safety incidents. While one key point of which is the need for high-precision, multi-perspective map for location-based services (Zhou et al. 2011).

Since 1994 Bill etc. proposed the concept of location services (Schilit et al. 1994), more and more attentions have paid for map which is an important basis of location-based service. Many companies launched their own map platform for location-based services, such as Street View of Google, Open Street Map of Microsoft, UpNext of Verizon and AutoNavi Map. At present, location data is mainly used for navigation and monitoring. Map for location-based services is mainly displayed in the form of 2D or 3D. Although some simple attribute information can be drawn on the map, it cannot provide on-demand, dynamic information and near real-time mapping, not to mention uniform standards and technical approach. It is still far from ubiquitous spatial information intelligent service which means people can access spatial information service whenever, wherever and whatever needed (Zhou et al. 2011).

In 2011, the concept of holographic location map (Ho-Lo Map) was proposed by the Chinese academy of sciences Zhou Chenghu etc., and it has aroused widespread concern in academic circles and become the major map form of ubiquitous spatial information intelligent service.

As closely related to user's context, the information and representation of Ho-Lo map are nearly real-time and dynamic, this will put forward stricter requirement about map design and production. The traditional, static, experiential mapping mode does not apply to Ho-Lo map. So this article takes cartographic model of Ho-Lo map as the object of study. Through analyzing the concept and characteristic of Ho-Lo map, the cartographic model is established in an algebraic way and each of process of this model is described in detail. This model illustrates the dynamic mapping mode and process of Ho-Lo map in theory. Because the phase of mapping is delayed to using so it will achieve truly near real-time mapping.

2 Current research of cartographic model

Research on cartographic model had lasted for many years. Many experts and scholars recognized that geographic information and visualized maps were different in the principle of data representation (Li et al. 2011), then they studied the conversion process of geospatial data to map data from different perspectives. For example, Aileen Buckley etc. put forward the concept of digital landscape model and digital mapping model, defined the cartographic data model from three layers of concept, logic and physics. And he elaborated the conversion process of GIS data to cartographic data (Aileen et al. 2005). Andrew U. Frank distinguished the difference between cartographic data model and GIS data model from the design viewpoint of cartographic database and pointed out the difference between them: cartographic data model was aimed at mapping, while GIS data model was aimed at geographic reality (Frank, 1991). Paul Hardy expatiated the conversion process of GIS data to map for the high quality graphics and illustrated the method of applying cartography rules to produce map in detail (Paul Hardy, 2009).

Chinese scholars have studied cartography model deeply for a long time too. Professor Li Lin and his team of Wuhan University had researched map symbolization and graphic expression model for a long period of time (Li et al. 2011, Yin et al. 2006, 2007). They proposed topographic mapping model based on the algebraic structure (Li et al. 2011). This model revealed the transformation mechanism of geographic spatial information, and provided a good theoretical basis for functional design of mapping system driven by database. Researcher Wang Yingjie and Professor Chen Yufen researched on self-adaptive map visualization and proposed automatically generated method of visual display mode based on state space (Wang et al. 2012). These studies have laid good foundation for this article. However, as a new type, the mapping process of Ho-Lo map will transform from traditional static mode to dynamic. We must research on its cartographic model according to its characteristics, and the model will provide a reasonable reference for Ho-Lo map producing.

3 Ho-Lo Map and its cartographic model

3.1 The concept and characteristic of Ho-Lo map

Zhou Chenghu etc. defined that Ho-Lo map was a kind of digital map based on location which can fully reflect location itself and various location-related features, events and things. It was a new type of map adapting to the needs of modern location-based services development (Zhou et al. 2011).

Using the term ‘holographic’, there are two meanings: ① we want to satisfy the location services at anytime, anyplace about anything for anyone, so the whole information of geo-features should be gathered, processed beforehand. The prefix ‘holo-’ has the meaning of ‘Whole, entire’. ② To holography, interference formed by a split laser beam is the key; while to Ho-Lo map, people, geo-features and event will interference by location. So it is the similar course to holography.

In this article, from the perspective of cartography, the Ho-Lo map is defined as follows: based on ubiquitous networks such as various positioning systems, sensor networks, internet and telecommunications networks etc., Ho-Lo map is a kind of digital map with uniform semantic relationships and space-time geographical correlation referred to location, and it can satisfy all kinds of demands by obtaining and merging multi-source heterogeneous dynamic information such as location coordinates, property, relationships, moving etc. in real-time. Being visualized, it can fully display various relevant features, events and things around the location.

Compared with traditional map, the Ho-Lo map has two major characteristics: all-inclusive and dynamic.

①All-inclusive: one meaning is all kinds of information will be integrated together, including directed association and implication relation based on location among users, objects or between users and objects, then the space-time location information frame with coherent and explicit semantic location will be made; the other meaning is that visualized form of Ho-Lo map may be 2D, 3D, panorama, augmented reality and their combined forms.

②Dynamic: to different users, their activities and preferences in different place at different time are different, Ho-Lo map will confirm the information needed dynamically, and merge the information dynamically in real-time. So the process of map producing must be dynamic and in real-time.

3.2 Geographic relevance

The concept of Geographic Relevance (GR), proposed by Raper first, can be defined as a relationship between the user's geographic information needs and the spatio-temporal expression of geographic objects in the user's surrounding environment(Tumasch Reichenbacher et al., 2009). Tumasch Reichenbacher etc. pointed out that the idea of current LBS is extended by shifting the location-based perspective to a relevance based perspective, including time, topic, and motivations(Tumasch Reichenbacher et al., 2009). According to the above analysis, the relationship among users, objects or between users and objects associated by location is the focus of Ho-Lo map. Stefano De Sabbata etc. analysed the criteria users apply when judging the relevance of geographic entities in a given mobile usage context(Stefano De Sabbata et al. 2009). Obviously, the cartographic model of Ho-Lo map and GR are very close. The cartographic model of Ho-Lo map is the special case of GR in location map. So we can use the criteria of GR, such as spatio-temporal proximity, hierarchy, cluster, co-location and association rule etc., to deliver location-related information to mobile users.

3.3 The cartography model of Ho-Lo map

Seen from the above definition and characteristics, the cartographic process of Ho-Lo map is an expression process of dynamic relevance of people, objects and things in a visual form. From reference 3, we can define reality expressed by Ho-Lo map as follow algebraic form:

$$\Omega = (T, C, R, u); \tag{1}$$

Here, Ω is the reality expressed by Ho-Lo map; T is element in Ω. T contains not only geographic features but also dynamic targets such as persons, vehicles, and aircrafts etc. R is the relationship of elements in T. u is the computational model of above relationship.

For the relationship R, along with the real-time changes of users' locations, time, goals, it can be further described as follows:

$$R = u(T, C); \tag{2}$$

Here, C is the context when Ho-Lo map is drawn.

The map space of Ho-Lo map is defined as:

$$\phi = (F, SR, v); \tag{3}$$

Here, ϕ is the map space of Ho-Lo map; F are the cartographic elements; SR is the spatial relationship of cartographic elements;v is a visual model to describe SR.

The cartographic model of Ho-Lo map is to establish a mapping relationship between Ω and ϕ. It can be described as follows:

$$\phi = f\ (\Omega); \tag{4}$$

Since the spatial relationships of map elements are attached on the geographic features, so the above equation can be rewritten as

$$F = f\left(T, C, u(T, C)\right); \tag{5}$$

Here, f is a function or procedure, which enables the geographic features meet the requirements of map expression. C can be described by a number of factors, namely:

$$C = g(t, l, p, e, \ldots\ldots); \tag{6}$$

Here, t is the time for mapping, l is the location of user, p is current user, e is the goal event of user, g is a function or procedure, which will convert single context factor into a comprehensive formalized context description. Simultaneous formula (5), (6) we can obtain:

$$F = f\left(T, g(t, l, p, \ldots), u\big(T, g(t, l, p, \ldots)\big)\right) \tag{7}$$

As t, l, p, e are all variable, the cartographic process of Ho-Lo map is a real-time, dynamic process, the key of which is to determine the three functions or processes f, u, g.

3.3.1 The Context model of Ho-Lo map

As viewed from technology, context is useful for representing and reasoning about a restricted state space within which a problem can be solved (Cristiana et al. 2009, 2011). In the linguistics view, context is the combination of situation and context. It represents the situation of real world and the background knowledge which what one says can be understood. A group of related contexts constitutes the cognitive model of the human brain. In formula 7 mentioned above, the function or procedure g will form comprehensive formalized context description. This description can be further analyzed as independent variables of relational computational model and representation model. Due to the instantaneous variability of the context, g is also required to have behavior prediction. So it can be characterized as follows:

$$g = \left(form(t, l, p, e, \ldots\ldots), reason(act_c, form)\right) \tag{8}$$

Here, $form(t, l, p, e, \ldots\ldots)$ represents formalized context description; $reason(act_c)$ represents predicting the next behavior according to current behavior.

①Formalized description of context factors

The independent variables of context model g are the data that sensors access and users input. The form of data is maily numerical value and informal description, and the number of independent variables may be very large or very small. It is necessary to convert to the form which meets the requirements of the context description. Such as, convert the time value to the period of time (ex. convert at 11:30 to lunch time); convert the weather and traffic crowded information into the driving speed information, and so on. This kind of transformation is close to the specific context and the regular knowledge of human behavior in the context, requiring the support of knowledge base of Ho-Lo map. Of course sometimes, the independent variables can't be converted to corresponding, normalized, descriptive information. For example, to the user's taste preferences, it's ok to describe using Sichuan cuisine or Guangzhou cuisine, as well using fresh, salty, sweet, spicy tastes and so on. This requires relationship computation according to semantic similarity, in order to meet the cartography's need.

To make the context description satisfied with the requirements of following relation computing and expression templates selecting, we need to organize the context factors according to certain logical form. For different contexts, the basic factors needed to be described and the roles of the various factors in the process of reasoning are different. So this article defines an abstract description method of context factors, which has the characteristics of openness, self-descriptive and formalized.

The formalize description of context can be described as:

$$C_1 = \{TYPE(M), NAME(n), SUB(num|S_1, S_2, \dots \dots, S_{num})\}; \tag{9}$$

$$S_1 = \{TYPE(L), NAME(n_{s1}), VALUE(v_{s1}), POWER(p_{s1})\}; \tag{10}$$

In the above formula, C_1 are the description styles of context factors which have sub-items; S_1 are the description styles of situational factors which have no sub-items.

Telling from the form, the above description way converts the context factors into tree structure. The nodes and depth of the tree are all alterable, and it suits the different demands of description in different contexts.

②Logical reasoning between behaviors

In the process of modeling and reasoning, people behaviors are the key. As the abstract tools for interpreting the close connection between the objective world and people behavior, activity theory solve effectively the hard problems in context information communication and sharing through action layering. Combining with the particularity of Ho-Lo map, this article constructs the following behavior related models:

Suppose one context can be divided into n behaviors, there are m contextual factors affecting these behaviors. Set the action as A, contextual information as C, the behavior related model a is expressed as follows:

$$\mathrm{a} = (\mathrm{A}, \mathrm{C}, \mathrm{r}); \tag{11}$$

Here, $A = (A_1, A_2, \ldots\ldots, A_n)$, $C = (C_1, C_2, \ldots\ldots, C_m)$. r represents the relationship between the elements in A. Picture 1 describes the logic structure of behavior reasoning.

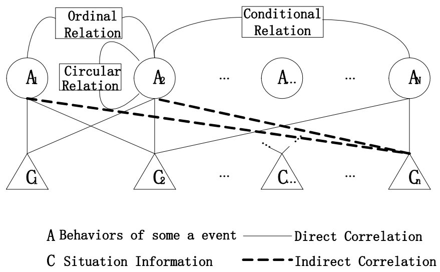

Figure 1. The logic structure of behavior reasoning.

3.3.2 The relationship computational model of Ho-Lo map

Formula 7 above, function or process u will calculate the relationship of features in T based on reasoning results of context, and choose a collection of features which meet the requirements of g.

Features relationship in T are divided into two categories: one is spatial relationship which mainly lies on features' geometry data; the other kind is the semantic relation which mainly lies on features' attribute data.

Therefore, the function or procedure can be expressed as follows:

$$\mathrm{u} = \left(\mathrm{u}_{\mathrm{spa}}(\mathrm{T}), \mathrm{u}_{\mathrm{sem}}(\mathrm{T})\right); \tag{12}$$

①Computation model of spatial relation

To Ho-Lo map, the purpose of spatial relationship computation is to extract the features within a certain spatial and directional range. The features mainly reflect Euclidean distance and direction relation between features and location of users, viz.:

$$u_{spa}(loc, T_i) = \{\, T_i \mid dis\,(T_i, oc\,) \leq \delta, \alpha \leq dir\,(T_i, oc\,) \leq \beta, T_i \in T\} \tag{13}$$

Among them, loc is current user's location.

②Computation model of semantic relation

Semantic relation $u_{sem}(T)$ can be used to select features according to matching degree of the features attributes and contextual demands. That means semantic similarity computation based on the knowledge database of Ho-Lo map.

Calculative process of the semantic relation is as follows:

- Make the description $D_1, D_2, D_3 \dots\dots$in the context correspond with Objects' attributes $A_1, A_2, A_3 \dots\dots$;

- For each attribute, compute similar degree $S_1, S_2, S_3 \dots\dots$ between attributes and context demands.

$$S_1 = \alpha \times DisSim(D_1, A_1) + \beta \times DepSim(D_1, A_1) + \gamma \times ConSim(D_1, A_1); \tag{14}$$

Among them, $DisSim(D_1, A_1)$ is semantic distance; $DepSim(D_1, A_1)$ is node conceptual depth. $ConSim(D_1, A_1)$ is semantic overlap ratio.

- Sort and valuate weights for each attribute, and a weight matrix is obtained:

$$E = [\alpha \quad \beta \quad \gamma \quad \dots](\alpha + \beta + \gamma + \cdots = 1) \tag{15}$$

- Compute semantic similarly for the whole question:

$$S = \alpha S_1 + \beta S_2 + \gamma S_3 + \cdots \tag{16}$$

- Through calculation of semantic similarity of targets meeting the requirements of spatial relation, we can get a sorted sequence of similarity, which can provide quantitative basis for 'finding the most comfortable target'.

3.3.3 The representation model of Ho-Lo map

The above formula 7, function or process f will make the extracted elements mapped to graphic symbols of Ho-Lo map based on g and u according to different applications, contexts and users to achieve different maps display. Therefore, the expression model of Ho-Lo map should contain two parts:

① Semantic description of expression template

Give a normative explanation of basic constraint when designing the expression template. It can be described as:

$$\mathrm{M_1} = \left\{ \begin{array}{c} \mathrm{PURPOSE(p_1), STYLE(s_1),} \\ \mathrm{CONTEXT(num|time_1, place_1, people_1, event_1, device_1, \dots\dots),} \\ \mathrm{GEOFEATURE(num|geoType_1, geoType_2, \dots\dots)} \end{array} \right\} \tag{17}$$

Among them, $PURPOSE$ says the cartographic purpose of the template, such as navigation, POI display, information indicating etc.; $STYLE$ says the style of the template, such as the cheerful, sedate etc. $CONTEXT$ says the context's description which suits template. When there are some difference between the description and the context model, we still can find the similar degree between the templates and the contexts by calculation of semantic similarity. This method can avoid a large increase of expression templates because of the context slightly change. $GEOFEATURE$ says the geographic features expressed in this template and it is convenient to match the geographic features coming from relationship computation.

②The expressive template

It contains the instruction of expressive methods, methods of the data classification, symbol forms; visual variables, such as color, transparency, dynamic and static state, size etc.; and auxiliary tools when reading the map, and so on. The template design is closely related to the display engine, such as the data classification methods are corresponding with the methods provided by display engine.

3.4 The Knowledge database of Ho-Lo map

In the cartography model mentioned above, the establishing and arithmetic of context model, relationship computation model and expression model are all based on knowledge database. Therefore, knowledge database should contain at least three aspects (Figure 2):

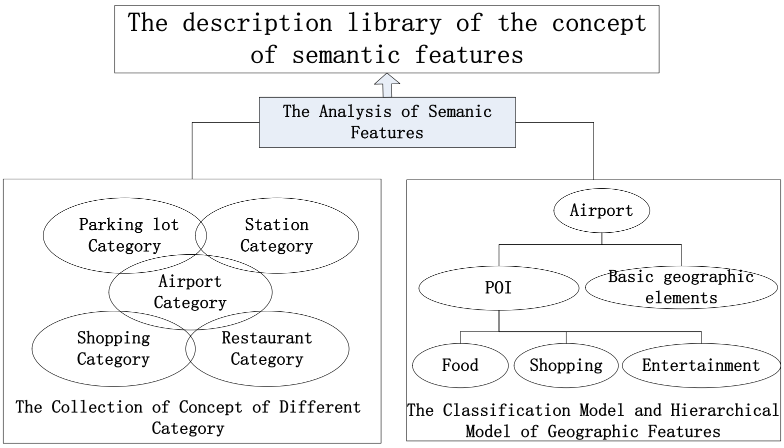

Figure 2. The knowledge database's structure of Ho-lo map.

①The conceptual collection of situations in different categories.

Ho-Lo map takes the relevance among people, events and things as map content, which will vary with the changes of context such as persons, locations, time, events etc. The change is due to variety of people thought essentially. Thus, only the concepts involved in people thinking are extracted, and the relevance among these concepts is established, can we meet the need of cartography. Human cognition is based on experiences, beginning with categorization and forming concept. Categorization is the basis of the category and concept. Therefore, we believe that Ho-Lo map should establish different categories of context collection based on prototype category theory. And in accordance with the far or near to central concept, a quantitative relationship can be established. These scenarios concepts and description of their quantitative relationship will become the fundamental basis for extracting the geographic information required for mapping.

Extracting context concepts and quantifying their relationship is the core and most difficult contents in the drawing of Ho-Lo map. We think context concepts should be constructed by top-down and bottom-up processes boundmutually . By means of questionnaire and talk to a sample of small number of people, the top-down process constructs concepts set and their relation. By analyzing the big data such as user path and user behavior in a certain place, the bottom-up process revises and supplies the above model. This process will continue in the real time cartographic process, in order to achieve the objective of constructing a whole context concepts set which complies with the rules of human cognition.

②Semantics aggregation model of geographic concept

The purpose of the knowledge database of Ho-Lo map is that we can reason out the geographic information and its means of expression needed in the mapping according to current context. Therefore, in the knowledge database, semantic aggregation model of geographical concept become the basic reference when selecting geographic information.

In this article, the geographical concepts are divided into basic geographic information and POI information according to the background and the subject, and then can be further divided into detailed aggregation relationship models. Semantic aggregation model of geographical concepts has a direct connection with the database of Ho-Lo map. Classification and coding mode of geographic data are based on this database.

③The description library of concepts semantic features

The above concept set of context makes it possible to find the largest correlated concepts set based on context information. But the concepts set of context can not be equated with geographical features. It is needed to establish incidence relation between the concepts set and semantic aggregation model of geographical concept.

From a cognitive perspective, the above concepts set reflect the cognitive mode of common users. But semantic aggregation model of geographical concepts partly reflects the cognitive mode of geography information professionals. The two models are not equivalent.

Therefore, we need to draw lessons from the theory and technology of ontology modeling method, establish the concepts set of context and the semantic features of geographical concept, and form the semantic features database to provide the basis for computing semantic similarity.

4 The Example of Ho-Lo map mapping

4.1 The cartographic process of Ho-Lo map

According to the above cartographic model, this article makes the cartographic process of Ho-Lo map specific. The process is a dynamic mapping information transfer process, which a previously established model as its foundation, real-time reasoning and calculation as its core (Figure 3).

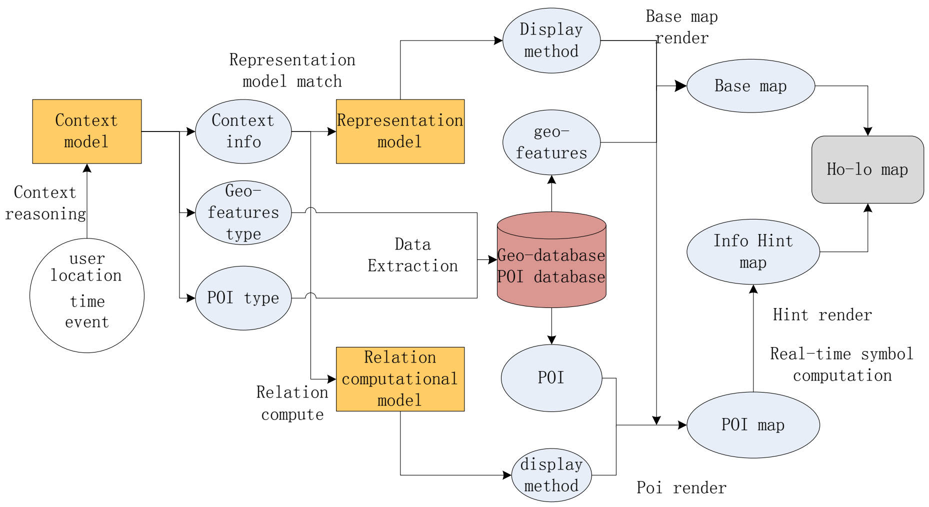

Figure 3. Cartographic process of Ho-Lo map.

In the pre-modeling stage, according to the specific application, establish context model, calculation model and expression model of Ho-Lo map. And each model should be abstracted from the real world to abstract concept, and then the concept is formalized to digital expression. In the real-time drawing stage, its process is as follows:

①Current information such as user, location, time and event as the input, through the reasoning process of context, find the matching context from the context models, so as to obtain the formal description of current context.

②According to formalized description of current context, obtain geography features by relationship computational model.

②According to required geography features, extract corresponding data from Ho-Lo map geographic database.

③Make the formal description of the current context as input to match cartographic express model of Ho-Lo map, in order to obtain map expressive template.

④Drawing base map of Ho-Lo map according to expressive template.

⑤ Make the formal description of the current context as input to relationship computational model, and obtain POI features.

⑥According to required POI features, extract corresponding data from Ho-Lo map POI database.

⑦Drawing thematic map of Ho-Lo map according to expressive template through real-time symbolic computation.

⑧Integrate the base map with the thematic map and eventually we can get a full holographic location-based map.

In the above process, there are many procedures of the transfer of cartographic information, which proposes the severe challenge to the real-time making of Ho-Lo map.

4.2 Cartographic example of Ho-Lo map in the context of airport.

① Establish the knowledge database of ho-lo map

- According to prototype category theory, establish a collection of concept of basic scenarios.

Conduct a survey of 13 people in the way of questionnaires and talking. Through extracting the concepts in the result, collection of concepts and their relationships are initially formed in airport category(Fig 4).

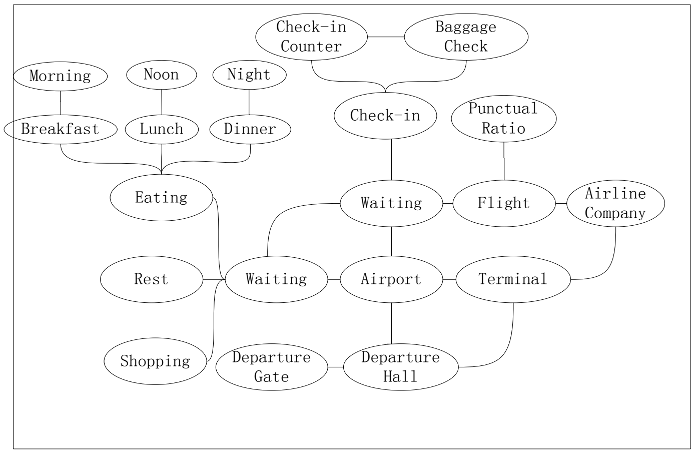

Figure 4. Collection of concepts in airport category.

- Establish classified model of geographical features in airport(Fig 5).

Confirm geographical features classified model of airport according to the relevant standards.

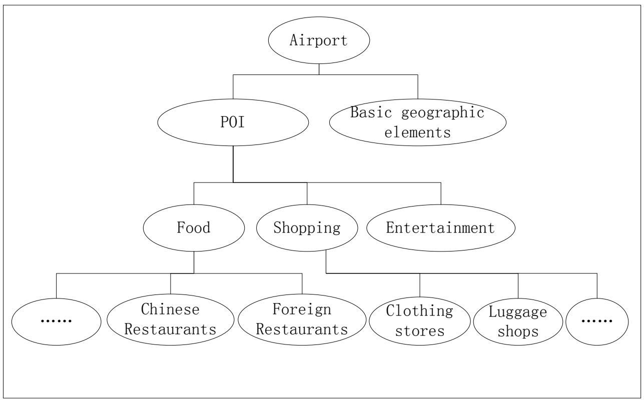

Figure 5. Classified model of geographical features in airport.

- Analyze semantic characters of concepts and classification mentioned above.

Analyze the semantic characters of concepts in the category using "Ontologic level" concept presented by Guarino, etc.

Ontologic level	Type	List of semantic characters
Social level	property	Military, civil, all
Social level	Arrival region	International, internal, provincial,

		extensional
Social level	rank	VIP、common、first-class、business class、tourist class、……
Functional level	function	Waiting, rest, food, shopping, medical, treatment, register, check……
Static level	reference	number of persons, speed, punctual rate, delay rate, number of departure gates, ……
Static level	state	open, stop, damage, close, …..
atic level	space-time information	Time, location, floor, ……

Table 1. Semantic characters of concepts in the category using "Ontologic level"

For example, when analyze semantic characters of the concept ‘airport lounge’, we can get formalized description as follows:

<airport lounge> ::= <civil> | <domestic> |< common > |< waiting > |< 1000 persons > |< open>.

② Compute context description by sensors’ information and users’ input.

Let the information acquired by sensors as a time of 11:30, the place as relative coordinates in some coordinate system. The information corresponds to the airport lounge and user Mr. Zhang, who will take the plane flying off at 2:30 pm to Beijing.

According to context model, calculate and reasoning the formalized description of the context (taking the description of time, place as example):

$$C_1 = \{TYPE(comp), NAME(airport\ ), SUB(3|T, P, U)\};$$

here, $T = \{TYPE(comp), NAME(time), SUB\left(2\middle|T_p, T_l\right)\};$

$$T_p = \{TYPE(ind), NAME(period\ of\ time), VALUE(midday), POWER(0.5)\};$$

$$T_l = \{TYPE(ind), NAME(remain\ of\ time), VALUE(2.5), POWER(0.5)\};$$

$$P = \{TYPE(comp), NAME(location), SUB(2|P_t, P_e)\};$$

$$P_t = \{TYPE(ind), NAME(type), VALUE(airport\ lounge), POWER(0.7)\};$$

$$P_e = \{TYPE(ind), NAME(func), VALUE(rest), POWER(0.3)\};$$

③ Calculate appropriate geographic features according to the description of context.

According to the keywords described in the context, such as ‘midday’, ‘airport lounge’, ‘rest’, etc., we choose the closest concept in the category: eating. Then we calculate semantic similarity of the concept of eating and geography to find the appropriate geographic features type: eatery.

④ Select the appropriate expressive template to mapping according to the description of context and semantic description of expression template

Select the expressive template which semantic description is similar to the semantic of the words ‘midday’, ‘airport lounge’, ‘rest’, and draw the map in accordance with the expressive template.

5 Conclusions

Ho-lo map is a new type of map which is constructed based on mobile internet. Compared with traditional map, it has significant differences in drawing objects, drawing body, drawing patterns and drawing technology.

Firstly, it is a kind of dynamic thematic map which regards the correlation, associated with persons, events, things based on human behaviors as its core. The representation contents of Ho-lo map are varying with user, environment, location and time.

Secondly, in order to achieve generated real-time, used once (Yan et al. 2006), the drawing objects of Ho-lo map is changed from experts to mapping system which having certain intelligent processing capabilities and supporting real-time mapping.

Thirdly, only the cartographic mode of Ho-lo map is from static to dynamic, and then to real-time, it can meet users’ demands in the process of moving. This change will lead to many changes in cartographic techniques.

By studying the cartographic model of Ho-lo map, this article reveals basic process and dynamic mapping procedure from theoretical level. However, the mapping process of Ho-lo map requires highly real-time and dynamic, and its drawing foundation is knowledge database. These put forward higher cartographic preparation request to Ho-lo map

Therefore, based on the cartographic model proposed in this article, the important task for the future is gradually improving and practicing to test each process of the model.

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Indoor Position Method Using Wi-Fi

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Abstract. The main objective of this paper is to present an indoor position method, developed for museums and hospitals, in order to known the position of persons and equipments. The method is composed by a particle filter algorithm to be embedded in smartphones or tags. The main goal is to develop a light method to run by not very powerful microprocessors, energized by batteries. The position method presented is based on a Wi-Fi structure, to lighten the use of the communication network, the position is generated by each device from raw data received locally.

Keywords. Wi-Fi, fingerprinting, algorithm, particle filter

1. Motivation and Context

The work presented in this paper is an output from two projects, one applied to hospitals, in which the position of persons and assets is used to control the proliferation of infectious diseases. The intention is to find contacts, between persons and infer the source of a disease.

The other project is dedicated to museums, the position of the persons is used by an application to show and describe, to the user, the assets which are nearby namely statues and paintings.

The use of the Wi-Fi signal level, to obtain the position is a requirement from these applications, it is required that the position should be given by the technologies offered by smartphones. There are several component sensors embedded in a smartphone, that could have been used to determinate the position, besides the Wi-Fi, namely the Bluetooth, NFC receiver, camera and to improve the positioning the magnet sensor and the gyroscope.

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After short study it was chosen the Wi-fi, Bluetooth and the camera, for the museum application and only the Wi-Fi for the hospital. The museum environment relies on the assistance of visitors to use the smartphones, but in the case of hospital the user interaction should be minimal and the smartphones should evolve to tags. This paper describes only the method that was used with the Wi-Fi technology.

2. Introduction

This work uses the Received Signal Strength Indicator (RSSI) to infer the position, the RSSI is the radio signal power present at the receiver at a distance (d) from the transmitter. In general the RSSI decreases proportionally with the distance [1][6], if the relationship between the signal level and the distance is known, it is possible to deduce the distance between two devices. The advantages of using the RSSI with radio technologies like Wi-Fi, is that it requires no hardware changes and the functionality of reading the RSSI is offered by almost of the communication devices. The localization can be produced by simply adding software to the hosts and does not require any kind of synchronization between receiver and emitter. The main disadvantaged is the unpredictability of RSSI levels for most indoor situations, due to the phenomena of multipath and attenuation, derived from walls or other objects that are between the emitter and the receiver. These phenomena can be overcome with other techniques, if we consider that a group of sources generate a single vector of RSSI for each position it is possible to determinate a position by comparing two vectors.

2.1. Measuring principles

There are several methods to process the information given by the sensors, the main methods are; geometric methods, fingerprinting and the proximity methods.

The most common geometric methods are multi-lateration [2][1] using ToA/ToF (Time of Arrival/Time of Flight), Round Trip Time (RTT), TDoA (Time Difference of Arrival)[5] or RSSI, with these methods the target location is estimated by measuring its distance from multiple reference points.

In the case of ToA/ToF the distances are given by the travel time between synchronized transmitter and receiver devices. Having into account the speed of the light, the receiver can find the time of arrival by subtracting the time at which the signal was transmitted from the time at which the signal was received.

For the RTT method [2] the time taken by the signal to travel from a transmitter to a receiver and back is measured. RTT avoids the need for time synchronization between the transmitter and the receiver, allowing its application in uncoordinated mesh networks with the advantage of low complexity and cost. The TDoA uses the time difference of arrival between multiple synchronized transmitters measured at the receiver.

The use of the RSSI in multi-lateration is based on the principle that the RSSI decreases with the distance, but in practice there are many other factors that make this method impracticable in most indoor situations. In (1) is described the model Log-distance Path Loss, in this model the received power (dBm) at a distance d (in meters) depends on the distance d, the path loss exponent α, and the power receive at 1 meter from the transmitter. X_σ represents a Gaussian random variable with zero mean and standard deviation of σ. The parameters α and σ define the statistical model and are heavily dependent on the environment [6].

$$Pr(d) = Pr_0 - 10\alpha log(d) + X_\sigma \qquad (1)$$

To implement an indoor system, with a minimum performance, these factors should be reflected in a huge central data base, requiring that the position is calculated in a central machine. This method also heavy for the local communication network that supports the positioning, the communication of the raw data from the targets to the central processing machine can became too heavy.

The proximity or Cell of Origin (CoO) [2][1] method is used to set the position of a target merely by its presence in a particular area, based on the RSSI. The procedure consists in simple forwarding the position of reference point where the strongest signal is received. The accuracy of CoO is dependent on the density of references and signal range. CoO is a simple positioning method used for applications with low accuracy requirements.

The fingerprinting is a method [1][2] that maps the measured data, example the RSSI, the magnetic field, audio signal or images, to a known grid-point covering an area of interest. Typically it consists of two phases, in the first phase, the RSSI received from fixed stations are measured at a number of grid-points and added to a database. In the operation phase the current measured RSSI are compared for the best agreement with a database.

2.2. Location Estimation Algorithms

This paragraph summarizes some of the methods commonly used to infer location from RSSI measurements.

K Nearest Neighbor Method (kNN) [2]. The nearest neighbor methods are deterministic algorithms they require only a set of constant location fingerprints which includes mean and standard deviation vectors of RSSI. The kNN method uses the RSSI to search for k closest matches of known locations in signal space from a previously-built database according to root mean square errors principle.

The probabilistic approach models a location fingerprint with conditional probability and utilizes the Bayesian inference concept to estimate the target locations. This approach presumes a priori knowledge of the probability distribution of the target's location.

An exmaple method considers positioning as a classification problem. Assuming that there are n location candidates L1, L2,...,Ln and Y is the observation vector, the following decision rule can be obtained[5]:

If $p(Li \mid Y) > p(Lj \mid Y)$, for i, j=1,2, . . . , n , $j \neq i$. choose Li (2)

Here, $p(Li|Y)$ is the posterior conditional probability, that the mobile is in location Li, given the observation vector Y. Also assumes that p(Li) is the probability that the target is in location Li .

Support Vector Machine Methods (SVM)[3][5]. To estimate the dependency between the RSSI fingerprint and the location from the observations, this approach does not require detailed properties of the dependency such as the propagation model as is in the probabilistic method. The strength of SVMs algorithm lies in its ability to generalize classification which minimizes the test error or the classification error for the data after the training period. The learning machine could be trained correctly by learning from a small training set and creating a sufficient structure for data classification without memorizing or over fitting the training samples.

This method particle filter is a powerful Bayesian algorithm. The particle filter robustness lies in the ability to handle non-linear system with non-Gaussian noise. The ability to incorporate a kinematic model of the moving target, in its probability model, makes this method a naturally suitable for sensor data fusion. The disadvantage is that it requires relatively high computational power.

2.3. The Location Fingerprint

A fingerprint based on RSSI is the basis for representing a unique position or location. It is created under the assumption that each position or location vector ($\mathcal{L}$), inside a confined area, has a unique signature $\mathcal{F}$[3]. The location and fingerprints are maintained in a database and used during the on-line phase to estimate the location. To create a data base of fingerprints, a number of sample vectors of RSSI are collected over a window of time for each position, 10 to 50 samples, from which is calculated de average value and the standard deviation for each AP. Extra fingerprint information such as standard deviation for each RSSI element, may be added into the data base fingerprint as another vector. For N access points, that can be heard at a location, a location fingerprint can be expressed as vector:

$\mathcal{F} = (\rho_1, \dots, \rho_N)$ (3)

Where each ρ_i is an average RSSI for the position location $\mathcal{L}$ for the APi.

The location vector and the standard deviation vector can be expressed as:

$\mathcal{L} = \{(x, y, z) | \, x, y \in \mathbb{R}^2, z \in \mathbb{N}\}$ (4)

$\mathcal{D} = (\sigma_1, \dots, \sigma_N)$ (5)

Each σ_i is the standard deviation RSSI for the position location $\mathcal{L}$ for the APi, (x, y, z) is the coordinate of a position inside the interest area, in meters for x, y, and z represents the floor.

Another approach to represent fingerprint information is to estimate the probability distribution of the $\mathcal{F}$ signature. This approach is referred to as the probabilistic approach since it is assumed that the location fingerprint is described by a conditional probability. The added element to location fingerprints is the probability distribution estimated for the RSSI signature at a given $\mathcal{L}$. The location fingerprint becomes a conditional probability distribution of the form P(Y| $\mathcal{L}$) where Y de notes the observation vector of RSSI at location $\mathcal{L}$.

3. The particle filter

This chapter describes the particle filter for localization as a Bayesian approach. In order to clearly describe the problem, some terms should be clarified. Target is defined as an entity (e.g.: object, person) from which the state is being estimated. State, is defined as the collection characteristics of the target (location, velocity, direction) and the measurements are the observed phenomena obtained from a sensor which carries information about the state, in this case de RSSI measurements. The particle filter estimates the target state, based on the observed phenomena or measurements.

The evolution of the target state and measurements, during localization, can be seen as statistical Hidden Markov Model (HMM). The parameter Xt describes the state, of target, at time t, X is hidden and cannot be measured directly. The parameter Yt depicts the measurement at time t, Y can be observed directly. One can only estimate the state X from the observed measurement Y.

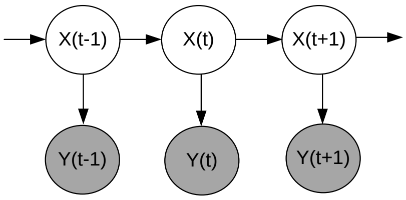

Figure 1. Representation of a Hidden Markov Model

The movement of the target state X_t and the measurement Y_t are defined by a discrete-time stochastic filtering model, composed by two equations the state equation and the measurement equation [7][1],

$$X_t = f_{t-1}\,(X_{t-1}, n_{t-1}) \qquad (6)$$

$$Y_t = h_t(X_t, e_t) \qquad (7)$$

The functions ft() and ht() are unknown, possible non-linear time varying functions, n_t and e_t are independent distributed noise.

A particle filter is an implementation of the formal recursive Bayesian filter using (sequential) Monte Carlo methods. It approximates the posterior probability to a finite number of discrete samples with associated weights, called particles. The particles are concrete instantiations of the state at time t, with the probability given by the weight ω_t^i. The posterior distribution of the state can be approximated by the (8) (when $N \uparrow \infty$), where X_t^i is the i-th particle, with 1<i<N, ω_t^i the weight of the particle i and N the number of particles.

$$p(X_t|Y_t) \approx \sum_{i=1}^{N} \omega_t^i \delta(X_t - X_t^i) \qquad (8)$$

The particle set is defined as χ_t.

$$\chi_t := X_t^1, \cdots, X_t^N \qquad (9)$$

The weight ω_t^i is called the measurement probability or the likelyhood observation probability, it is the probability of a state X_t^i that received the measurement Y_t. It is the probabilistic representation of $h_t(X_t, e_t)$.

The likelihood observation function $p(Y_t|X_t)$ or measurement model is an important part of the particle filter algorithm, this function should describe as accurate as possible the reality of the observation phenomena. In literature are some models that may suit an application, in this text we will reference just some simple models based on the distance between the signature vector $\mathcal{F}^i$ of the particle i and the measurement vector Y. The weight w_t^i should get larger as the measurement vector approximates to the signature vector [4].

$w_t^i = \frac{1}{||\mathcal{F}^i - Y_t||}$ (10)

Some examples of norms $||z||(z \in \mathbb{R}^{n_z})$ are:

$||z||_p = \left(\sum_{i=1}^{n_x} |z_i|^p\right)^{\frac{1}{p}}$ p-norm (11)

$||z||_{mp} = \left(\sum_{i=1}^{n_z} \frac{1}{w_i} |z_i|^p\right)^{\frac{1}{p}}$ modified p-norm (12)

$||z||_\infty = \max_i(|z_i|)$ infinity-norm (13)

Finally w_t^i is normalized making

$\omega_t^i = \frac{w_t^i}{\sum_{j=1}^{N} w_t^j}$ (14)

To estimate the target state location T_t, at t time, there are some methods based on the normalized values of ω_t^i and using the position location $\mathcal{L}_t^i$ vector, (14) and (15) are the two most used methods, other mixed methods may be used.

$\overline{T}_t = \sum_{i=1}^{N} \mathcal{L}_t^i . \omega_t^i$ mean value (15)

$T_t = \mathcal{L}_t^{\max_i(\omega_t^i)}$ location of the max ω_t^i value (16)

4. Application of the Particle Filter

4.1. The use of a probabilistic method

In order to improve the localization algorithm, it was chosen the probabilistic method, where the target and the particles of the filter are constrained by the following conditions. The particles can only travel inside of a map or network composed by nodes (where the particles are located) and connections that permit the particles to travel between nodes. This approach presumes a priori knowledge of the probability distribution of the target's location.

The figure 2 illustrates a network of nodes (in green), with connections between nodes (in red). The nodes are placed in positions where there is more probability to find a target and the connections are not placed randomly but enter in account the possible movements of the target. The particles are free to travel among any adjacent nodes, for each observation measurement, it means that $p(X_t|Y_{t-1})$ may have a probability of zero for most of the situations.

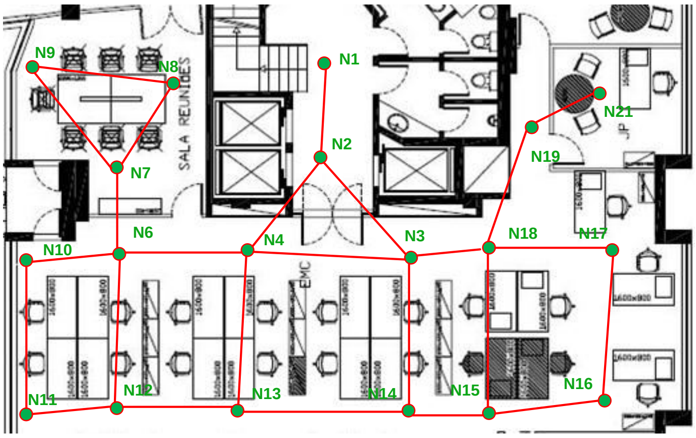

Figure 2. A network of nodes and connections

The network of nodes with fingerprinting introduces some extra variables to the process but eases the implementation of the algorithms and the complexity of the database of the fingerprinting. The network is composed by a fixed number of nodes, Nnodes, each node may have a number of cles, np_t^n at a given time t and to each node is attributed a weight W_t^n. The weight, W_t^n is dependent on the number of particles inside of the node and their weights. The nodes also have other attributes like the position in space and the signatures.

The fingerprint set is defined as Γ and is composed by N_{nodes} nodes.

$$\Gamma := \upsilon^1, \cdots, \upsilon^{N_{nodes}} \qquad (17)$$

Each node is composed by the following quintuple;

$$\upsilon^n = (\mathcal{L}^n, \mathcal{F}^n, \mathcal{A}^n, np^n, W^n) \qquad (18)$$

$$\mathcal{L}^n = \{(x, y, z) |\, x, y \in \mathbb{R}^2, z \in \mathbb{N}\} \qquad (19)$$

$$\mathcal{F}^n = (\rho_1, \dots, \rho_{NumberOfAP}) \qquad (20)$$

$$\mathcal{A}^n = \{(\wp^1 \dots \wp^{nbc}) | \wp^i \in \Gamma\} \qquad (21)$$

Where (18) is the quintuple representing the node υ^n, (19) is the location vector of the node υ^n, (20) is the fingerprint or signature vector and ρ_i represents the average value of RSSI for the APi, (21) is a group of pointers $\wp^i$, which point to the nodes connected to the node υ^n.

4.2. The motion model

The motion model is a representation of the target's kinematics behavior, it is used to construct the transition probability $p(X_t|Y_{t-1})$ which has an important role for the prediction step in the particle filter.

To introduce a motion model, the distance between the nodes, which is dependent on the observations sample frequency and the speed of the target, should be chosen. From practical tests it was found that a person can travel (indoors) at maximum 6m/s with a mean value of 3m/s, which requires that a system with a sample frequency, of the observed measurements, of 1Hz should have the nodes distanced of about 3m.

Another characteristic of this model is that the target can change direction instantly (in about 1s, corresponding to the sample rate) meaning that the motion of the particles have the same direction probability in all directions.

The figure 3 shows all possible movements of a target/particle in N1, it may stay at the same place or move to node N2 or to node N4, all other movements are forbidden for an observable measurement. The direction depends on the direction of the adjacent nodes and the speed on the distance between nodes and sample frequency. For a particle in N1 may have de speed of $v = 0$, $v = D1/T$ or $v = D2/T$ (where T is the period of sample)

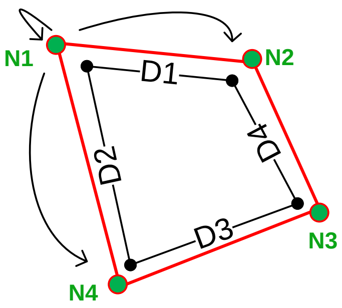

Figure 3. Movements of a particle at N1

4.3. Particle filter implementation

The algorithm (22) describes the implementation of a particle filter with the modifications and adaptations necessary to use with a network of nodes.

$(\Gamma_t, i_{maxW}) = \text{particlefilter}(\Gamma_{t-1}, Y_t)$ (22)

1: $\Gamma_t^* = \Gamma_{t-1}$ //use an auxiliary network of nodes

2: //assign zero to the number of particles and weight of the nodes of the auxiliary network

3: $np *_t^{1..N_{nodes}} = 0$; $W *_t^{1..N_{nodes}} = 0$

4: for $j = 1$ to N_{nodes} do //project particles

5: $np *_t^j = np_{t-1}^j$

6: for $i = 1$ to nbc do

7: $\wp^i.np_t * = \wp^i.np_t * + np_{t-1}^j$

8: end for

9: end for

10: $\Gamma_t = \Gamma_t^*$

11: for $j = 1$ to N_{nodes} do

12: if $np_t^j\,! = 0$

13: //assign weight to the nodes with the likelihood observation function

14: $W_t^j = p(Y_t|X_t) * np_t^j$

15: end if

16: end for

17: k=0;

18: for $j = 1$ to N_{nodes} do

19: $k = k + W_t^j$

20: end for

21: $Np = 0$

22: for $j = 1$ to N_{nodes} do

23: $W_t^j = W_t^j/k$ //normalize

24: $np_t^j = \text{round}\left(W_t^j/p_{min}\right)$ //resample

25: $Np = Np + np_t^j$

26: end for

27: $Np_{remain} = 1/p_{min} - Np$

28: $i_{maxW} = \max_i(\omega_t^i)$

29: $np_t^{i_{maxW}} = np_t^{i_{maxW}} + Np_{remain}$

30: return(Γ_t, i_{maxW})

This particle filter without the resample function would suffer from a degenerative problem, this happens when after some iterations, all but one particle would show a weight near zero. The resample is an important step of this algorithm, it will force the particles to be distributed according to $p(X_t|Y_t)$.

The (21) algorithm describes the implementation of the particle filter. In the first loop (lines 4-9) the particles are projected to adjacent nodes, according to the motion model defined by the sample frequency and the distance between nodes. The particles of each node have equal probability to move to the neighbor nodes, so the numbers of particles that exist in one node, are kept in the node and added to de adjacent nodes.

Then we have the prediction stage (lines 11-16) of the filter, it calculates the weight $p(Y_t|X_t)$ for each particle inside of the each node, so for the node n we have $W_t^n = p(Y_t|X_t) * np_t^n$. The weights W_t^n for each node are normalized (lines 18-26) based on the total weight K calculated adding all the W_t^i .

The resample is made with the use of the function $round(W_t^n/p_{min})$, this function transforms nodes with a weight superior to p_{min} into one or more particles, those particles that have a weight inferior to p_{min} simply disappear, from the nodes where they were. The particles that may have remained are added to the node with the highest W (lines 27-29) in this case the position of the target. Where $p_{min} = 1/\Omega$ and Ω is equal to a defined number of particles that should subsist in the network for the next iteration.

The function returns (Γ_t, i_{maxW}), the fingerprint set with new positions of the particles and the index of the node with the highest W, to be used as the position of the target, the target location is set to $T_t = \mathcal{L}_t^{i_{maxW}}$.

4.4. The measurement Model

The measurement model describes the process by which the likelihood observation function $p(Y_t|X_t)$ is generated. The likelihood observation function is generated having into account the measurement vector $Y_t = (\varrho_1, \dots, \varrho_{NumberOfAP})$ the state of the particles X_t^i and the fingerprinting vector or signature of each node $\mathcal{F}^n = (\rho_1, \dots, \rho_{NumberOfAP})$. The value of $p(Y_t|X_t)$ should decrease directly with the difference between the vectors fingerprint and measurement, $|Y_t - \mathcal{F}^n|$, where $NumberOfHeardAP \le NumberOfAP$.

$$||Y_t - \mathcal{F}^n||^2 = \sum_1^{NumberOfHeardAP} (\varrho_i - \rho_i)^2 \qquad (23)$$

$$W_t^n = p(Y_t|X_t) = \frac{NumberOfHeardAP}{||Y_t - \mathcal{F}^n||^2} * np_t^n \qquad (24)$$

From the likelihood observation function $p(\mathbf{Y}_t|\mathbf{X}_t)$, of the particles, it is deduced the weight W for each node, taking the number of particles of the node (n) at t.

5. Experimental phase and results

5.1. Development

This phase consisted in developing two applications in java, which permitted to test the position algorithm written in C++. The first application is used to generate the network of nodes over a plant, running in a PC. The output of this application is a plain text file referencing the nodes and the connections.

The second application was developed to be used in a smartphone, with the OS Android, which permits the user to select the APs that will be used, with the location algorithm, and to construct the fingerprint data base. This application is composed by a graphical interface, where the area of test is represented by a bit map with the network of nodes and connections, represented by circles and lines, see figure 4.

To implement the fingerprint data base, the user stars by positioning over a node and sets an event to start the readings of the APs (this event consists in just touch the node where the user is), these readings take about 10 to 15 seconds and make at least 10 sample, from which is taken the average value for each AP representing the signature for a node. This procedure should be done for all the nodes that compose the network. The figure 4 a) is a screenshot of this application, where it is shown the nodes (in blue and red). The red means that the user didn't created the signature for that node and the blue ones have already a signature.

After the constructing of the fingerprint data base the application is ready to run the position algorithm. The user sets the algorithm by pressing the button "Next" and the application enter in the positioning mode. The figure 4 b) shows the position found by the algorithm, represented by a blue dot, ideally this dot should follow the position of the smartphone.

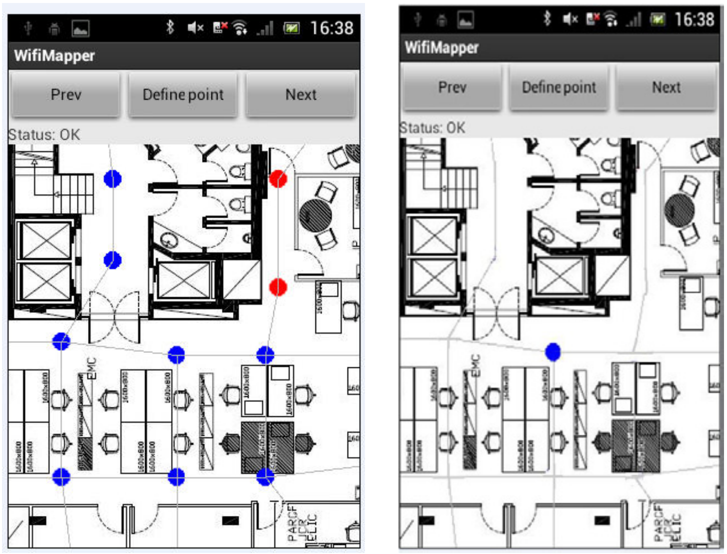

Figure 4. Screen shoots a) b)

5.2. Tests and results

For the test phase some constraints should be taken into account, regarding the filter and the environment. The input measurement vector Y_t is not the ideal, the body of the user forms a barrier to the radio waves and behaves as a source of noise. The other source of noise are persons that move around between the target and the APs, for a person that is positioned steady the measurement vector Y_t has noise associated that is not Gaussian.

The sample frequency of the measurement vector Y_t is not constant, the overcrowded number of Wi-Fi APs, make the readings of Y_t difficult and sometimes producing random a delays.

The variation of the sample frequency, the deterioration of the measurement vector Y_t and the velocity of the target may create some difficulties to the filter, it increases the error of the measured position and can make the filter to lose the position of the target, definitively. To overcome this last situation were created two instances of the algorithm. One instance is reissued every 10s (reset filter) and other is running continually (user filter). Having into account that the reset filter takes about 3 to 5 seconds to converge to the position of the target, after 5 seconds the reset filter target position is compared with the user filter target position. If the distance between the two is larger than a distance of one node, the state of the reset filter is copied to the user filter, with the new target position. Although this improves the performance of the filter, increases the processing load of the machine.

For the tests were studied two different situations, the static position and the dynamic position (it is considered “static position” a position that has more than 5sec). The performance of the static measurements are better than the dynamic measurements, in the dynamic measurements the algorithm presents a latency of about 1s or 2s representing a distance of 2 to 6 meters to be added to the static performance error.

The figure 5 is an histogram with the results of a test with the target statically positioned over a node and the adjacent nodes at 2,3 and 5 meters. The testes were made with 3, 4 and 5 APs, a number of less or equal to 2 AP were not used because the accuracy was shown be too poor for the applications requirements.

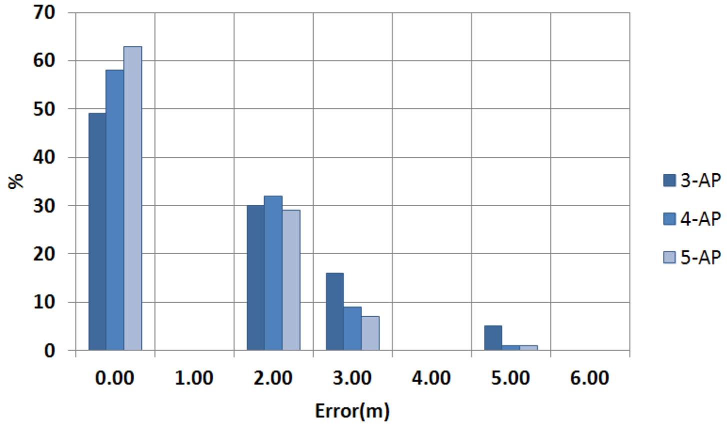

Figure 5. Histogram of the target positioned over a node

The figure 6 is a histogram with the target, statically positioned, at a distance of 2,3 and 5 meters from nodes 3 nodes.

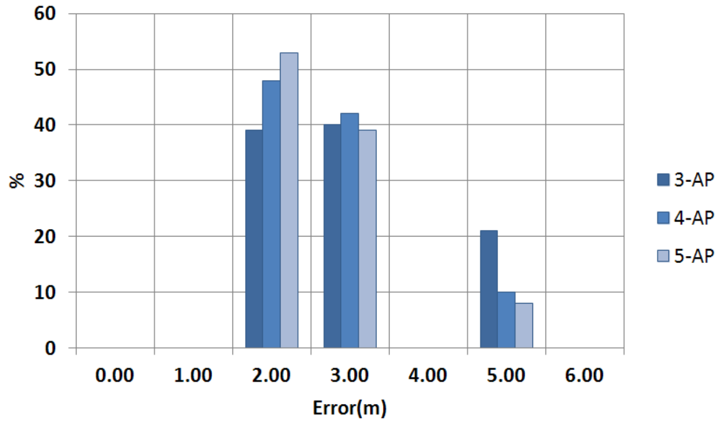

Figure 6. Histogram of the target positioned at 2 meters from a node

These resuslts are only indicative because the environment is critical to the performance of this kind of positioning. In small areas defined by brick walls like areas A and B, from figure 7, the performance of the algorithm is considerably better than in open space similar to area C. This happens because the small areas confined by brick walls produce signatures well defined and in open space the signatures are not so well defined, two nodes may have very similar signatures resulting in W_t^n almost equal for adjacent the nodes.

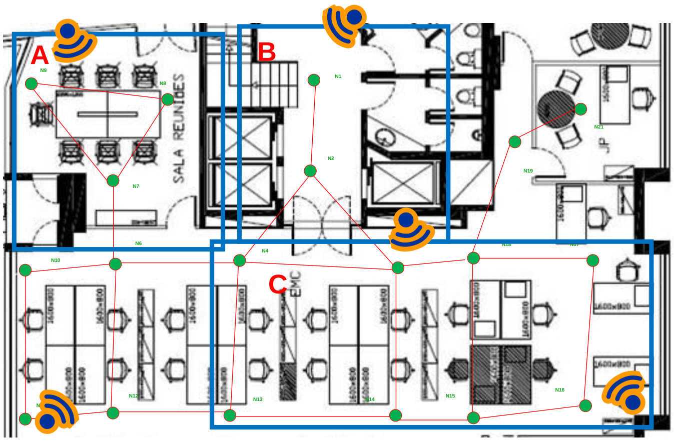

Figure 7. Test set-up with 5 APs

The distribution of the APs was also important for the accuracy of the system, it was verified that the APs should be placed around test the area. If the APs are placed internally to the area, mainly at the center or aligned, results in a poor performance.

6. Conclusions

The present approach presents an alternative to a particle filter that does not dependent on the number of particles but only on the number of nodes, improving the use of computation consumption. For the, measured position, were not used statistical algorithms to interpolate positions between the nodes, which would heavier the process. Taking into account the results of the work [8], which showed that similar positioning systems would have, at the best , an accuracy of 3 meters (for 80% of the samples), for that it is no use to represent an intermediate position. Having in consideration the required accuracy for the hospital and museum application the method shows a good performance.

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Study and Simulations of an Angle of Arrival Localization System for Indoor Multipath Environments

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Abstract. Present-day RF indoor localization systems generally underperform due to multipath propagation. This paper presents a new localization method based on Angle of Arrival estimation and ray tracing. This system exploits the reflections that are generally considered as a burden in conventional systems. In order to design the proposed system, a virtual test bench is created that enables adjusting all parameters. This test bench is then used to evaluate various antenna array elements. Also the Beamscan, MVDR, MUSIC and ESPRIT angle of arrival estimation algorithms are being tested and the effect of spatial smoothing is studied for each of these algorithms. The tests demonstrate that directional microstrip patch antennas result in the best array response for the proposed system and that spatial smoothing is indispensable in multipath environments.

Keywords. Angle of Arrival, Antenna array, Localization, Multipath

1. Introduction

In modern network applications, information on the location of persons and objects is very valuable. Several indoor positioning systems are commercially available, but they generally underperform and require expensive installations that need ad hoc tuning (Hui et al. 2007). Most of these systems are based on Received Signal Strength (RSS) measurements of electromagnetic signals, relying on the decreasing signal strength with increasing distance. Other systems use Time (Difference) Of Arrival (T(D)OA) technology, measuring the travelled time of the signal. However, these technologies suffer from reflections, scattering, diffraction and fading in indoor multipath environments, where line-of-sight connections are scarce

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(Sayed et al. 2005, Seybold 2005). In this paper, a new kind of indoor positioning system is proposed that exploits the reflections of electromagnetic waves in indoor environments. The considered system consists of a phased antenna array at a fixed location in a room and a mobile omnidirectional transmitter. The array is used for Angle Of Arrival (AOA) estimation of the received signals with beam forming techniques (Munoz et al. 2009). With this information and a detailed map of the environment with its reflecting obstacles and the position of the antenna array, ray tracing algorithms can determine the actual position of the mobile transmitter. Unlike T(D)OA or RSS techniques, the proposed technique could even enable accurate indoor positioning in non-line-of-sight situations.
In order to develop the proposed system, the influence of all design parameters on the system performance should be evaluated in a reference environment. This paper presents the first results of this evaluation with a virtual test bench in computer simulations.
This paper is organized as follows. Section 2 details the system setup and all the configurable parameters. Section 3 explains the tests that were carried out and the performance of the system in different configurations. Section 4 contains the conclusions and future work.

2. System setup

2.1. Proposed system

Figure 1 represents a basic configuration of the proposed system. It consists of a rectangular room with a mobile omnidirectional transmitter. A receiving antenna array is positioned in a corner of the room. It is positioned under an angle of 45°, so all signals impinge under an angle of -45° to +45°. Due to this restriction of the field of view, a higher accuracy and/or resolution can be achieved, as discussed in (Van Trees 2002). Figure 1 depicts a situation in which a line of sight signal is received by the array, together with two first order reflections. In order to detect D signals, the array should consist of M elements, with M>D (Chen et al. 2010). When the directions of these signals are determined with an AOA estimation algorithm, the location of the transmitter can be traced back with ray tracing techniques. In order to dimension this system, a virtual test bench was designed as detailed in section 2.2.

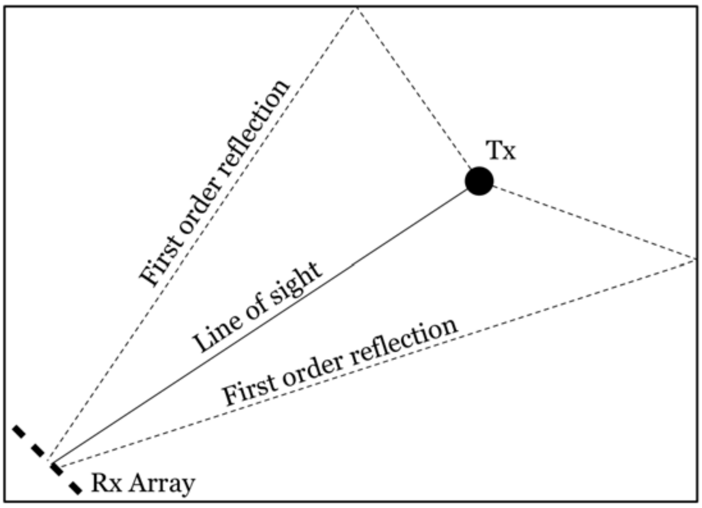


Figure 1. Proposed system architecture

2.2. Virtual test bench

In the first phase of testing and dimensioning the system, the antenna array and AOA estimation algorithms are simulated in order to evaluate their behavior in different configurations and for different incoming signals.

The model of the antenna array features a uniform linear array with an adjustable number of array elements and adjustable inter-element spacing and operation frequency. In standard configurations, frequencies of 2.4 GHz or 5.8 GHz are chosen because this simplifies future hardware implementations, given the commercial availability of components for these frequencies. Furthermore, this results in a feasible array size for indoor use. Standard inter-element spacing is $\lambda/2$ to prevent grating lobes (Van Trees 2002). However, inter-element spacing can be adjusted if a smaller field of view is allowed. The elements themselves can also be defined by inserting their radiation pattern. Currently tested options include an isotropic radiator, a half-wavelength dipole, a wavelength dipole and a directional microstrip patch antenna.

Apart from setting these array parameters, it is also possible to define multiple impinging signals by their angle of arrival, signal strength and delay. These inputs can be coupled with the outputs of a ray tracing algorithm, but this is considered as future work. In standard simulations, the signal is defined as a carrier with a certain signal power, attenuated by a free space loss that is calculated from the travelled distance, and an extra loss due to reflections at material boundaries. Apart from these signals, a noise source with selectable noise power (standard −75 dBm) is included. The resulting signals are combined and sampled at each array element, taking the radiation pattern of the elements into account. The data that is obtained in this way, can then be processed by an AOA estimation algorithm. The implemented algorithms include non-parametric methods, such as the Minimum Variance Distortionless Response (MVDR) or Capon method, and the Beamscan method (Munoz et al. 2009, Van Trees 2002). Parametric methods that were implemented, include the Multiple Signal Classification (MUSIC) algorithm (Spielman et al. 1986) and the Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT) algorithm (Roy & Kailath 1989). In order to improve the performance of these algorithms, a technique called spatial smoothing was implemented for these algorithms. This technique improves AOA estimation of correlated sources, which is useful in multipath environments where reflected signals are highly correlated.

3. Simulation results

In order to develop the proposed system, the influence of the design parameters is investigated with the help of the developed virtual test bench. This paper shows how various array elements influence the array's response. Also the performance of the AOA algorithms is investigated, as well as the influence of spatial smoothing.

3.1. Array elements

In the virtual test bench, standard simulations are performed with isotropic radiators as array elements. The response pattern in the 0° elevation plane for such an array with 10 elements, steered at 0° azimuth, is shown in figure 2. It is clear that the array response is symmetric along the -90° ... 90° azimuth axis, which means that no distinction can be made between signals arriving on the front and the backside of the array. This is a very unfavorable situation, since all signals impinging on the front of the array will also reflect against the wall and impinge again on the backside, given that the array is located in a corner of the room, as visualized in figure 1. The same response pattern is obtained in the 0° elevation plane when the isotropic radiator is replaced by a (half) wavelength dipole.
In order to solve this problem, the array elements are defined as directional microstrip patch antennas. The resulting array response in the 0° elevation plane is depicted in figure 3. This configuration is not sensitive to signals arriving on the backside of the antenna. Also, the array is less sensitive to signals arriving at more than 45° from the 0° azimuth axis. This characteristic is not disadvantageous in the given configuration, since the field of view is defined from -45° to 45° azimuth.
We can conclude that the use of directional microstrip patch antennas is the best of all considered options, given the insensitivity to signals arriving on the backside of the array.

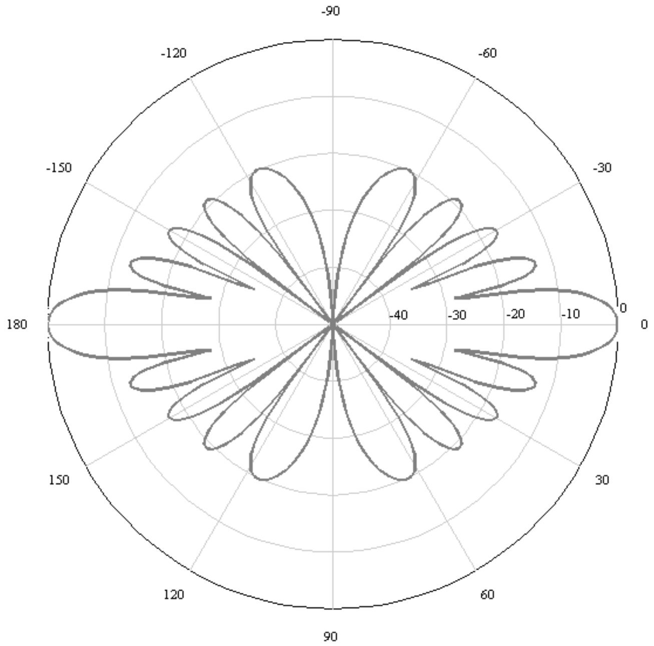


Figure 2. Response at 0º elevation for array with isotropic elements, steered at 0º azimuth

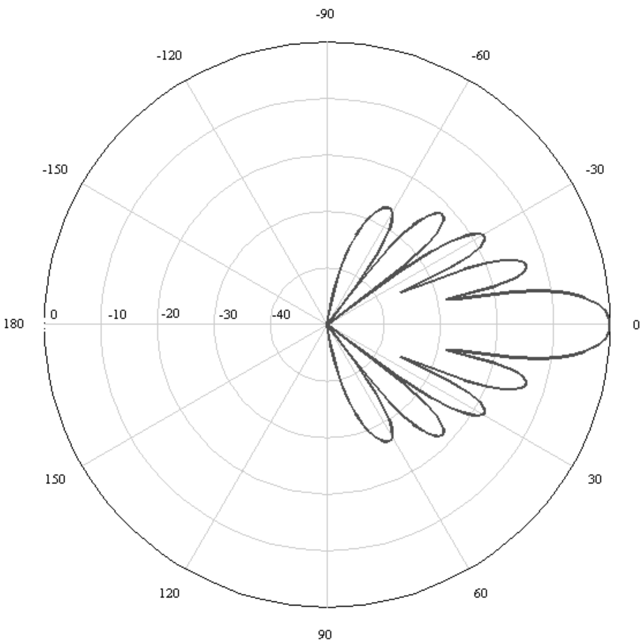


Figure 3. Response at 0º elevation for array with directional microstrip patch antenna elements, steered at 0º azimuth

3.2. Performance of AOA algorithms

The test bench includes 4 AOA algorithms in order to determine the directions of incoming signals. However, the performance of these algorithms degrades when signals are correlated (Van Trees 2002), which is the case in indoor environments, where multiple (reflected) signals descend from the same source. Spatial smoothing can be applied in order to decorrelate the signals, but one has to remark that every decorrelation is equivalent to reducing the array with one antenna element. This results in one less signal that can be distinguished.

In order to test the AOA algorithms, a setup was configured in the test bench, with a direct signal impinging at 10° azimuth and a reflection at -30° azimuth. The goal of this test is to compare the performance of the AOA algorithms, with or without spatial smoothing.

Table 1 displays how much the reflected signal can be attenuated, compared to the direct signal, while still enabling a correct AOA estimation.

	Beamscan	MVDR	MUSIC	ESPRIT
No spatial smoothing	-5.2 dB	-5.5 dB	-	-
Spatial smoothing	-6.6 dB	-53 dB	-63 dB	-55 dB

Table 1. Attenuation of the reflected signal that still results in a correctly estimated AOA

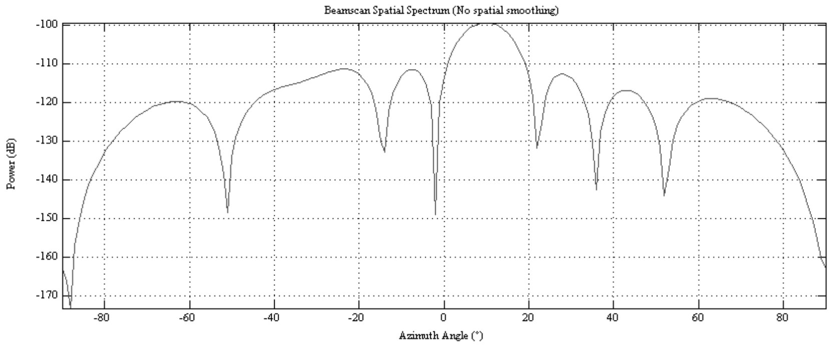
The table shows that the MVDR algorithm performs best of all when no spatial smoothing is applied. A reflection can be attenuated up to 5.5 dB and still be detected. The parametric methods (MUSIC and ESPRIT) exhibit a different behavior. When no spatial smoothing is applied, they cannot correctly determine the AOA of as well reflected as direct signals.

When spatial smoothing is applied, the performance of the algorithms is generally increased dramatically. The high resolution parametric methods function precisely, even with strongly attenuated reflected signals. Only the Beamscan algorithm shows a minor performance improvement.

These results are further demonstrated in figures 4 and 5. These figures display the spatial spectrum for the Beamscan and MVDR algorithm, without and with spatial smoothing. The largest peaks in these spectra represent the AOA and should therefore be located at -30° and 10°. Parametric methods are not represented because they don't use spatial spectra.

Figure 4 shows that a 5.2 dB attenuated reflection is nearly undetectable without spatial smoothing. But when spatial smoothing is applied, the -30° peak becomes more pronounced. Figure 5 shows a more apparent influence of spatial smoothing for the MVDR algorithm. Not only do peaks in the spatial spectrum become more pronounced, they also narrow, enabling more precise AOA estimation.

(a)



(b)

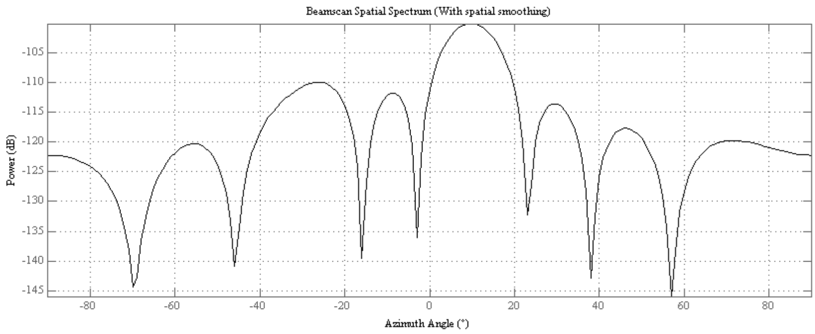


Figure 4. Spatial spectrum for Beamscan algorithm without (a) and with (b) spatial smoothing

(a)

(b)

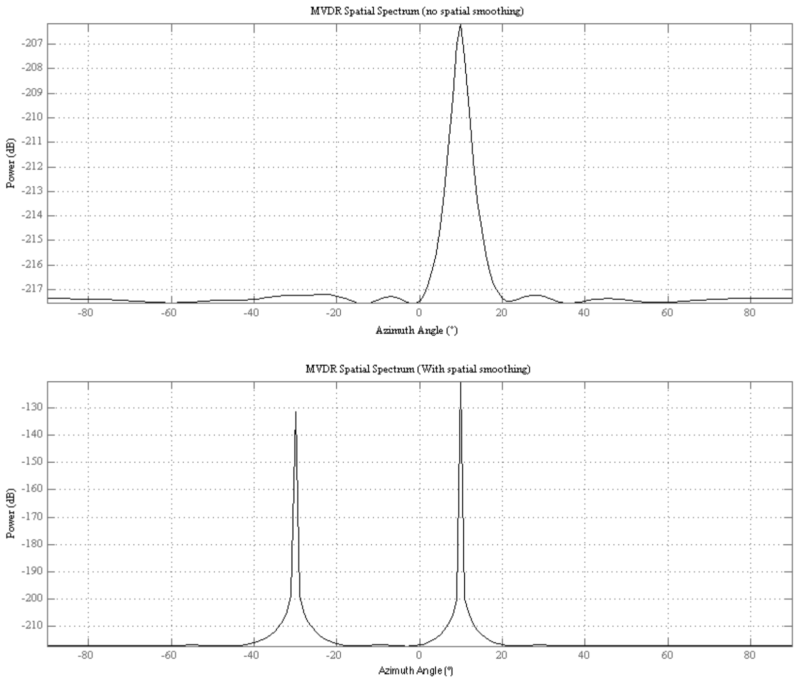


Figure 5. Spatial spectrum for MVDR algorithm without (a) and with (b) spatial smoothing

4. Conclusions and future work

A new type of indoor localization system that exploits reflections in multipath environments was proposed. A virtual test bench was created in order to evaluate and lay down system parameters. This test bench was then used to evaluate various antenna array elements. A directional microstrip patch antenna showed to be the most appropriate option, since it eliminates the array response at the backside of the array. Also the performance of different AOA algorithms was investigated, with or without spatial smoothing. It was shown that MUSIC and ESPRIT underperform in multipath environments when spatial smoothing is not applied. MVDR performs well with spatial smoothing and without this technique, it still exhibits the best results. Furthermore, the value of spatial smoothing in combination with the Beamscan algorithm appears limited.

Future work involves the investigation of other design parameters (e.g., the operation frequency, inter element spacing, signal waveform,...). Afterwards, the current test bench will be coupled with a ray tracing algorithm, enabling total system simulations. These results can then be verified in practical tests. Also the integration in existing wireless networks will be investigated.

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A proposal for obtaining 3D tracks based on multiple non-geodesic GNSS.

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Extended Abstract

With the increasing number of mobile phones and other devices with GNSS capabilities, the number of geopositioned information is growing (Oxera, 2013). This geopositioned information is not obtained only about points of interest but related to other activities like walking, trekking, etc, a great number of applications to use these geocapabilities has been developed creating a great opportunity for benefits (Henttu et al., 2012). However, the data captured using these low cost GNSS devices (integrated or standalone) has not high positional accuracy. For this reason, several techniques to combine multiple tracks have been developed (Lima and Ferreira, 2009). All these techniques are developed in two dimensions and use different approaches to remove outlier points (Long and Trisalyn, 2013). A brief review of the parameters and values used to remove these outlier points can be seen in Table 1.

Authors	Parameter	Values	Action
Agamenomi et al. (2010)	Delta time	3 seconds	Split track
	Maximum distance from other tracks	100 meters	Discard point(s)
Cao and Krumm (2009)	GPS Precision (deduced from minimum attractor distance)	5 meters	No action
Fathi and Krumm (2010)	Maximum delta time	10 seconds	Split track
	Speed	5 – 90 mph (8 -145 km/h)	Split track
	Distance between points	5 meters	Points interpolated to 5 meters

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Authors	Parameter	Values	Action
Lima and Ferreira (2009)	Minimum number of satellites	5 satellites	Discard point
	Maximum delta of time	7 seconds	Split track
	Minimum distance to trace (Douglas-Peucker Algorithm)	1 meters	Discard all intermediate points
Liu et al. (2012)	Maximum speed	180 km/h	Discard last point
Niehöfer et al. (2010)	Minimum distance between points	5 meters	Merge point below threshold
	Maximum speed	200 km/h	Discard last point
	Acceleration	4 m/s^2	Discard point
	Direction change	Function depending on velocity (not specified)	Discard last point
Zhang et al. (2010)	Maximum speed (highway/urban)	250 / 100 km/h	Discard last point
	Maximum distance	300 meters	Split track
	Maximum direction change	45º	Split track

Table 1. Filtering criteria as indicated by different authors (Own preparation).

As the previous table indicates, there are different criteria and different actions applied, even if the same criteria are employed. This is the reason that has leaded us to analyze the correlation between parameters and how these parameters interact with the resulting tracks.

Following that, in this work, we propose a methodology to create a set of 3D filtered tracks from raw GNSS position data using different parameters and adjusting them to reduce correlation and handle differences between two and three dimensional data. The followed methodology can be briefly defined by these stages:

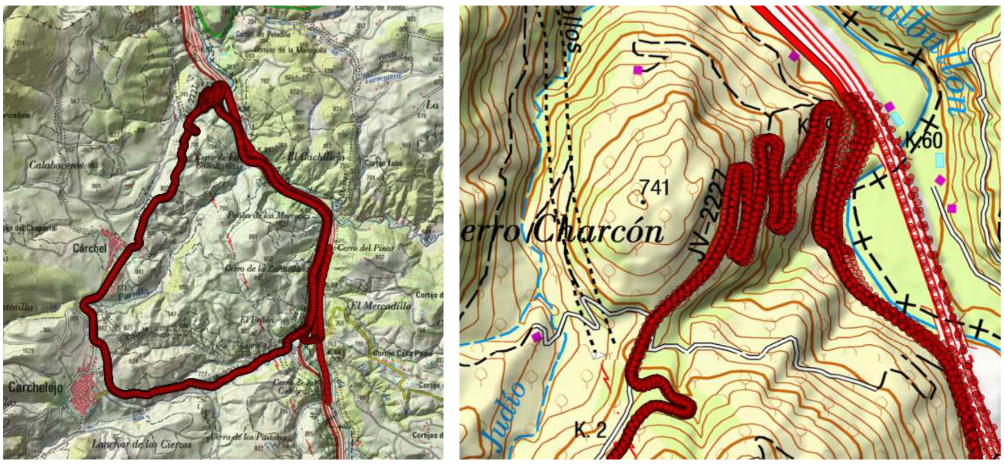
1. Extract points and attributes from captured tracks of GNSS.
2. Order these points by timestamp to create a time sequence.
3. Enrich information by determining new attributes like distance from previous points to the next, angularity of the displacement vector, etc. in a 3D space.
4. Remove points with no additional information, e.g. points captured while user is stopped.
5. Filter the points using approaches of Agamenomi et al. (2010), Cao

and Krumm (2009), Lima and Ferreira (2009), Liu et al. (2012) and Zhang et al. (2010) but having different thresholds for ascending and descending parts of the tracks, for sinuous parts of the track, etc.

6. Reconstruct tracks using algorithms based on Fathi and Krumm (2010) and Cao and Krum (2009)
7. Maintain continuity of aligned tracks.

The methodology have been tested using several approaches to create tracks from a set of low cost GNSS devices and compared to another GNSS data that have not been used as a surveying system. The set of low cost devices are three standard datalogger GPS with up to 1.5 meters precision (as described by manufacturer) and a frequency of 1Hz. While the other surveying system is a Racelogic VBox GPS with DGPS correction deactivated and having up to 0.50 meters precision including IMU data with a frequency of 100Hz. The devices were installed inside a standard car using an external antenna.

The test site was a set of roads (Figure 1.a), all outside any city and in a sloppy zone having different ranges slopes, curvatures, sinuosity and even possibility of multipath error due to embankments (Figure 1.b). All the tracks are composed by points having, at least general information like the one defined in NMEA protocol. The points, captured with the described devices, were continuous (not stopped at the beginning or end of the each section), can be self-intersected (if joined in tracks) and covers the selected roads several times in both directions.



(a) (b)

Figure 1. (a) Motorways and captured points represented by red circles (b) Detail of the captured points in the north part (Basemap: IGN Raster - http://www.ign.es/wms-inspire/mapa-raster?SERVICE=WMS& -, Points: GPS captured by the standard device).

Once the points were captured, following the first stage of our methodology, we have approximately 128000 points with the standard dataloggers and 1724000 points with the VBox GPS. Both datasets have information about position and timestamp. However, while dataloggers have DOP information, VBox GPS has no precision information because of the use of IMU that interferes with the GPS original precision calculation. These points were ordered using timestamp (grouped by device) to assure continuity of the point sequence, as indicated in methodology's second stage.

With the previous point sets from the GNSS devices, we selected several parameters among the described in Table 1, the chosen set was: time delta, distance, velocity, angularity, acceleration and precision (PDOP for the dataloggers and number of GPS satellites for the VBox GPS). Furthermore, in order to include 3D information we determine increment of height and slope. All points were enriched, following the third stage of the method, with these parameters and then they were filtered by removing points with a zero delta time or distance. All distances were calculated in 3D and the angles are determined in the plane defined by three consecutive points. The number of these removed points was marginal (less than 0.1%). However, it was necessary to simulate track division by assigning an allowed maximum delta of time in order to remove parameters between stops in the devices and data captured between different days. The chosen value was 3 seconds following the most restrictive value defined by Agamenomi et al. (2010).

After that, we apply the correlation coefficient to determine basic correlation between parameters, the results show almost a perfect correlation between distance and velocity parameters (see Table 2 and Figure 2.a & 2.b). With regards to the other parameters, Table 2 indicates the direct relation between slope and delta of height that is obvious based on its equation and a medium correlation (0.40) between both distance and velocity versus angle (Figure 2.c & 2.d). However, the last correlation does not represent a parameter that can be avoided when filtering because it constricts the tracks' sinuous parts. With respect to the rest of parameters, both point sets have a similar behavior even with a more reduced correlation in the case of VBox with IMU.

		accel.	angle	ΔZ	distance	Δtime	precision	Slope
Standard datalogger	angle	-0.0226						
	ΔZ	-0.0154	0.0204					
	distance	0.0678	-0.5355	0.1424				
	Δ time	-0.0192	0.1672	0.0215	0			
	precision	0.0022	0.0311	-0.0079	-0.0775	0		
	slope	-0.0222	0.0410	0.8917	0.1051	0.0298	-0.0028	
	velocity	0.0700	-0.5451	0.1400	0.9866	-0.1032	-0.0792	0.1046

		accel.	angle	ΔZ	distance	Δtime	precision	Slope
VBox GPS	angle	-0.0006						
	ΔZ	-0.0103	-0.0100					
	distance	0.0079	-0.4092	0.1269				
	Δ time	0.0005	0.0556	0.0002	-0.0176			
	precision	0.0003	-0.1842	-0.0146	-0.0016	-0.0070		
	slope	0.0231	0.0238	0.8384	0.0925	0.0026	-0.0307	
	velocity	0.0079	-0.4092	0.1269	1	-0.0176	-0.0016	0.0925

Table 2. Correlation coefficients between point parameters using both devices (Own preparation).

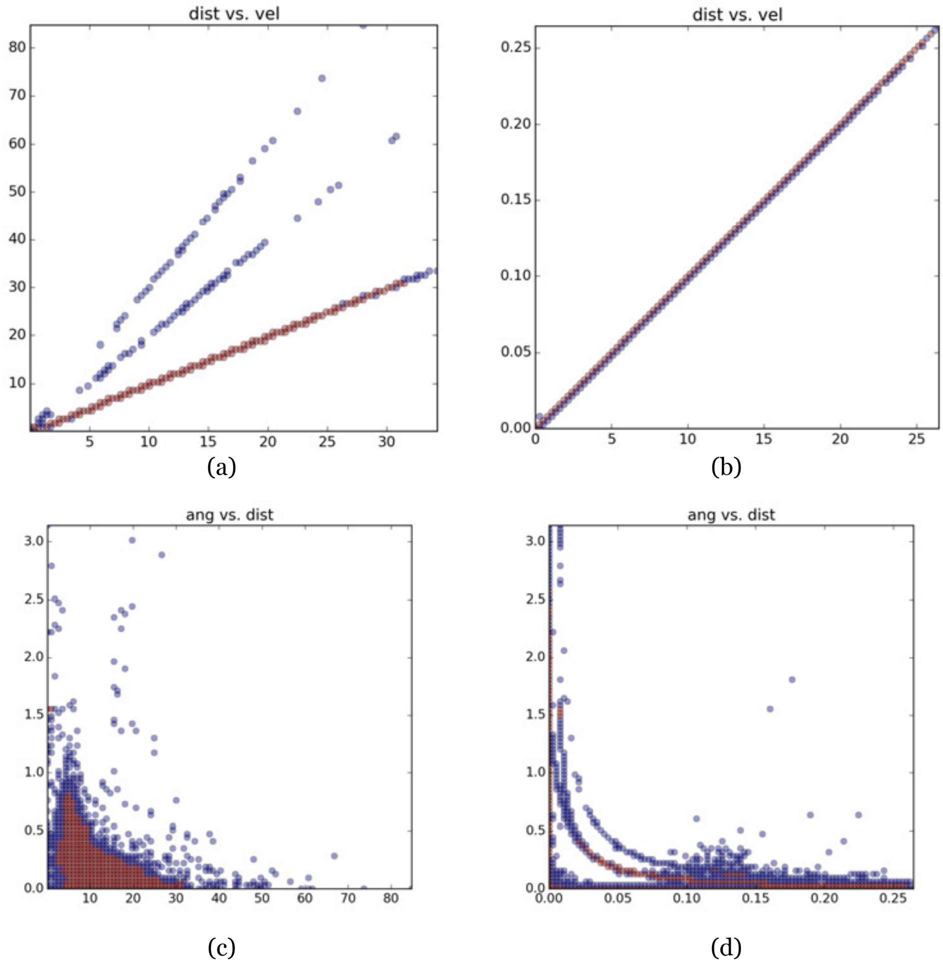


Figure 2. (a) & (b) Scatter plot of distances (meters) versus velocity (m/s) (a – Standard dataloggers, b – Vbox GPS). (c) & (d) Scatter plot of angle (radians) versus distance (meters) (Own preparation).

Taking into account the correlation described in the previous paragraph, we remove the velocity as a filter value and selected the following pair of values and parameters: (i) Maximum distance: 100 meters (Agamenomi et al, 2010), (ii) Acceleration: 4 m/s^2 (Niehöfer et al, 2010), (iii) GPS precision, based on number of satellites with a minimum of 5 satellites (Lima & Ferreira, 2009) and (iv) Delta time: from 1 to 3 seconds (previously used). The percentage of removed points is shown in table 3. The results show different number of points filtered for the high frequency GPS and the standard datalogger GPS. While the first tends to overvalue acceleration, even with IMU correction, the last tends to reduce precision.

Filtering parameter	Standard Datalogger	VBox GPS
Maximum Distance	0%	0%
Acceleration	0.00%	13.49%
GPS Precision	1.30%	0.15%
Delta time	0.36%	0.00%

Table 3. Percentage of removed points based on the filtering parameters (Own preparation).

On the other hand, we analyze the differences between points in ascending and descending zones (zero-slope points are ignored) in order to determine if both dataset are similar. The results of applying Kolmogorov-Smirnov test show that both sets of data are clearly different. For the purpose of these tests we have not used height change nor slope because the two point sets are selected using these parameters (ascending and descending parts of tracks). Moreover, we have not tested differences in time because it is a discrete value equal between points.

After that, we created the tracks from points ordered by time and filtered as it was described in previous paragraphs. The filtering has been applied using only one set of parameters because the differences shown by Kolmogorov-Smirnov test are lower than the range of values accepted for all the parameters. On the other hand, we have tried to recover some points from the filtered set using Lima & Ferreira (2009) limit, 1 meter in the normal direction, as it was indicated in the last stage of the methodology. However, there was not possible to recover any because the distance is too short and increasing this value should interfere with other parameters like local angle.

In table 4 we present the statistics of reconstructed tracks, for both devices using the points previous to the filtering process (pre-filtering) and after the filtering process. The results show that high frequency capturing devices like VBox are very interesting because they recover faster than low frequency devices. For this reason, minimum distances of VBox GPS are very significant versus the same distances in the standard datalogger devices. This frequency also affects the maximum distance per track and the number of tracks reconstructed, that are too fragmented in the case of using a standard datalogger. Moreover, the low minimum distance in standard dataloggers indicates the need to use a threshold value for this parameter that we propose to be equal to the precision of the GNSS.

	Standard datalogger		VBox GPS	
	Pre-filtering	After filter	Pre-filtering	After filter
Max	72709.44	51393.73	122420.29	121871.29
Min	0.09	0.09	677.98	673.25
Mean	6467.68	3173.89	81663.17	61217.46
Number of tracks	287	576	3	4

Table 4. Distance statistics of created tracks, all distances are in meters. (Own preparation).

The results showed in this work indicate that several of the approaches for filtering point data from GNSS use similar parameters and these parameters are correlated, even using 3D information. This correlation makes very difficult to tune threshold values in each stage of the methodology thus forcing to choose different sets of original parameters. Even though choosing only a non-correlated set of parameters, the differences in sinuosity and slope of the roads change some threshold values like acceleration and others like maximum angularity or maximum distance. These changes cut tracks in several parts reducing total distance of the track, that is another parameter that could not be directly determined as correlated.

In this work, we have presented a methodology and a set of parameters and threshold values to reconstruct 3D tracks from GNSS devices observing different types of motorways. The used algorithm is based on several previous algorithms modified to include the Z dimension and has been tested with this new dimension and changes in slope or direction of the track and to remove both direct and indirect correlation of the parameters. Finally, the chosen zone has samples of different slopes, sinuosity and is surveyed several times by different types of GNSS devices (non-geodesic) in order to be equivalent to the ones used by common users. In our ongoing work, the methodology will be applied to more positional accurate observations using geodesic GNSS devices and will be extended to cover roads inside cities to filter multipath errors.

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Application Method for Streetview Database as Auxiliary Data to Estimate Mobile Device Users' Location

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Extended Abstract

As distribution rate of smart devices reaches 22% of global people as of 2013 (Heggestuen 2013), we live in the flood of diverse sensors. A smart device unveiled to public for the first time was 'Simon' which developed by IBM in 1993 (Sager 2012) and then Nokia and Apple received baton by releasing PDA and iPhone. From PDA to iPhone, a lot of mobile devices have equipped several sensors such as camera, GPS, magnetometer and so on for clear location based service and this multifaceted sensors suggested many kinds of mobile services in multiple fields from map to games. This flow of development of mobile devices is connected to the appearance of wearable devices such as Google Glass, Moverio and this have ultimately changed environment of sensor usage. That is, as smart devices have penetrated in our life, usage of sensors become fundamental option unlike past smartphone environment in which user can select whether they will use mobile sensors or not.

Meanwhile, various geographic information services for providing spatial database is being operated by a lot of organization. In case of South Korea, as public web service project for disseminating public database known as 'Government 3.0' has been leaded by each government division, spatial information such as DEM(Digital Elevation Model), land registration map can be also accessed through web network. 3Dimensional models which reflect shape of buildings on real world is included in this flow and these can be proper dataset for realizing location based service using images. Likewise, 'Streetview' services which can show image-based information of each street in a perspective view are provided by portal services. Basic interface of the service is that users can move their imaginary location on map

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service and they can get and catch the feature of the location where they are interested through the image information. Representatively, in case of Naver, Daum in South Korea, they construct huge image database of street and update once a year. Accordingly, each vendor can collect massive image data which reflect environmental information in a regular interval. These two kinds of distinctive trends can be great significance for smart devices users. The change of usage pattern of sensors with collecting vast image database enables camera which wasn't recognized as sensor to be used effectively.

In this project, various dataset mentioned previous paragraph was adopted to implement location based service using wearable devices. Whole flow can be divided into database and client layer. In database layer, we focused previous works in diverse field such as computer vision and image processing and try to establish methodology about how to apply the suggested dataset for location based service. In client layer, to realize environment of head mounted device released by general vendor, two smart devices which have modules for Bluetooth connection were adopted as wearable device and smart phone server. Through these component, we implement prototype for processing real time 3D images and deducting client's location.

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Deterministic indoor detection from dispersions of GPS satellites on the celestial sphere

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Abstract. This paper suggests a deterministic scheme to detect whether a mobile device is located indoor or outdoor by comparing visible satellites information from GPS and the medium earth orbit information of the GPS satellites. As positioning methods which used indoor and outdoor is significantly different, the mobile device should alter the positioning method according to its environmental situation. Unfortunately, there are few prior researches on how to determine the trigger points for the transition of the positioning methods. This paper proposes a passive, low-power and deterministic indoor/outdoor detection scheme compared by sensor and learning based one. And the performance evaluation section shows the test results by the category of availability, accuracy, latency, and power consumptions. Finally, the paper concludes with some limitations and future works.

1. Introduction

Determining an absolute or relative position of a mobile device is an essential technic for the most location based services. Global positioning system is the basic approach to obtain locations of the mobile device when it is outdoor. As the GPS receiver should secure at least four line-of-sight signals from the GPS satellites, the GPS receiver cannot calculate its location or make quite errors when it is in building or underground. Indoor positioning methods like wireless positioning system might be useful for the mobile devices located indoors. However, utilizing both indoor and outdoor positioning system simultaneously will cause heavy battery drains, especially when the service needs to track the mobile device continuously. The ideal solution is to select the appropriate positioning method according to the situation of the mobile device. To achieve the goal there should be an indoor/outdoor detection. I/O detector is one approach to the detection of in/outdoor using light intensity sensor, geo-magnetism sensor, and cell

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tower RSSI variation. I/O detector adopts basic machine learning mechanisms to classify the status of mobile devices by aggregating various sensor data. We will discuss the limitations of the learning based approach and the needs of deterministic approach in Section 2. Section 3 will describe the system design of the proposed deterministic indoor detection technic and Section 4 will show the evaluation results. Finally, Section 5 will conclude the paper with applications and future works.

2. Background and motivation

2.1. Learning-based indoor detection

I/O detector is the latest and representative method of learning-based indoor detection. The learning based mechanism observes the significant changes on the sensor values when a mobile device is located indoor or outdoor. The sensors may be a light intensity sensor, a geo-magnetism sensor, a temperature sensor, a humidity sensor and so on. The aggregation of such sensor values will be helpful to improve the quality of the detection mechanism. After setup the system, the learning phase should be followed for various indoor and outdoor situations like rooms with many windows, standing near walls, underground, etc. And then the detector can classify whether the mobile device is indoor or not using the trained binary classifier. As many as training data provided and as clear as the sensor data distinguished, the learning based indoor detector will show high precision and recall for a specific situation to be classified.

2.2. Limitations in learning-based approach

The learning based indoor detection mechanisms have some limitations when it applied in a commercial location based services. In many cases, the sensor reading value is ambiguous and the vague condition may cause the false positive or false negative output results. And for the sensors that need to track the variation of the sensing value, the initial state should be referred. For example, in the cell tower RSSI monitoring method, if we define the increasing RSSI as a transition from the indoor to the outdoor, the system should know whether it was indoor or outdoor when it was powered on, as the RSSI can also vary by the distance from the cell tower even if it moves outdoor. Furthermore, some sensors like temperature and humidity sensors need to be trained over long time period as that kind of sensing value may vary by the seasons. The temperature of indoor in winter might be higher than the temperature of outdoor in summer. In that case, the training data should be supplied over the whole year. Geographical characteristics and national regulations also can be obstacles to adopt the learning based indoor detection mechanisms.

2.3. Needs to deterministic approaches

To detect whether a mobile device is located indoor or outdoor without prior knowledge or training, a novel deterministic approach must be developed and the approach will satisfy the following criteria.

- Deterministic detection method

The decision should be made by the combinations of given conditions excluding statistic or probabilistic factors. By doing so, the method will be applicable without any temporal and geographical restrictions. GPS could be a candidate solution as the orbits of satellites are fixed and the satellites revolve around the earth twice per a day.

- Minimize additional power consumptions

The battery life is a insistent problem of most mobile devices. Location-based services already consume numerous powers to detect the location of the mobile device. As a result, the method should minimize the power consumption itself or work passively by other fundamental operations.

- High availability and accuracy

Besides the deterministic and low power operation, the method should be applicable in most indoor/outdoor conditions and the detection result should show over 90% accuracy compared by the learning based approach. The detection latency also needs to be minimized.

3. System design

To develop the deterministic, low-power, and accurate indoor/outdoor detection system, this paper proposes to use GPS visible satellites information from GPS chipset in a mobile device and the medium earth orbit information of the GPS satellites from NASA. By plotting the information on the celestial sphere, the system could detect obstacles which are hiding the GPS signals. And the detected obstacles will be used to determine whether the location is indoor or outdoor.

3.1. GPS visible satellites

Generally, GPS chipset consists of GPS frontend and GPS baseband. The signal from a GPS satellite is received by GPS antenna and processed to digital data in GPS frontend. The digitized GPS signal is handled in GPS baseband. After complex calculation of FFT/IFFT, the GPS chipset finally get the pseudo ranges and azimuth/elevation of each visible GPS satellites. The most appropriate four satellites are selected to calculate location by trilateration. However, the information about unselected remaining satellites are still quite important as they let us know which direction is open to see the sky. NMEA 0183 is a protocol specification between a GPS chipset and a host system. Application layer protocol of NMEA consists of several sub-messages like GPGGA and GPGSV. GPGGA message contains information about fix time, longitude, latitude, altitude, HDOP and etc. GPGSV message contains azimuth and elevation of all GPS satellites from which currently the GPS module can receive the signal. Furthermore, the GPGSV message is available when the GPS chipset does not fix the location. After getting azimuth and elevation from GPGSV message, each satellite can be plotted on the celestial sphere like figure 1.

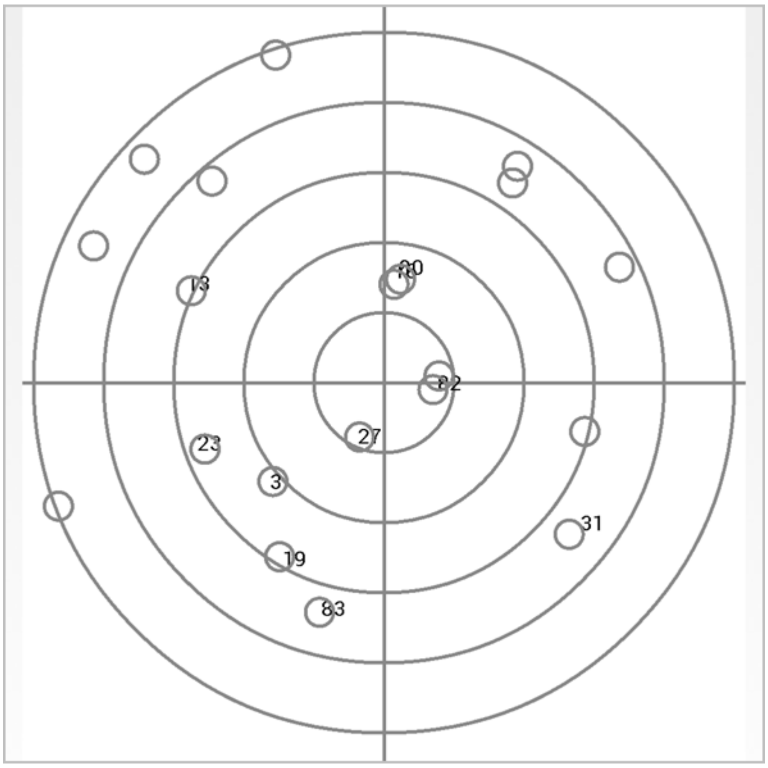


Figure 1. The celestial sphere is illustrated which the position of GPS satellites are noted on. Circles are actual satellite locations and the numbers are the satellites which can have line-of-sight signals. Circles without mapped number mean there exist obstacles by the direction to those satellites.

3.2. Orbit information of GPS satellites

All artificial and natural objects revolving the earth orbit are tracked by NORAD and NASA, and the orbit information is announced publically on each week or month. GPS satellite constellation is located in the medium earth orbit, thus the orbit information of GPS satellites also could be found by online in format of two-line element sets. By using the orbital information, we can calculate the expected position of satellites at a given time. PREDICT is an open-source software to track the position of satellites from the orbital information. If we set the location of ground station to the current location and calculate locations of the GPS satellites for the current time, the software will produce azimuth and elevation information of all the satellites over the horizon. And then each satellite can be plotted on the celestial sphere at the same way to the Section 3.1.

3.3. Determining the condition

Till now, the maps of two celestial spheres are generated which have marks from the position of the GPS satellites. By comparing the two celestial spheres, the system can detect which GPS satellites are actually on the sky and which GPS satellites have line-of-sight signals from the current location. If a GPS satellite is positioned somewhere on the sky and the mobile device cannot receive a signal from that GPS satellite, there might be an obstacle between the satellite and the mobile device. As the GPS system is designed at least six satellites to be observed at any time and any location on the earth, the proposed system can know how many obstacles are near by the mobile device and can determine the mobile device is located indoor or outdoor from the information. The metric can be defined as the degree of open skies (DOOS). And this paper will evaluate the relationship between the DOOS and the detection accuracy in the next section.

4. Evaluations

In this section, the performance evaluation results will be described. The reference detection system is developed on android smart phone and the experiments are performed at the places near latitude 37.25 north and longitude 127.05 east.

4.1. Detection accuracy

The accuracy could be parameterized by the ratio of false positive and false negative. The false positive means the situation when the mobile device is actually located outdoor but the system results the mobile device is located indoor. The false negative means vice versa. Figure 2 shows the relationship between the degree of open skies and the measured false positive ratio. Figure 2 also shows the relationship between the degree of open skies and the measured false negative ratio. If we set the DOOS threshold too tight, the ratios of false positive would increase. Otherwise, if we set the DOOS threshold too loose, the ratio of false negative might increases. So we need to find the optimal threshold value that minimizes both false positive and false negative ratio.

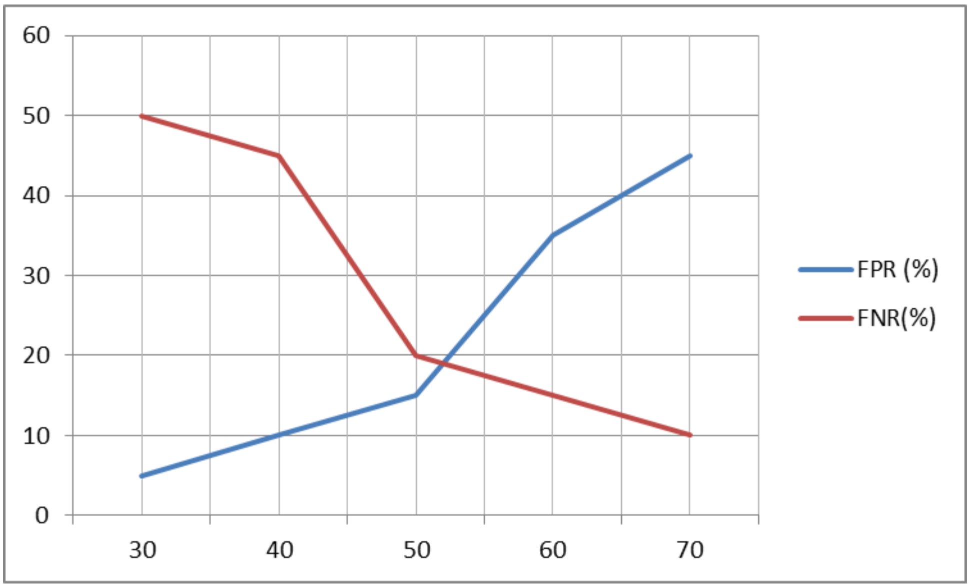


Figure 2. False Positive Ratio(FPR) and False Negative Ratio(FNR) according to the DOOS threshold of the proposed system. Both FPR and FNR are minimized at near 53 of DOOS.

4.2. Power-consumptions

Figure 3 shows the power consumptions when the indoor detection performs periodically. However, the result includes the power consumption of both GPS positioning and indoor detection. So if the positioning is already requested from other location based service, the additional power consumption of the indoor detection is negligible. Furthermore, the information concomitant with the positioning can be used to save more power of the location based service itself and filter out location errors caused by the multi-path, attenuation, and reflection of the GPS signals when it is located indoors. Figure 4 (a) illustrates the GPS position based location tracking service without the indoor detection, and the Figure 4 (b) shows the effect of the indoor detection. By filtering out fixed location from indoor, location errors of GPS were eliminated.

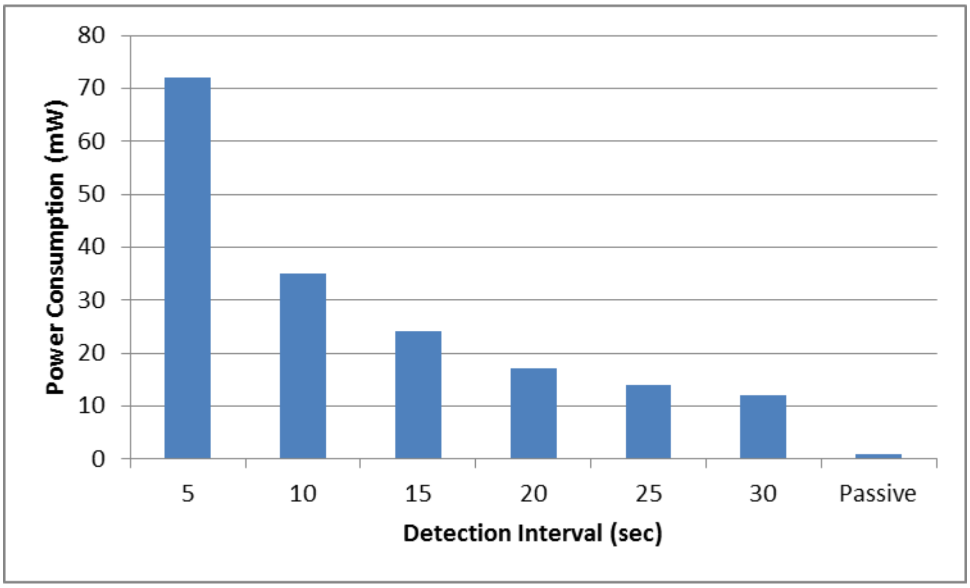
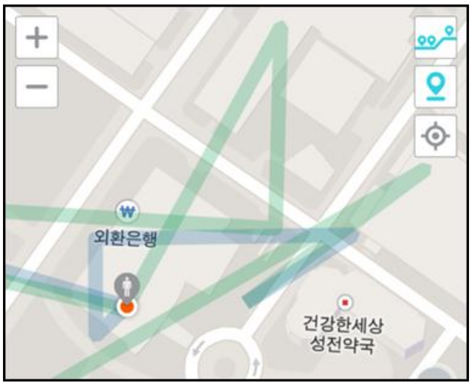


Figure 3. Average power consumptions according to the detection intervals. As the system could work passivly when other services use GPS, the power consumption might be measured extremely low.



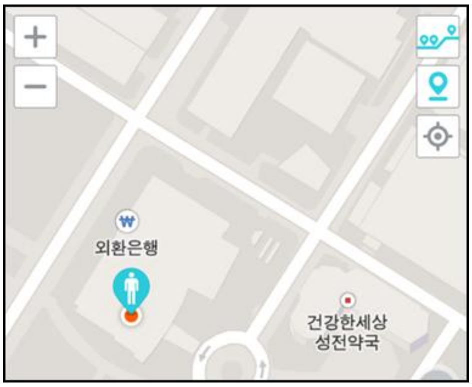


Figure 4. (a) The location from GPS shows quite errors while staying indoors.

(b) There are no need to use GPS while staying indoors.

4.3. Availability

To evaluate the availability of the indoor detection system, we selected fifteen locations mixed indoor and outdoor and numbered the location from 1 to 15. Figure 5 shows the ratio of false positive and false negative on each location. The result implies that the detection system can be applied generally over various indoor and outdoor conditions.

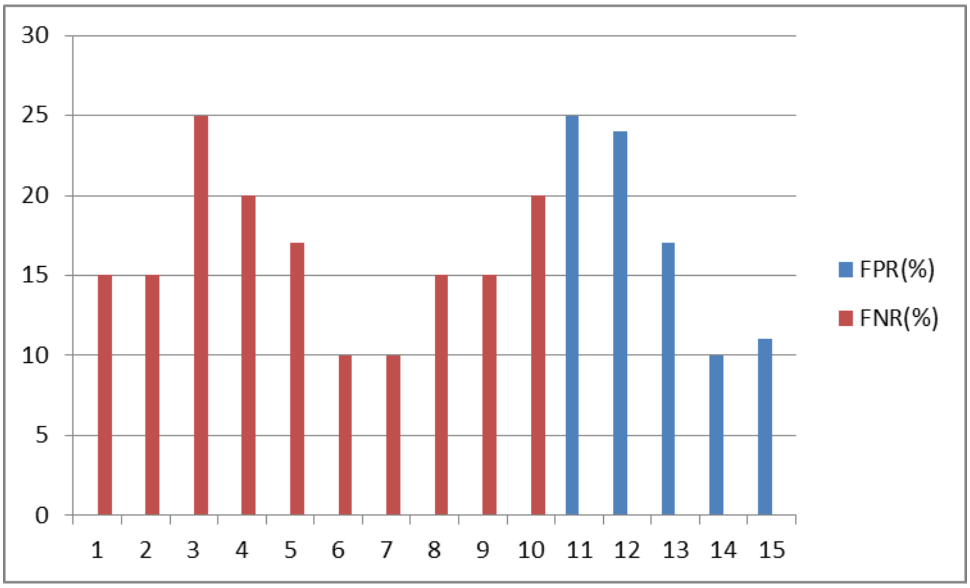


Figure 5. Measured false positive and false negative ratios by the fifteen identical locations. The ratios vary by the charicteristics of the specific location.

5. Conclusion

The global positioning system is an essential part to most location based services. However, the GPS cannot be utilized when the mobile device is located indoor, and even worse, the location from GPS when it is indoor could show quite errors by the distortion of the GPS signals. So it may very helpful if we can know the mobile device is located indoor or outdoor exactly and with less additional costs. The deterministic indoor detection method which this paper propose shows a low-power operation, high availability, and high accuracy by utilizing concomitant information generated while locating from GPS. It's deterministic nature can make it possible to be applied in most indoor and outdoor conditions. Performance evaluation results support that the proposed method can meet the design criteia discussed in Section 2.3. By adopting the indoor detection to the location based services, the service could save power and reduce location errors.

Acknowledgement

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The effects of hardware and software-based signal distortion in multi-platform indoor positioning systems

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Abstract. With the constant platform fragmentation in the global smartphone and tablet market, providing a multi-platform indoor positioning technology is and ever more complex task. RSSI-based hybrid indoor positioning technologies provide hope for a unified indoor positioning solution without the need for calibrating each and every device manually before use. But differing antenna construction, sensor designs and differences in software provide measurement readings that are challenging to compare and thus make the development of multi-platform indoor positioning solutions challenging.

The different hardware and software platforms on a wide array of hardware provide massively differing measurement readings on a number of sensors essential for indoor positioning. Magnetometer, accelerometer and gyroscope readings from a multitude of devices are presented all measured from a custom-build software infrastructure designed to provide comparable readings on different platforms.

Keywords. Indoor positioning, RSSI, Wi-Fi, Bluetooth, accelerometer, gyroscope, magnetometer, magnetic field sensor, signal strength, hybrid positioning systems

1. Introduction

In these last years there have been many attempts to solve the problem of indoor navigation on different platforms, but such a solution has not yet been revealed which is really platform-, manufacturer- and sensor-independent. The drawback of most of these solutions is that such specifica-

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tions must be met that exclude some devices. There have been many attempts to solve indoor positioning with the help of Wi-Fi, which has numerous disadvantages. Suffice to say that how much distortion the scattered signals cause when locating the exact position. Of course it's possible to filter interference cause by scattered signals with the help of different algorithms (e.g. Kálmán filter), but it would require so much resource and computational capacity that it would become uneconomical.

Also RFID proved to rule out fewer devices. However, in this case the problem is that it needs a special sensor, which is only built in the latest generation smartphones as standard equipment. But the spread of such devices will take years. These were only two examples showing how present solutions fragment the mobile market in the terms of indoor positioning.

Our goal is to develop a platform-independent method that would operate on most smartphones. But first we need to aware of the qualities and sensitivity of the sensors in devices.

2. Material and Method

2.1. Hardware and Software

In our present research we analysed the sensors of devices with the help of the software developed by Lanoga Kft. It can record data sensed by the accelerator, gyroscope and magnetometer. At the beginning of the measurement it defines the exact location, then we can choose which sensor we would like to use. Before the start of the measurement the sampling frequency is adjustable.

Measurement activities were conducted with the following sensors of all of the below-mentioned devices in 30 second intervals with a frequency of 10 measurements per second.

We conducted our measurements with the following devices: Google Nexus 5 (Android 4.4.4), Nokia 1020 (Windows Phone 8.10328.78), HTC One Max (Android 4.4.4), HTC 8X (Windows 8.1). The software screenshot is shown in Fig. 1.

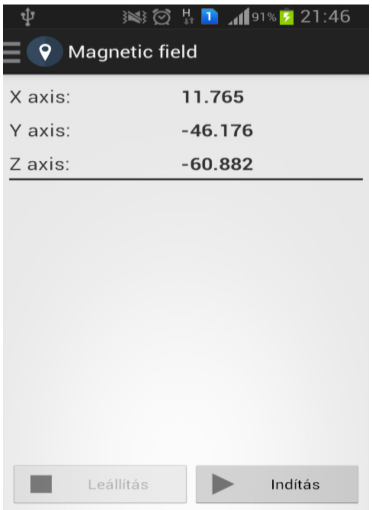

Fig 1. Software applied in the measurements

As it can be seen on the graph the software captures the data of the magnetometer thus determining the spatial position of the device. After the measurement we can export the data to an excel file, hence their processing starts here. During our measurements we collected nearly 120.000 records from different test areas.

2.2. Test area

The measures were done in a classroom and in the dormitory hall of University of Pécs, Hungary. For each measure no other electric or interference-causing device were running in the room to make an influence to the magnetometer (G Tejada et al 2013). A room with four corners (A, B, C, D) was chosen to be our test area.

In addition there was no other active device during the measurement activities to avoid any interference in order to ensure the accuracy of raw data as much as possible.

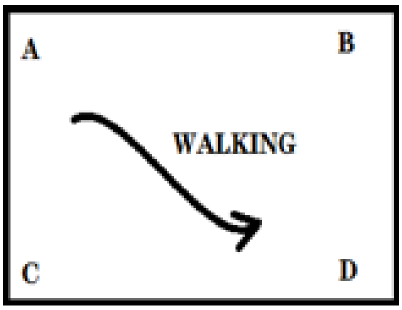

Fig. 2. The classroom measuring area

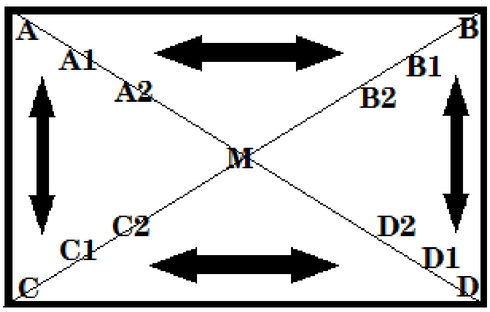

Fig. 3: A more detailed measure taken indoors

First we measured the corners in the room. The corner settings are as Fig. 2 and 3.

We collected data from corners A, B, C and D while walking with the phones for both the dormitory and the classroom. The second time, in order to distinguish among the statistical characters we completed measurements with the phone moving and being stationary. The latter gave more precise results. the following measure method is designed as Fig. 2 and 3. Measures were done walking from A to D, then from A1 to D1, and from A2 to D2, M being the centre of the room; as well as walking with the phone on the path A-B, B-D, D-C, C-A and back and forth between the corners.

In this paper we are following the methodology proposed by Galván-Tejada et al.[12] to obtain indoor location. The process consists of five steps

Several notable results[12, 13] in using a single device for wireless fingerprinting-based indoor localization exist, the most promising ones use K-nearest neighbours, Bayesian classification method, Decision trees or Kálmán filter, to name just a few. To extend any model to several hardware platforms without the need for training the algorithm for hundreds of possible devices, handling the challenge of massively different measurement readings from one device to another shall be tackled.

To reach this goal we suggest enhancing the normalisation process proposed by Galvan-Tejada et al.[14] described in equation (2) to better accommodate readings from several different devices. The raw magnetometer readings are first used to generate a vector described in equation (1):

$$|M| = \sqrt{{M_x}^2 + {M_y}^2 + {M_z}^2} \qquad (1)$$

Then the generated magnitude vector is normalised as described in equation (2):

$$\forall i \in M : z_{i,d} = \frac{r_{i,d} - \mu_d}{\sigma_d} \qquad (2)$$

Where M is the magnitude vector, M_x, M_y and M_z are the magnitude readings for the x, y and z axis of the magnetometer, $z_{i,d}$ is the normalised magnitude, $r_{i,d}$ refers to the i^{th} observation of the signature in dimension d, μ_d is the mean value of the signature for dimension d and σ_d is the standard deviation of the signature for dimension d. This method works well in all cases where the hardware is fixed and continuous readings provide more details. However, when using several different devices, the readings from one device to another tend to be way too different in real life. To demonstrate this some basic statistical descriptive data of 1500 magnetometer measurements is given from all 5 devices in point A of the data collecting test area.

As the data reveals, the average readings differ far too much not to require individual training of each specific device in an indoor positioning system.

The first strategy to enhance the measured data is to first do normalisation on the raw measurement data and then generate the magnitude vector for each reading.

$$\forall i \in M : q_{i,d} = \frac{s_{i,d} - \mu_d}{\sigma_d} \tag{3}$$

Where $q_{i,d}$ is the normalised reading, $s_{i,d}$ refers to the i^{th} observation of the measurement in dimension d, μ_d is the mean value of the measurement for dimension d and σ_d is the standard deviation of the measurement for dimension d.

$$|N| = \sqrt{N_x{}^2 + N_y{}^2 + N_z{}^2} \tag{4}$$

Where N is the normalised magnitude vector, N_x, N_y and N_z are the normalised magnitude readings for the x, y and z axis of the magnetometer.

3. Results

We examined the measurement results from the standpoint of what dispersion they show. In the aspect of our study it is interesting since we used devices from the same manufacturer and running the same operation system. Therefore it would be evident for devices equipped with the same sensor to provide dispersions with no difference. After we processed the date, it turned out it is not our case. On the next figure the deviation we measured with the two HTC devices is seen.

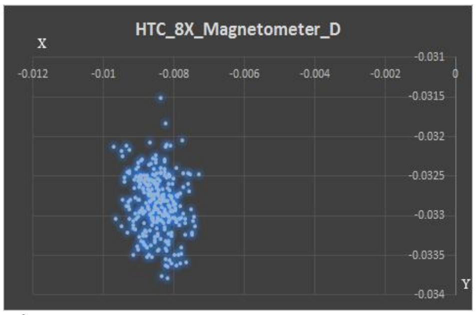

Fig. 4: Corner ’D’ by HTC 8X

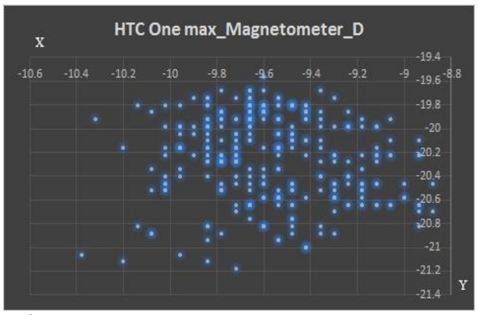

Fig. 5: Corner ’D’ by HTC One Max

We got similar results with devices using the same operation system. We can see this on the following figures.

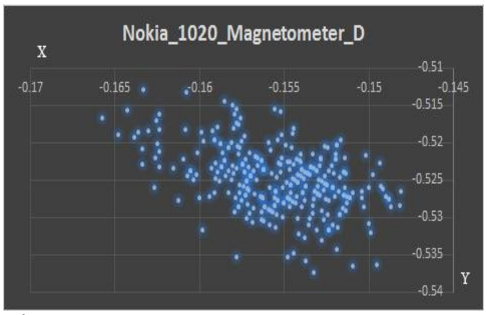

Fig. 6: Corner 'D' by WP

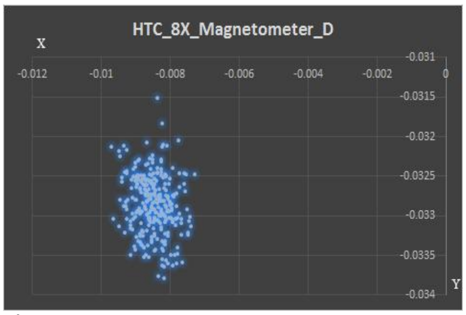

Fig. 7: Corner 'D' by WP

With the help of the several measurement results we attempted to replicate the floor maps of the test areas, but because of the many distractions unfortunately we didn't get useful results. This can be seen in the following figure.

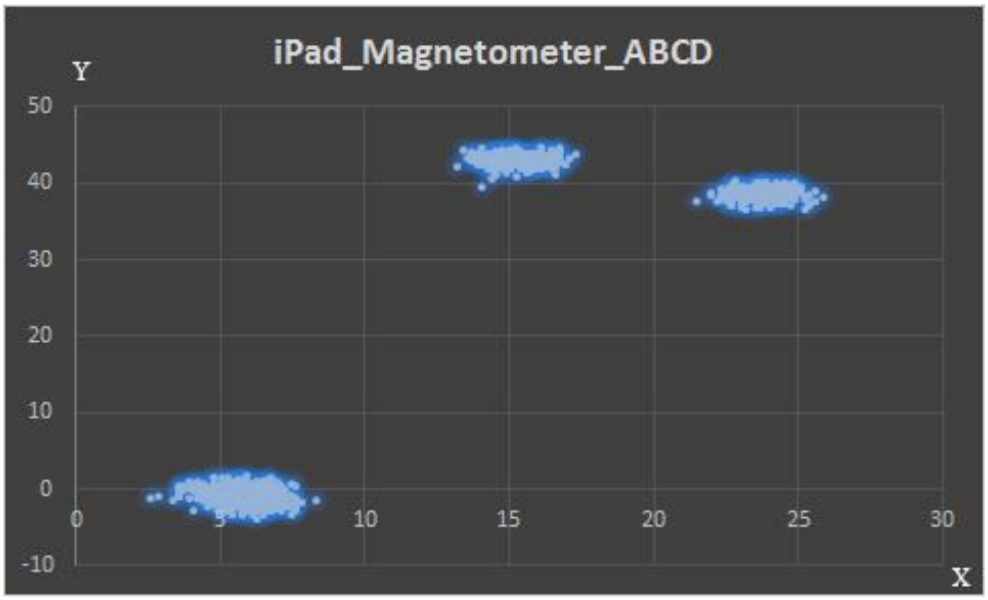

Fig. 8: The effect of interference on the measurement results of iPad mini

As the graph shows above, the sensor of iPad mini is so sensitive and works with so large error that is can't make a difference between corner 'C' and 'D' – though in reality they were 540 cm away from each other –, and made them one point.

We experienced similar result in the case of NOKIA 1020 device. Here the error was caused by the interference, which comes from the refrigerator in corner 'D'. After the equipment was turned off, we could sense all four corners. This can be seen on the next figure.

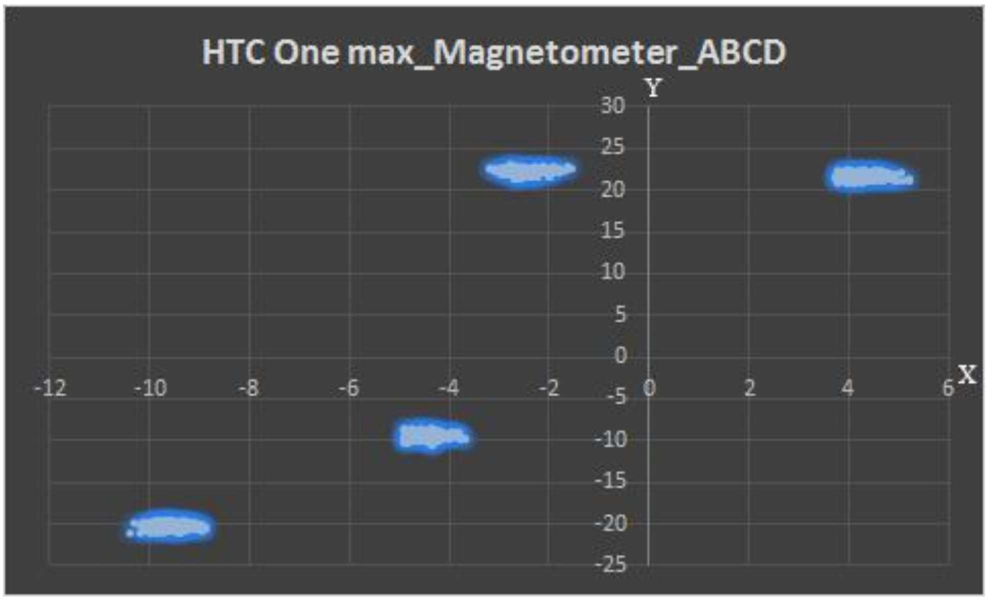

Fig. 9: The measurement results of HTC One Max after eliminating the interference

4. Conclusion

From the results described above it turns out that the operation of sensors is greatly influenced by the operating system running on the device. In addition we have to take numerous other factors causing measurement error in consideration. In many cases distortion attributable to interference exceeded 24%, which is considered to be a very high value in the case of indoor positioning. Interference also can be induced by cables running in the wall, which would cumulatively disturb the measurement result when in a large supermarket. Filtering it can be solved only by complex, elaborate algorithms, but then the load of available resources would grow again.

Due to the sensitivity of sensors we cannot estimate the sizes of the test area at the moment, and the accuracy of positioning is yet to reach the desired level.

5. Acknowledgement

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Linear Location-Based Services

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1. Classifying LBS by their degrees of freedom

Location-based services (LBS) support users during their mobile decision-making. They are information services which are sensitive to their user's location and relate it to the surrounding environment, which in turn provides location-based information to facilitate the successful completion of spatio-temporal tasks. Traditionally, LBS have been classified into different application areas [5].

We propose to describe LBS by the degrees of freedom they offer to their users in choosing the space-time path [6] while using the service. Two dimensions are considered: whether or not an LBS offers the freedom of choosing 1) the spatial trajectory, and 2) the speed of locomotion. These lead to the following four categories (see also Table 1):

A) *Explorer LBS*: the user can freely choose both, spatial trajectory and speed. Most LBS fall into this category, such as pedestrian tourist guides where points of interest (POI) can be visited in arbitrary order.

B) *Flow LBS*: the user can freely choose her trajectory, but not her speed. A car driver's speed, for example, is typically constrained by the traffic flow, while there is usually more than one route option. Location-based in-car entertainment systems for drivers fall into this category [1].

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C) *Path-following LBS*: the user is bound to a linear path, but can choose her speed freely. Examples include tour guides for bikers or hikers traveling along a linear feature, such as a hiking trail or a river [2].

D) *Passenger LBS*: the user passively follows a given space-time path, being able to neither influence the route nor the speed. This applies to passengers of different means of transportation, such as buses, planes, trains, or boats [4].

Table 1: Categories of LBS, based on the degrees of freedom they offer in choosing the spatial trajectory (T) and the speed of locomotion (S)

T	S	Name	Example application areas
yes	yes	Explorer LBS	Pedestrian tourist guide
yes	no	Flow LBS	In-car entertainment for drivers
no	yes	Path-following LBS	Biking/hiking tour guide
no	no	Passenger LBS	Boat/train trip guide

Thinking of LBS in these categories helps us to identify the issues particularly important for the spatio-temporal LBS design: LBS with speed constraints (B and D) require the system designer to adjust the presented content according to temporal parameters. The user cannot stop in order to consume the content, therefore it should be delivered in chunks of appropriate length. LBS with trajectory constraints (C and D), on the other hand, require a spatial adjustment of the content. This can be achieved by selecting only those POI appearing along the track, and/or by dissociating the interesting place from the trigger region where the information service for that place is presented.

2. StoryLiner: a Passenger LBS

As a first step of this ongoing research, we have considered the design of a *Passenger LBS* for touristic boat trips on the Lake Lucerne, Switzerland. The goal of this LBS is to reveal the hidden imaginary literary worlds connected with the Lake Lucerne region, as a complement to the nature experience of the Swiss mountain region. The content was developed by Barbara Piatti [3] for the project "A Literary Atlas of Europe" (http://www.literaturatlas.eu/en/).

In a Master's thesis [4], an Android app (*StoryLiner*) was developed which notifies the tourist when places of literary importance come into sight (see Fig. 1). Text passages of books related to this place, its author, photos of the place, and general touristic information are offered on a smartphone. A panorama view adaptive to the device compass helps the user identify the place in the surroundings.

A specific focus during the development of *StoryLiner* was put on dealing with the *Passenger LBS*-specific design issues. Since the places of interest are located somewhere in the mountains surrounding the lake while the boat is following a fixed track on the lake (trajectory constraint), trigger regions were defined based on a visibility analysis on a digital elevation model. As further constraints, the trigger regions had to be placed in a way that each information is triggered exactly once, and that the respective place is in sight for at least a given duration threshold, based on the known speed of the boat (speed constraint). This ensures that the tourist can perceive all information before the place gets out of sight and before the next trigger region is entered.

The analysis was done by combining ArcGIS tools with a custom Python script. Figure 2 displays the result of the analysis for the 14 places selected by a literary scholar.

3. Conclusion and Outlook

A first pilot study with 6 users indicated that, while the app was generally perceived as helpful, some usability issues need to be resolved in future work: the current implementation of the panorama view with static images shown at predefined positions was confusing and will be replaced by dynamically created panoramas or an augmented reality view. Participants also noted that places on the map should be labeled. The main challenges of *Passenger LBS*, however, seem to be solved quite well: participants were able to identify the literary place in the surroundings, and no negative remarks were made w.r.t. the spatial and temporal presentation of content. A larger user study will help to confirm these findings.

Spatio-temporally restricted LBS have certainly been developed before. We aim at classifying a larger number of those previous LBS w.r.t. our classification scheme (section 1). A specific focus on how they solved the spatial and temporal constraint problems will help to develop general guidelines for linear location-based services.

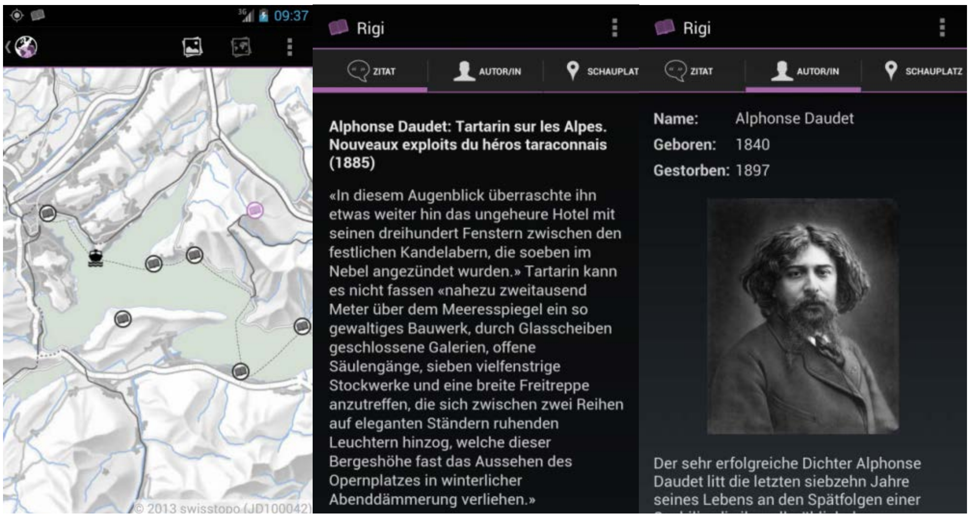

Figure 1: The *StoryLiner* app. Map view (left), book citation (center), and author information (right)

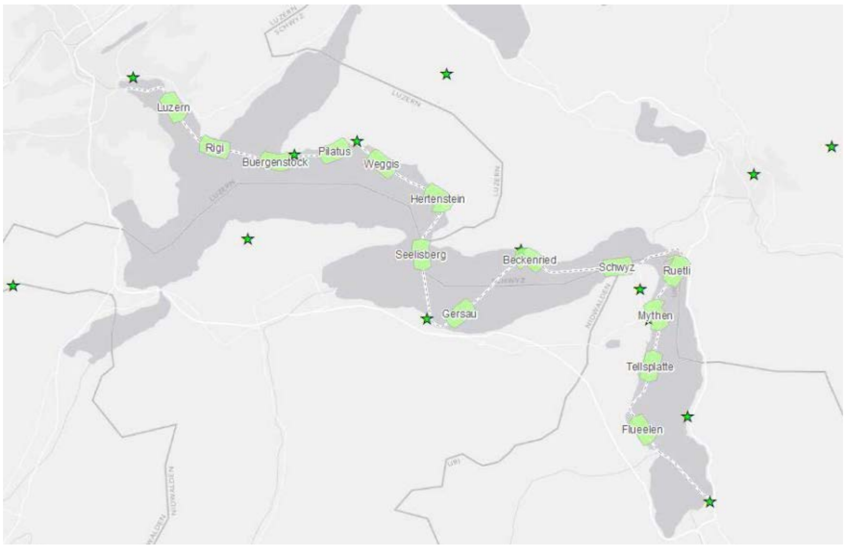

Figure 2: Trigger regions (polygons) and places of literary interest (stars) for the *StoryLiner* app

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SmartLiving – LBS and Social Media for Comprehensive Democratic Positions in Urban Development

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Extended Abstract

Introduction

Location-based services (LBS) in general allow information processing with respect to three dimensions: space, time and semantics/content. Social media allows using people's social network for information processing. The wide use of both techniques motivates to merge them into new application domains. In this paper we present our first experiences with the design and development of a mobile application for comprehensive democratic positions in urban development. Our application enables users to mark, track and comment interesting locations. It is used in a concrete urban development project where stakeholders (in our case young people and children) go into the development area with their mobile devices and give suggestions about "objects" they would like to have there. The combination of LBS with social media allows integrating stakeholders like young people and children in the urban development process which normally do not participate in the traditional process.

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Scenario

The "communicative turn" which gained increasing influence in the planning disciplines since the 1990s framed a new understanding towards urban development tasks. Today an informal participation process belongs to urban design projects in nearly every municipality. However, criticism spread even though the participation readiness of the municipalities is high and the instruments are various. Classical procedures like forums, round tables and meetings reach only few and require a high level of intellectual ability. Especially children and young people belong to the excluded social groups.

With the usage of our mobile application within the urban development project we demonstrate how new and direct forms of an urban development dialogue appropriate for youths and children arise. Our application offers a systematic insight in democratic processes by combining a user's actual position (dimension space) with his or her preferences/needs (dimension theme) in that specific situation (dimension time). Research questions include the action radius of young people in the neighbourhood, a social area analysis based on qualitative comments or a stakeholder oriented information service (e.g. where is the next meeting point of the group I belong to?)

Architecture

In the area of LBS there are several challenges that need to be addressed. One is that the in-built location sensors of smartphones provide a limited accuracy. For the application in use this was not a problem because the users would use the provided in-built location to approximately place their objects of interest or locate their commentaries on the map.

From a technical point of view one challenge is the necessity of native developments because of the variety of operation systems. To avoid this obstacle the application was designed as a HTML5 application with CSS3 (hybrid approach).

Figure 1 shows the technical architecture of the application that was implemented by the Institute of Geomatics Engineering in a first version.

Instead of programming new services from scratch we combined and enriched existing services. To ensure the location aspect of LBS, we used the built-in sensors of smartphones in this scenario that can be accessed via the HTML5 approach while we used the functionality of Yammer[1] for the social

[1] https://about.yammer.com/

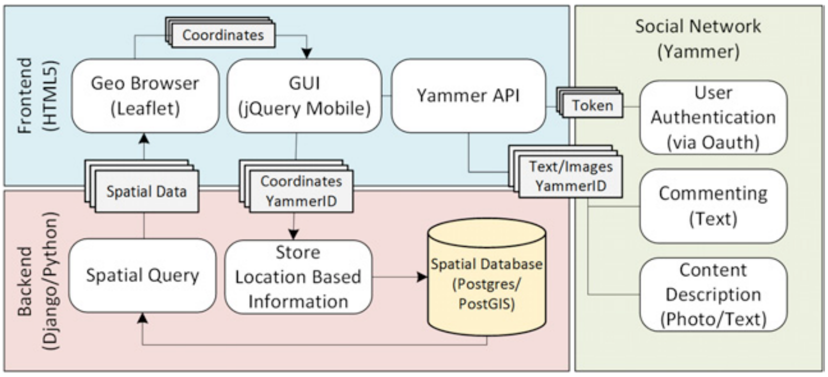

Fig 1: Technical Architecture of the mobile application

media functionalities. Integrating a social network via a suitable application programming interface (API) allows direct interaction with a social media platform and provides the possibility to link its data directly onto the map.

In the backend a component that supports spatial queries was chosen. Relational databases such as PostgreSQL can be enhanced using the spatial extension PostGIS, which fully supports spatial data.

Data management for location-based services requires rather large datasets to be inserted, updated and removed. The handling of such datasets can be done by employing a streamlined framework. In this case Django was used.

Lessons learnt so far

Using hybrid mobile apps as described above offers wide possibilities for different users to interact with the same user interface that is independent of both browser and underlying (mobile) operating system.

The HTML5-based application facilitates easy integration into a mobile environment using the local browser of a mobile device or even into a hybrid framework such as Cordova[2].

The application must also be easy to use and require as little user interaction as possible. In a first version a problem occurred with this aspect because the social media component (Yammer) did not operate smoothly with the mapping framework and thus as a consequence implied an annoying registering process in the social media part for the user. In a second version this obstacle was removed by replacing the social media component.

[2] http://cordova.apache.org/

Crowdsourcing Energy Data for Participatory Renewable Energy Planning and Modeling

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Abstract. As renewable energy is increasingly fed into regional energy networks, they face significant additional spatial and temporal load fluctuations, making a reliable energy supply more difficult. This is particularly true in the context of varying weather conditions. Thus, diverse energy data on a building or household-level are essential for sustainable renewable energy planning and modeling. However, such data are hardly accessible – if existing at all – because they are mostly owned by private companies like energy providers or network operators. In this paper we tackle this challenge and propose a crowdsourcing approach to acquire fine-grained building and household-specific energy data. Further, we present a technical infrastructure which is based on (mobile) location-aware technologies. We focus on two complementary user interfaces for data acquisition, namely a web application and a smartphone app. The results demonstrate that crowdsourced building and household-specific energy data can support renewable energy planning and modeling processes.

Keywords. Mobile energy data acquisition, location-aware technologies, public participation, VGI, solar thermal systems

1. Introduction

Within the broad and long-lasting political debate about an energy transition to renewable sources, three main trends are clearly identifiable, especially when considering the dependence on the weather: The energy production shifts, firstly, from planned to fluctuating and, secondly, from centralized to decentralized. Thirdly, expensive and nonrenewable energy carriers are increasingly replaced by cost-free and renewable ones (Appelrath

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et al. 2012). Thus, the increasing integration of renewable energy sources into existing energy infrastructure necessitates extensions and modifications of power and heat networks, as well as the construction of additional power plants and storage facilities (SRU 2011).

From a more general perspective, the increasing use of renewable energy sources causes significant additional spatial and temporal load fluctuations in regional energy networks due to the dependence on weather conditions. These fluctuations present novel challenges for planning new energy infrastructures and optimizing existing ones (Törnros et al. 2014). The sources that cause such fluctuations include industrial as well as private wind parks, photovoltaic systems, solar heating systems etc. This diversity of renewable sources and the manifoldness of owners make it difficult to establish a common data base that enables GIS based modeling and planning for renewable energy.

A best possible estimate of overall energy supply and demand, especially when considering renewable energy sources, requires detailed and fine-grained energy-relevant data (Resch et al. 2014). Such data can support renewable energy providers, energy infrastructure companies, or city planners in modeling and planning reliable energy supply. Besides the demand of electrical energy, the demand of heat energy can vary considerably if buildings or households are using private solar thermal systems since this decreases the need for external heat energy, e.g., from a district heating network.

However, in contrast to private photovoltaic systems, which are subsidized by the government, and for which at least some technical facts are publicly available due to legal obligations, private solar thermal systems are typically not registered at all. So, in order to tackle the challenge of filling the gaps of energy-relevant data on a building or household-level, specifically with respect to heat demand and heat supply, new data acquisition approaches are needed.

Within the context of renewable energy data acquisition, we derive the following research question: how can mobile and location-aware technologies facilitate crowdsourcing energy-relevant data, thereby supporting renewable energy planning and modeling? In addition to several technical challenges, this research question also addresses aspects of the users' small but valuable contributions, as well as the potentially increasing awareness of the public about the complexity of sustainable renewable energy planning and modeling.

In this paper we describe a crowdsourcing approach for acquiring fine-grained building and household-specific data relevant for renewable energy planning and modeling. We focus on the underlying location-aware technical infrastructure, particularly on complementary user interfaces. The basic idea is to spread simple tasks such as taking a picture of solar panels to many collaborators rather than single experts – in other words, many people are available that can do a simple job, but few people are available who can do an expert job. Therefore, we rely on the knowledge and the willingness of the broad public to contribute to the overarching goal of a successful energy transition to renewable sources.

The paper is structured as follows: the next section, section 2, is dedicated to related work. In section 3, we describe the concept of the system architecture, which is the technical basis of our crowdsourcing approach. Then, in section 4, we elaborate on prototypical implementation aspects, particularly on the complementary user interaction interfaces for energy data acquisition. In section 5, we discuss the results achieved as well as the limitations of our crowdsourcing approach. Finally, in section 6, we present our main conclusions and close with some future research needs.

2. Related Work

Within the last years, governments, governmental-related organizations, as well as private companies have recognized the value of GIS-based public participation platforms as an effective instrument to increase both the awareness and acceptance of the broader public with respect to renewable energy planning and energy infrastructure projects. Since the public acceptance strongly influences planning and investment dependability, it is of vital importance for the project initiators, project sponsors, and project executives. Otherwise, an effect called the NIMBY phenomenon (Not In My BackYard), can potentially cause an enormous public outcry against such projects, can lead to severe (and expensive) delays and even to a cancelation of the entire project (cf. Devine-Wright 2011). One successful strategy to tackle the NIMBY phenomenon is providing participation opportunities for citizens and people interested in planning processes in order to increase transparency and to improve access to information about a specific project. For this, modern web-based concepts such as Public Participation GIS (PPGIS), Government 2.0 and Web 2.0 have been found useful. For instance, in a recent empirical study related to renewable energy planning, Kropp (2013) shows that more than 90% of the study's participants (n=377) believe that conventional public participation methods (disclosure of project plans in the city hall, open councils, etc.) should be extended by map-based applications on the Internet.

However, public participation applications have been typically developed for specific projects or for single use. Concrete concepts and implementation for crowdsourcing energy data are rarely documented in scientific literature. One promising approach by Karnouskos (2011) proposes the use of smartphones for energy data acquisition. Although the paper shows a comprehensive vision of using modern Internet and Communication Technologies (ICT) to enable communication between “prosumers” and the energy system, however, a concrete practical implementation is missing.

Bazilian et al. (2012) present the idea of open energy analysis tools in combination with energy-relevant open data. However, apart from the overall concept described, concrete technical implementations as well as potential practical issues imposed by a real-world context are missing.

Furthermore, Volunteered Geographic Information (VGI) (Goodchild 2007) has been proven to be a valuable additional data source for diverse research areas, e.g. for assessing building footprints (Fan et al. 2014). However, the potential of VGI need to be evaluated in the context of renewable energy, specifically with respect to energy production facilities, private small-scale power plants, energy consumption data, measurements from private weather stations, or citizen science oriented approaches for acquiring additional energy-relevant data.

3. System Architecture Concept

The goal of our approach is the establishment of a location-aware system architecture that enables the acquisition and management of locations and properties of renewable energy systems, as well as detailed household data relevant for heat demand estimation. Herein we focus on the solar thermal systems case.

3.1. Overall Modular System Architecture

The overall system design follows the loose coupling approach, which allows for separating content, style and logic. As illustrated in Figure 1, the core of our location-aware infrastructure is a Django-based web framework. Simply speaking, Django as a middleware application mediates the communication between the data management and the web and mobile interface, where the data is entered, edited and displayed.

The back end is a conglomerate of Open Source software: we use an Apache webserver with Django’s Web Server Gateway Interface (WSGI) module, which is a requirement for Apache to serve Python applications. Django also provides an out-of-the-box Create, Read, Update and Delete (CRUD) interface, which allows direct data exchange to the database (Figure 1). In order to turn Django into a geographic web framework, we added the extension Geo-Django. Geo-Django in turn requires PostGIS, the geographic extension of the open source database management system PostgreSQL. PostGIS offers geospatial data types, which enables the integration of the collected geodata into Geographic Information Systems for further spatial analyses.

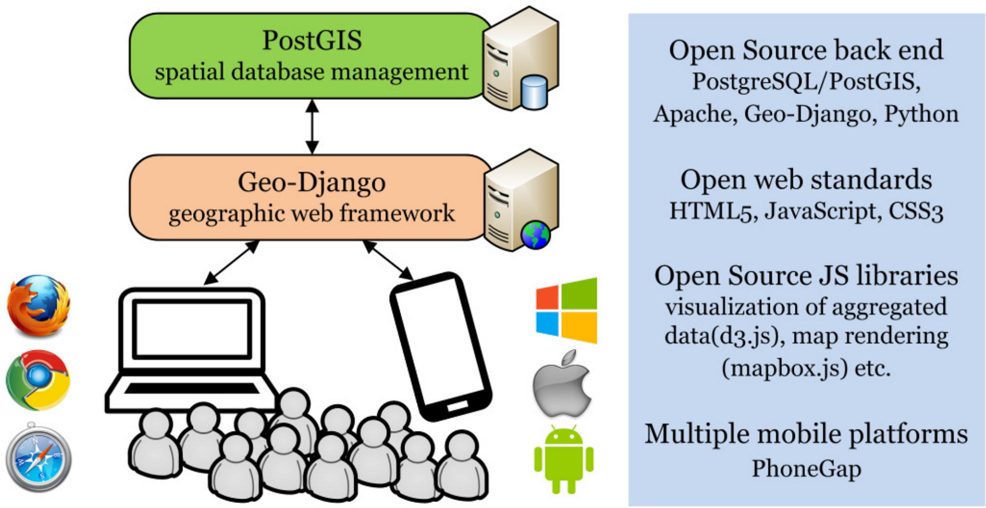

Figure 1: Schematic overview of the location-aware technical infrastructure

On client side, we focus on easy and intuitive data acquisition and data editing regarding solar panels and households. The solar panel data acquisition process comprises panel detection and panel information collection. Herein, panel detection involves the acquisition of a picture of a solar-panel and its corresponding location. The panel information collection requires more detailed knowledge of solar panels and, moreover, information about the panel's corresponding household. In order to support an optimal solar panel data acquisition we offer two complementary web-based tools with graphical interfaces: a fully-fledged web application and a light-weight mobile app.

3.2. Web Application

The web application is designed for easy data acquisition, data editing and data visualization on different screen sizes. Therefore, „responsive web design“ ensures the intuitive use of the web app on diverse (mobile) devices such as standard desktop computers, laptops, tablets, smartphones etc. In order to minimize technical barriers for contribution, the user interface of a crowdsourcing application should not contain any technical, logical, legal or intellectual barriers (Nelsen 2006). Adhering to this principle, we provide a set of predefined attribute values for solar-panels in a simple Hyper Text Markup Language (HTML) form. Furthermore, since the user's current location is of crucial importance for further spatial analysis, a correct and accurate location input is supported through a combination of different location mechanisms such as HTML 5 GeoLocation, as well as standard base maps including satellite imaginary and street map.

The web application is intended for comprehensive data manipulation tasks, specifically enriching already existing data sets with more details like type of solar collectors or the orientation of the solar panel. In order to provide a clear overview and make these tasks highly intuitive and straightforward for the user, the web application is designed for devices with larger displays (desktop computers, laptops, tablets, etc.). Nonetheless, due to the use of responsive web design methods, e.g. Cascaded Style Sheets (CSS) media queries, the web application can also be accessed via a standard web browser from small-display devices such as smartphones. For data acquisition and data manipulation via the web application, we follow a two purpose strategy:

- *Intended Use:* the web interface is intended for devices with a larger screen, e.g., laptops or desktop computers, thus providing a convenient way for advanced but easy typing, filling in forms and data fields.
- *Intended User:* the web interface is designed for experts or trained people who are able to assess a solar panel on a picture, as well as the owners of solar panels who add household-specific data.

3.3. Mobile App

In addition to the web application, the mobile app serves as an intuitive and easy-to-use tool that is specifically designed for on-site energy data acquisition, e.g. solar panel image acquisition. As for the web application (refer to section 3.2 for details), we follow a two purpose strategy.

- *Intended Use:* The mobile app primarily serves the purpose of on-site solar panel detection, comprising four simple steps: (1) determine current position and time (automatically), (2) taking picture(s) of the solar panel, (3) entering basic attributes of that solar panel, and (4) submitting these data to the central server instance.
- *Intended User:* The mobile app is designed as a mobile, on-site data acquisition tool for everyone with a smartphone or tablet willing to contribute to the energy transition in the broader sense, even without any previous knowledge on the subject.

Following these two criteria we designed a mobile app that is easy to use and exactly fulfills the purpose of crowdsourcing energy data for renewable energy planning and modeling. The app has four main characteristics: first, a clearly structured interface that guides the user through the process of entering a new solar panel; second, an intuitive way for correcting input data such as re-taking a picture, or canceling the entire data acquisition process; third, a location-based, semi-automated cross-check mechanism should avoid multiple database entries about the very same solar panel; fourth, transparency of the data acquisition workflow, i.e., the user should know which data is collected when. Further aspects regarding data privacy are discussed in section 5.

4. Validation: Prototypical Implementation

The prototypical implementation follows the system architecture design explained in section 3. Since both the web application and the mobile app exchange data with the database via Django, a RESTful[1] web service that serializes the existing data set is implemented. The data format used is JSON[2] due to its light-weighted structure as compared to, e.g., XML-based alternatives. The base maps used are part of the open source mapping platform "mapbox", an open source mapping platform, and provide an unobtrusive style for easy geographic orientation.

From a thematic point of view, this prototypical implementation is tailored to crowdsourcing location specific data in the context of solar thermal energy systems. We therefore term this specific implementation instance Solar Thermal Energy Locator Applications, in short "STELA". So far, the standard language for the web application and the mobile app is German due to the test region of Heidelberg, Germany.

4.1. Web Application

The Graphical User Interface (GUI) of the web app "STELAweb" comprises the main menu bar at the top, a sliding data entry form on the left side, and a map container (Figure 2). The main menu bar combines the functionality of user management and data creation. A user registration is not mandatory for adding solar panel data, but it is for household data to enhance data privacy. Within the main menu on the top left, a user can add data for "solar

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[1] Representational state transfer (REST), a specific architectural abstraction style within distributed systems

[2] JavaScript Object Notation (JSON), an open standard as an alternative to XML

panel" or "household" via the corresponding data entry form – Figure 2 on the left shows the example of the data entry form for solar panels, a similar form is available for household data. For visualization purposes, individual solar panels available in the database are aggregated using spatial clustering and rendered as markers on a base map, thereby balancing information density across spatial scales while zooming. Only data about solar panels are shown, household data are not available via that interface.

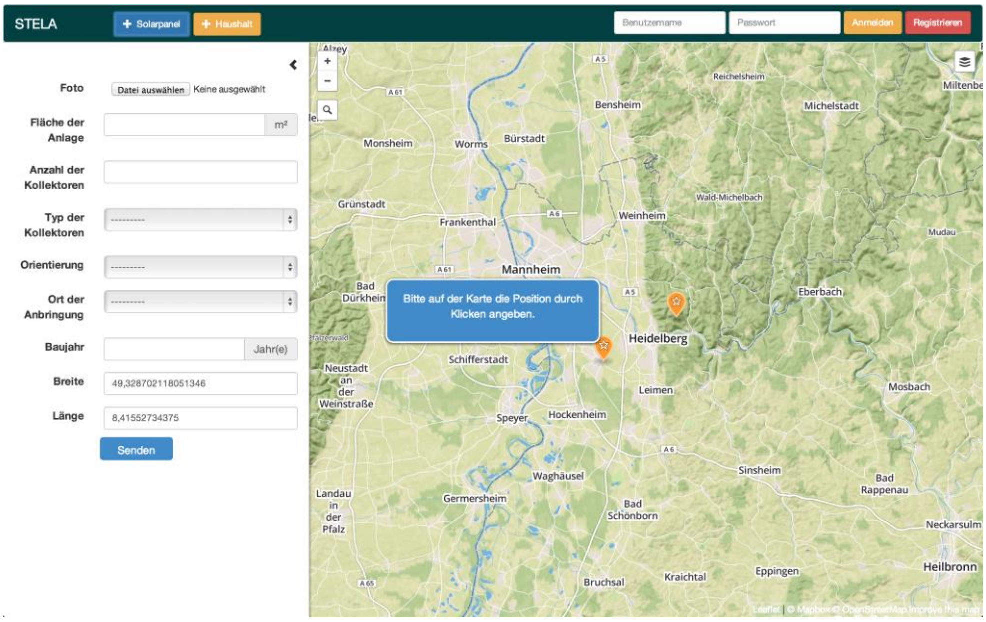

Figure 2: "STELAweb" – Graphical User Interface of the web application; forms on the left allows for adding solar panel data and household data

Entering new data or revise existing data consist of five steps:

1. When starting the web app the map is centered at the user's current position or, if current location data are not available, the map is centered to the bounding box of Germany. Alternatively, the user can use the address query function to center the map at the desired location.
2. New entries for solar panels or households are added by clicking the corresponding buttons in the navigation bar and filling in the respective HTML form appearing in the side bar.
3. Submission of the data to the server. The user receives a short feedback whether the data are successfully submitted and entered into the database on the server.

4. A successful submission about solar panel data is immediately available and visualized at the client.
5. Available solar panel data can be edited or deleted; household data can be added to each solar panel data set.

Besides creation and visualization, other operations of the solar panel data such as update and delete are supported as well (Figure 3, at the bottom of the pop-up window).

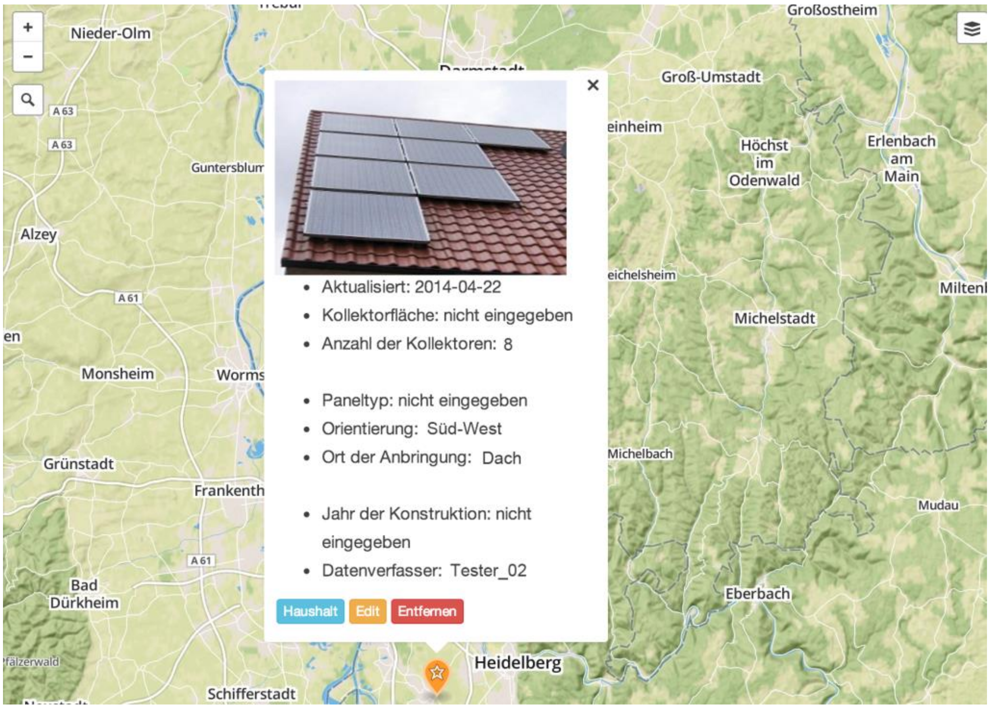

Figure 3: “STELAweb” – example of a popup window comprising solar panel data;

4.2. Mobile App

The mobile app “STELAapp” consists of six screens, which cover the four-step sequence of data acquisition. These four steps relate to “position”, “picture”, “details”, and “submit” and are displayed as a progress bar within the app. As shown in Figure 4, the first four screens refer to “position” and “picture”.

The first screen shows a map with the locations of solar panels already captured. The initial map is centered at the user's location, which is visualized using a position symbol. If automatic geo-localization is not possible, the user can enter an address. Further, the solar panel locations are visualized as individual locations or as clusters, depending on the zoom level and the number of solar panels. This visualization provides the user an overview of existing solar panels nearby. Moreover, it enables the user to check whether a solar panel data entry already exists in the database and, if so, to validate it. On the second screen, the user can add a new solar panel location while the user's current location is updated in case the user moved from the initial location (step 1).

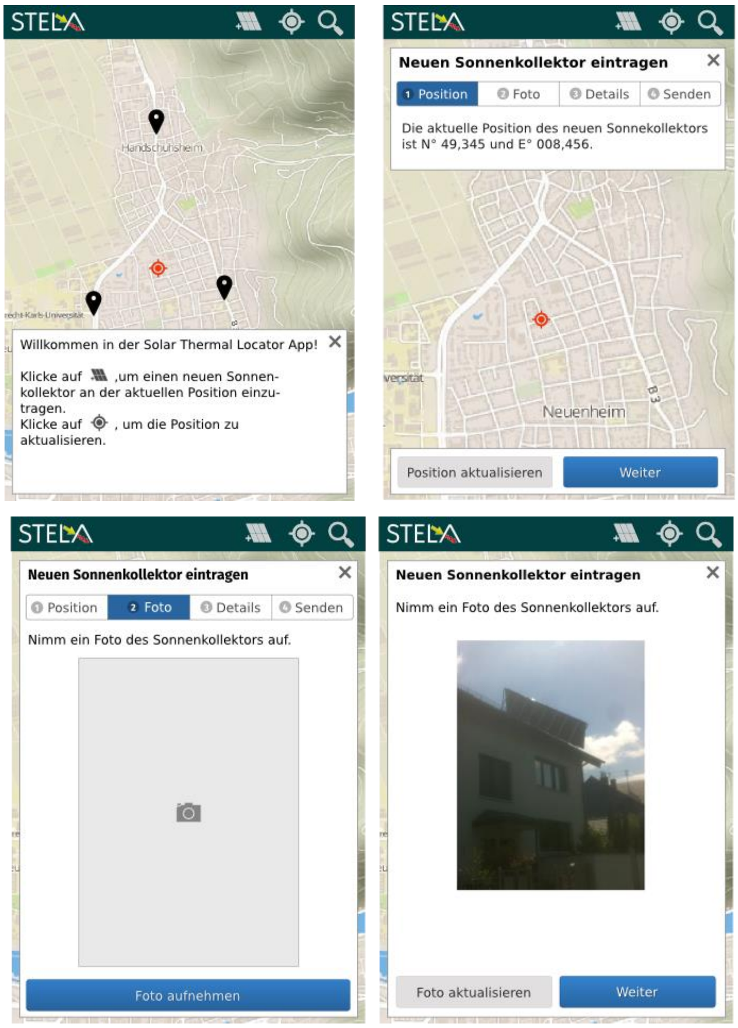

Figure 4: "STELAapp" – four screens of mobile energy data acquisition

The third screen is used for taking a picture of the solar panel, which is then displayed on the fourth screen. Here, the user can decide to keep or retake the picture. The fifth and sixth screens are not illustrated herein. The fifth screen is very similar to the corresponding form of the web app (Figure 2, left); it allows the user to insert additional information about the solar panel. This part is optional, because not all app users may have detailed knowledge about a specific solar panel. In the sixth and final screen the user can check the data entered and submit it to the central server instance.

Throughout the data acquisition process the user can navigate back and forth among the screens by clicking on the steps on the progress bar. As a result of the overall user interface design and the progress bar in particular, the user can control every single step within the data acquisition workflow and get informed which data are send when.

From an implementation point of view, the mobile app was created using state-of-the-art open web standards (HTML5, CSS3, and JavaScript JS). Exemplarily, the app was then ported to Android via Apache Cordova, a freely available platform for building native mobile applications using aforementioned web standards. The six screens are encapsulated in one single HTML document with objects, which are dynamically manipulated via the Document Object Model (DOM) using JS. This also improves the performance of the app by avoiding (re)loading entire HTML pages, thereby providing a more native app-like feeling.

5. Discussion and Limitations

Within the crowdsourcing approach for energy data acquisition presented herein, two complementary user interfaces are designed and implemented. First, the web application STELAweb is the main user interface for entering rather comprehensive details of solar panels or households (Figure 2 and Figure 3). Furthermore, the web application is particularly useful for manipulating and editing already existing data sets on devices with a larger screen (e.g., laptops or tablets). Second, the mobile app STELAapp is specifically designed for acquiring data about solar thermal systems on site, e.g., in the form of geo-referenced pictures of solar panels. Although the mobile app comprises less functionality than the web application, it nevertheless allows for crowdsourcing objective data in form of pictures. Such pictures can then be examined by experts or trained persons in order to get the most information out of a picture. Thus, STELAweb and STELAapp are complementary applications that facilitate the crowdsourcing of fine-grained energy data on the level of households or buildings, thereby supporting renewable energy planning and modeling. We demonstrated this on the example of solar thermal systems.

However, several limitations and constraints need to be addressed. As described in the introduction, not only information on the solar panels is valuable for renewable energy planning and modeling, but also data about the household, such as number of people living in the house, energy consumption, the house's age etc. Such data could therefore be considered private and, therefore, a clear privacy policy needs is inevitable (cf. Damiani 2014). Consequently, the mobile app should include optional log-in functionality – like the web application. Such an authorization mechanism could help to build trust with inhabitants that can provide valuable energy-related information.

Furthermore, in terms of user encouragement and motivation, the authorization functionality mentioned before could be used to provide anonymized activity summaries or "score-sheets", thereby offering location-aware feedback in a gamming manner (e.g., who are the most active contributors, where are the latest entries from, what is the degree of completeness of those data, has an data entry been cross-checked on site, etc. Potentially, highly active user could be rewarded by energy-related institutions. Following this idea of "gamification", STELA could turn into a community-driven project, like Open Street Map (OSM 2014), that supports a successful energy transition using the local knowledge of the crowd.

Another issue refers to data quality in the context of crowdsourcing. The approach described herein is designed for crowdsourcing renewable energy data, exemplarily demonstrated for the solar thermal system case, and also bringing together energy experts and laymen. In any case, the extraction of specific energy-related information from a picture would require certain "quality standards" with respect to both the picture and the person that took that picture. For instance, a minimum picture resolution, the object's exposure to light, the ascertainment of relevant details such as orientation of the solar panel should follow a minimum standard. However, such aspects can hardly be standardized in order to keep a certain data quality level high. The approach of crowdsourcing energy provides nonetheless an additional opportunity of data acquisition for participatory renewable energy planning and modeling.

6. Conclusion and Outlook

In this paper we presented an approach for crowdsourcing energy data for participatory renewable energy planning and modeling and focused on the underlying location-aware infrastructure: we allow people to contribute energy data by means of web-based crowdsourcing and public participation platforms using both a mobile and a standard web application. Mobile technologies such as smartphones are used for on-site data acquisition in the form of geo-referenced images of solar panels and solar thermal systems in combination with supplementary input – this was demonstrated on the example of the mobile app STELAapp. The web application STELAweb provides a more convenient way for adding or editing detailed data of solar panels. Additionally, STELAweb is used to acquire and edit household data.

Hence, referring to the research question stated in the introduction, the overall location-aware infrastructure described herein enables an innovative and complementary way (web application plus mobile app) to collect relevant and fine-grained energy data on a building or household-level. Since such data can hardly be acquired otherwise, they are potentially valuable for renewable energy planning and modeling. Furthermore, such a crowdsourcing approach (e.g., using a mobile app) in combination with an online participation and information platform (e.g., a responsive web application) potentially induce high public visibility and, therefore, increase the awareness of the complex topic of a sustainable energy transition.

The scientific contribution of the research outcomes presented in this paper is twofold. First, the crowdsourcing approach described is an efficient and complementary way for acquiring energy data, thereby supporting the establishment of a more complete energy data base. So far, data attributes include the size and orientation of solar panels, the number of people living in a household, the number of households in a building, the size of heated rooms and areas. Second, the location-aware infrastructure combines the advantages of efficient on-site data acquisition (mobile app) and advanced off-site data entering and data manipulation (web application). The fine-grained building and household-specific energy data gained that way can support renewable energy planning and modeling. We validated the approach and the location-aware infrastructure on the example of solar thermal systems in the context of heat energy supply and demand.

Furthermore, due to the modularity and the loose coupling, the system architecture can easily be extended and applied to several other crowdsourcing and data acquisition needs. Such application domains include, for instance, urban flora and fauna monitoring, or urban infrastructure damage registration and assessment.

In a next step we will focus on the enhancement of the location-aware component for data quality improvement. For instance, when a user is nearby a location with already captured solar panel data or household data, the user might be asked to confirm that data. Another challenge is the preparation of energy data acquisition guidelines in order to maximize the information content in the data acquired.

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Development of Location API for Tracking Continuous Non-Response Calls

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Extended Abstract

In every year, the occurrence number of children, the disabled people and the dementia patients' disappearance has been increased. Statistics data of Korea National Police Agency show that, in comparison with average one between 2006 to 2008, the number of missing people is significantly increased from 18,681 to 33,142 in 2009 and was even marked 41,836 people in 2010 – 2012. Children are the most portion of the missing people, dementia patients and disabled people are followed. To solve this significant issue, it is the most important to find the location of missing people as soon as possible.

Recently, as many kinds of smart device such as smart phone, tablet have been suggested, a lot of research about location-tracking using GPS sensor of smart devices have been studied (A. Al-Mazloum et al. 2013, Kim & Lee 2013). And a lot of applications related with the location tracking for children's safety such as "Famy", "ZoeMob Family Tracker", "Tutu Bell" is being provided through Google play store and Apple App store. These location-tracking applications for the disappearance of protected persons can be categorized in two in accordance with feature of each application, "Active" and "Passive". The features of active applications is to send their family the status message of protected persons automatically and to share the location of whom should be cared with protectors periodically. In contrast, the features of passive applications is that not the applications but the protected persons can decide whether they will send their protectors their own location information or not by various interface such as gesture or actions. Most notable technical features of these applications are continuous and real time tracking and transmission of location message by short message service (SMS), social network service (SNS) and messengers. But the applications have some problems and considerations.

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These tracking systems can cause a lot of problems in various aspects. In respect of hardware, battery of mobile device can be ran out by consistent operation of GPS and in the case of applications which can personally inform current location, the disconnection of internet network can be also considerable problem in emergency situation. And if we think of indoor situation, GPS has numerous error in the circumstance so supplement means are needed. Finally, in ethical aspect, continuous monitoring by mobile applications can cause the privacy issue.

To solve these problems, in this study, location tracking application programming interface (API) to implement the system which can transmit protected persons' location information to their protectors through SMS is developed.

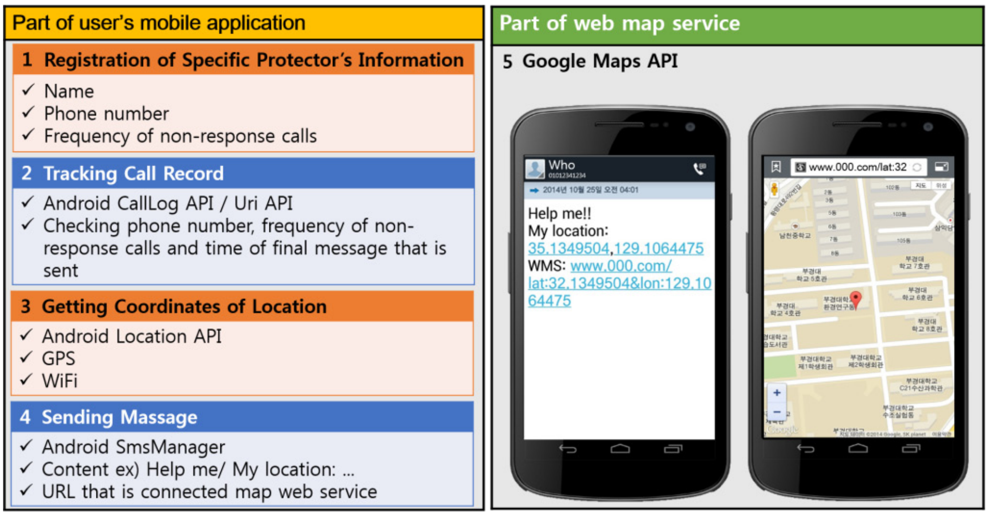

Figure 1. System Flow

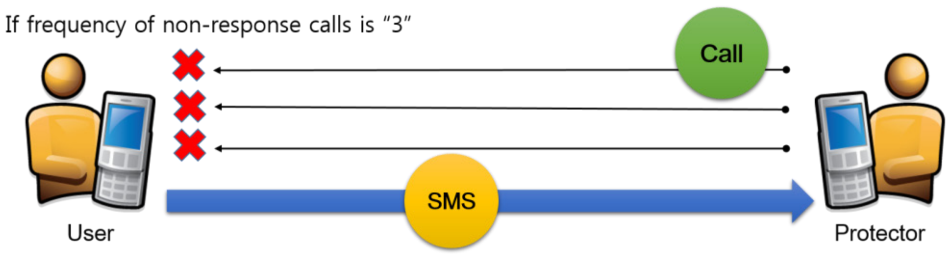

Figure 2. Concept of Application

Conceptual process and structure of application can be explained by figure 1 and figure 2. API can be divided into web and mobile application parts and main functions to trace the clients' location information is operated in mobile application part. In aspect of mobile, Protectors can register their attributes such as phone number and the frequency of missed call before using the application, and this attributes can be used as a trigger in the situation in which application should deliver the location information to protectors. When the frequency of missed calls reaches or exceeds preset attribute, users' location information is sent to protectors by using SMS independent from internet network. For example, as depicted in figure 2, if protector defined preset number as 3 and protected person didn't respond to protector's call as much as preset number, location description message can be sent to protector. In aspect of web server, Web Map Service (WMS) is adopted as interface for indicating provider's location information. If protectors received the protected person's location through SMS, they can click URL defined by the tracking application and location information included in URL parameter can be marked on map service of web server. As a result of these endeavor, mentioned problems in previous sentence can be solved.

Acknowledgement

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Seamless Expression of Active Traffic Safety Mobile Map Based on Location

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Abstract. Currently, the expression of mobile-map is incomplete and discontinuous, and users in different places have different needs for map information. In this issue, a seamless expression of mobile map based on location is proposed. The implementation of this technique is based on ArcGIS Server and mobile terminal develop kit. Firstly, this paper proposes a main progress of seamless expression of mobile map, and analyzes the architecture of the server and the client respectively. Then we introduce the publishment technique based on ArcGIS Server. We also give frame design and data-optimizing tactic of release based on the specific data. Finally, we take the urban traffic zone as an example to achieve the implementation of seamless expression algorithm of the map in the mobile terminal.

Keywords. ArcGIS Server, Map Cache, IOS, Seamless Expression

1. Introduction

In the mobile Internet era, with the development of computer technology, GIS and smart phones, car navigation, portable navigation devices (PND) and otherr intelligent terminals, mobile location-based services (LBS) become more and more popular in our daily life. LBS technique gives a prospect of spatial information services, that is, when a user has interaction with the real world models, at different times, in different locations, this model will dynamically provide different information services to different users [1]. In daily life, with a variety of socio-economic activities, more than 80% of the information pertains to the geographic location of the characteristics of spatial information, users are more eager to get the service information around them. And mobile map can effectively promote the development of LBS industry by collecting diverse spatial information in one

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carrier. As a result, many mobile operators have greater interest in and increased their investment into mobile Internet.

In 2010, the domestic company Navinfo, AutoNavi, and some other navigation electronic map production companies went public one after another. At the same time, Chinese public version of the National Geographic Information Public Service Platform - "Tiandi Map" website has officially opened services [2]. In technical applications, Google, Microsoft, Apple and other companies have launched global products for mobile and Internet map and update regularly. And the leading enterprise on geographic information industry ESRI also introduced mobile platform development components for these three companies, and took the lead in providing the ability to support cloud computing on the ArcGIS 10 platform. These companies quickly occupied a large part of the global online map service market [3]. Thus, on the second quarter of 2012, the accumulated account number on China's mobile map client market has reached 229 million, a quarter-on-quarter increase of 33.0%, and a year-on-year increase of 206.0%. Some local Mobile Map products such as Baidu Maps, Mapbar and Sogou Map achieved a growth rate of more than 60% [4]. However, the current mainstream mobile terminal navigation map products such as google, Baidu, AutoNavi, Mapbar, Sogou and Kay Rucker expand their business in aspects of map dimensions, additional function, related life services and are of expression deficiencies such as incomplete mobile map, discontinuous expression insufficient mining of the potential value of the position information for the map expression, and also lack of the demand analysis of mobile users on the map.

Therefore, this paper proposes a method which integrates different scale map data, carry out dynamic seamless switching and make integrated analysis since the smart mobile client could obtain real-time position information based on the dimentional feature of city electronic map and analysis of the user’s need for the map according to the location. Thus, this method could continuously display details on the region of interest at different levels based on the real-time location of the user, and it also provides further details of different adaptive digital maps from the global overview to the local level of detail.

2. Mobile location technologies and the demand for spatial information in LBS

2.1. Mobile positioning technology framework

Since space positioning technique is not only the foundation to achieve LBS, but also evident advantages over traditional GIS (Desktop GIS, Web GIS).

Real-time location information obtained can provide a series information services in people's lives on "Where are you" (spatial information), "Whom are you with" (society information) and "What resources are nearby" (query information) [5].

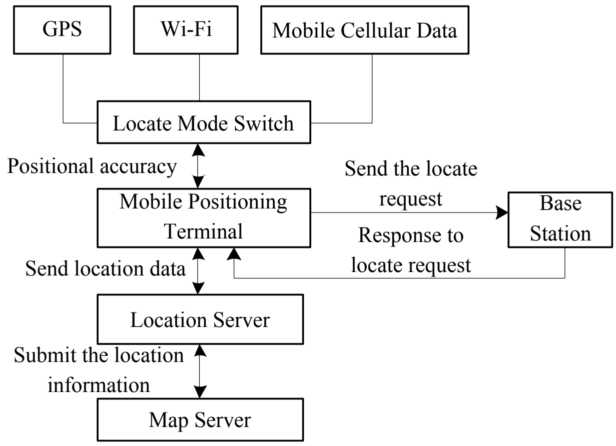

Figure1. The framework of mobile terminal positioning

Currently the positioning techniques of smart phone terminals are mainly of three kinds: GPS, mobile wireless cellular, WIFI. GPS is based on satellite positioning technology, mobile wireless cellular and Wi-Fi are based on network positioning. Which mode the terminal chooses depends on the positioning accuracy. As is shown in Fig.1, the mobile positioning procedure can be described as following: firstly, the mobile terminal makes a request to the surrounding base station, then the base station responds to this request and the terminal could obtain the latitude and longitude coordinates. Secondly, the user terminal transmits the positioning data to the map server, including latitude and longitude, and at the same time, submits this information to the location server. Finally, based on latitude and longitude, the map server calculates the user's current location and sends map results, pictures, text to the specific user.

2.2. Demand for spatial information of LBS

Spatial information refers to many related information in the geographic area, such as buildings and roads in the region, as well as locations of the region and what kind of service it can provide in the area, etc [6]. LBS can provide spatial location-based information services for mobile (physical and logical moving) object by using the GIS technology, spatial positioning technology and network communication technology in the mobile computing environment, heterogeneous environments [7]. The main objective of LBS technology is to make the user access to geographic information services based on location at anytime and anywhere. Therefore, the massive wealth spatial information is an important part of LBS. It provides the positioning framework foundation and real-time dynamic information carrier for LBS, so it is an essential information platform for LBS.

3. Seamless expression of the mobile map based on the location

3.1. Technology architecture of mobile map expression

The core of mobile terminals is to provide human-computer interaction interface, browsing the map display and query. Its data sources mainly include three aspects. The first is the data file that comes with the mobile terminal, including map data and common attribute data. The second is the data obtained from the server through the wireless network. The third is the data collected by the mobile terminal which generally is the coordinate position data.

The map representation of mobile terminal is achieved through the static map service technology of slicing technology, namely using the map slicing technique to establish the image of pyramid in advance. The technical route is shown in Fig.2.

First of all, analyze the original vector data, design the mapping scheme, then make a series of data processing, include projected coordinate system transformation, conversion of data structure format, spatial adjustment ,etc. After being composited, the data will be symbolized and optimized for better display of map according to the principle of mapping and the need of browsing. And the map data conduct the conversion from vector to multigrade raster. Slicing it by the setted scale, we can obtain multiple scales raster images. Then we store it in the database or folder in the server-side according to certain rules. Clients only need to specify the data source, the server will be able to calculate the needed sliced map to display and go on its stitching and indexing process according to the geographical coordinates range of current client requests. At last, it could be sent to the client for display, forming a complete map.This process make sure the display expression of the map data on the mobile phone from the server side.

3.2. The framework of server

ArcGIS server is an enterprise solutions based on Web GIS, providing an efficient platform for creating and managing the GIS applications based on Server. ArcGIS Server is built based on core ArcObjects component library,

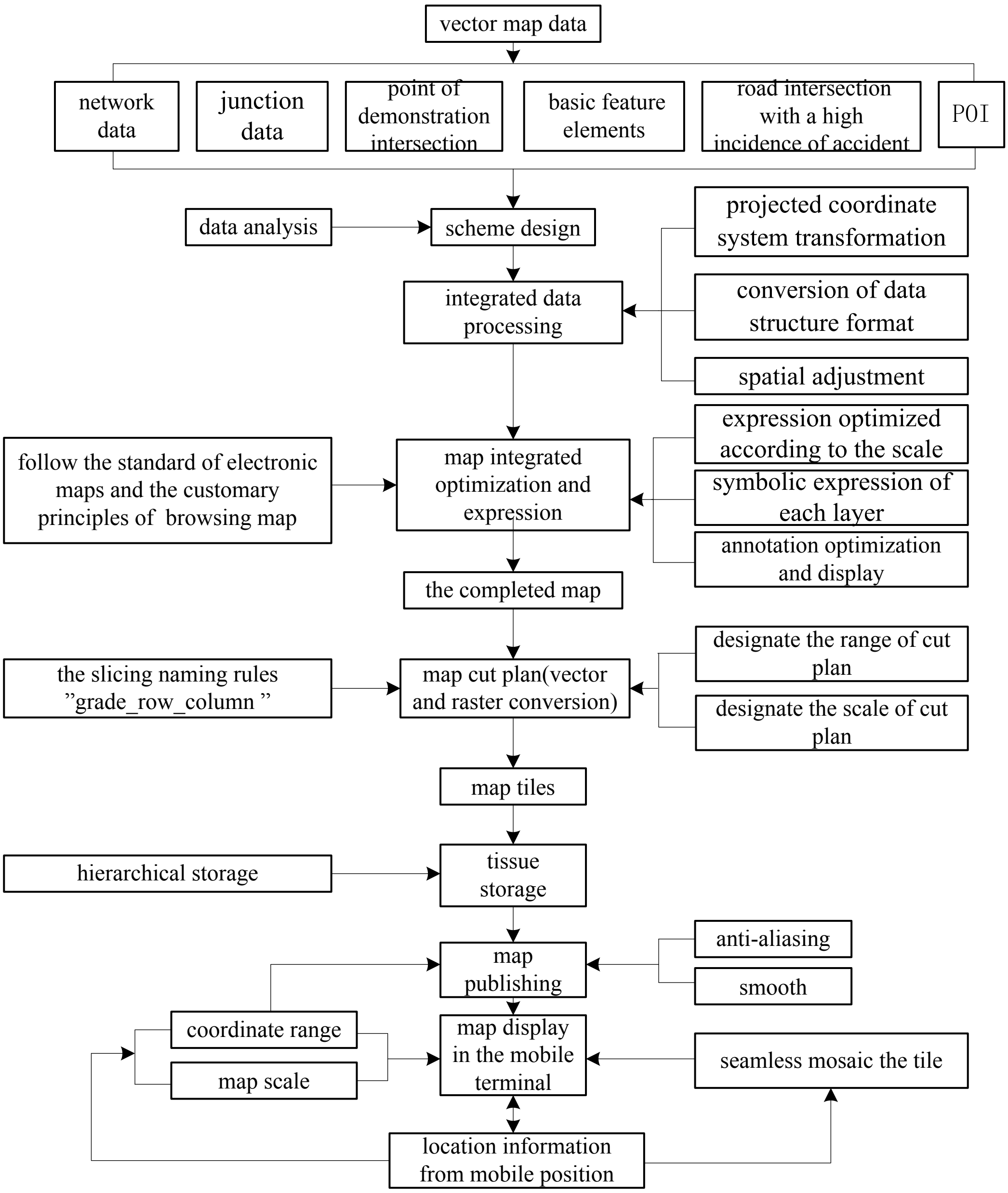

Figure2. The overall technology route of the map tiles publish

3.3. The framework of server

ArcGIS server is an enterprise solutions based on Web GIS, providing an efficient platform for creating and managing the GIS applications based on Server. ArcGIS Server is built based on core ArcObjects component library, combining GIS and network technology, which are two powerful technology, and then complete global networking and spatial analysis and processing. Since ArcGIS 10.1 for Server, using the ArcGIS Server site architecture instead of the previous SOM-SOCs architecture. They're mainly composed by the GIS Server, Web Adaptor, Web Server and Data Server, and they may be selectively distributed on different machines and work to increase the computing power.

3.4. Mobile client application architecture map

ESRI ArcGIS API for ios is the latest launch for Apple OS API. The API is Objective-C library. The library can be embedded in an iphone or ipad application using ArcGIS map, and implement business applications based on ArcGIS. After the map service is published, ArcGIS Server REST provides calls interface to realize the function of GIS. Each map service and every operation has its corresponding address. If it is map service, open the virtual pages that published map layers, projection and other basic information can be retrieved. If it is operation, the function parameters and return values which related to the operation can be retrieved[8]. The relationship between the various parts is shown in Fig.3.

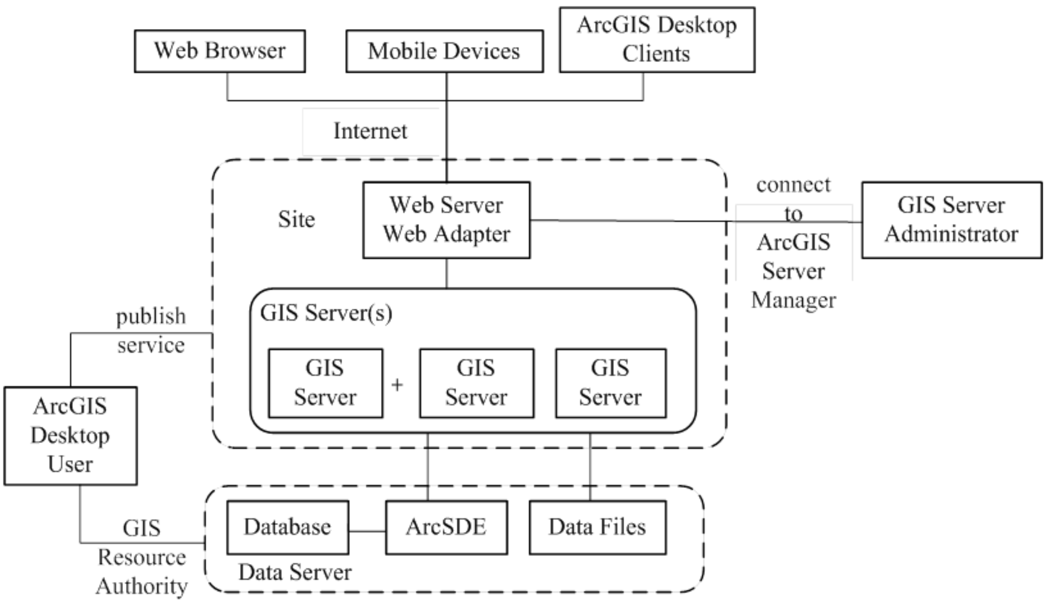

Figure 3. The framework of server

4. Multi-scale expression and caching techniques of mobile map

4.1. Multi-scale representation of electronic map

The establishment of city multi-scale electronic map is not only to meet the demand of government, but also to meet the demand of the companies, the public and every industry in society for their spatial information and thematic information. Multi-scale expression of electronic map is implemented by graded layers and the selection of elements content. Layers grading refer to “Public platform of geographic information service Data specification for electronic map”, it adopts pyramid hierarchical uniform rules and the layers ratio (i.e. tile ground resolution) is fixed. Thus the display pyramids layers of tile dimensions is determined [9], as is shown in Tab.1. Selection method of elements content is based on the relevant specification, firstly selected by classification (an important feature has high selection priority), and then selected by key-elements. And the content of the elements should be increased as the scale increases. However, on a smaller scale levels the surface appearance need to be considered, so it should not be placed too many elements [10]. On the scale of all levels prominent represent important buildings surface, water surface, surface vegetation, road lines, the iconic feature and associated annotation.

Table1. The map layer classification

Level	Corresponding country platform level	Ground resolution(m/pixel)	Display scale
0	9	305.75	1:1155583.42
1	10	152.87	1:577791.71
2	11	76.44	1:288895.85
3	12	38.22	1:2144447.93
4	13	19.11	1:72223.96
5	14	9.55	1:36111.98
6	15	4.78	1:18055.99
7	16	2.39	1:9028
8	17	1.19	1:4514
9	18	0.6	1:2257

4.2. Electronic map caching strategies

Since, massive map data are managed by the server, there is inevitable delay between the client’s request and the server’s response. So it is difficult to meet the needs of users instantly. Therefore, in order to ensure the display speed on mobile side, fluency and good visual effects of electronic map, electronic maps pre-caching is very important, i.e. pre-built pyramid tiles. The layer of tiles refers to the raster image which is cut to a plurality of lines and columns in accordance with the vector map size and format within a certain range set, according to the zoom level or scale [11]. Each layer feature of the geographic scope represented by the same, and scale becomes smaller gradually from bottom to top. Typically there are two times level relationship between adjacent layers.

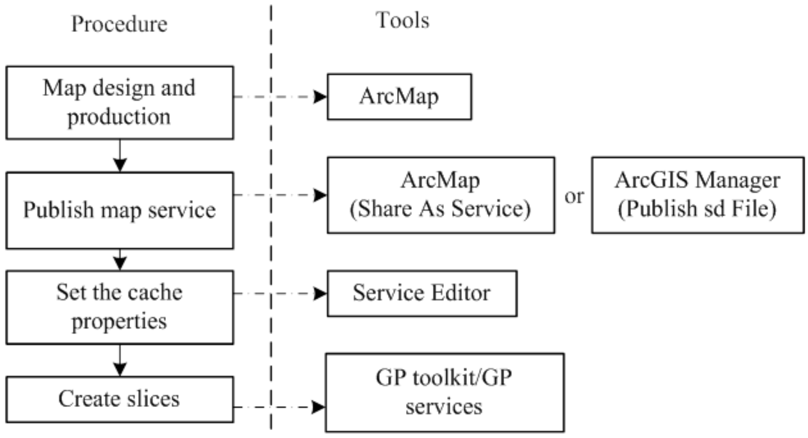

Figure 4. Build the map cache

The creation of a map cache is shown in Fig.4. After completing the illustration of the electronic maps in ArcMap, a map service can be published. There are two ways to publish the service, one is making a good electronic map directly to a shared service, the other is to release packaged sd files in ArcGIS server manager. Publishing process needs to set the cache property, including cutting map scale, scope, storage format, slice width and height, whether antialiasing, DPI (Dots Per Inch) and so on. Anti-aliasing will be used in order to ensure linear elements' smoothness of the published map. Geoprocessing(GP) service can be called after settings to complete the creation of a map cache. This work is always implemented on the server side. The server generates space service data and makes effective management in order to facilitate the mobile terminal to call the appropriate scope and level pictures, and to realize fast browsing.

5. The application of mobile map in the urban traffic active safety

5.1. The urban traffic basic spatial data

The instance is the demonstration application to the urban traffic active safety in Pudong district of Shanghai, the specific scope includes: Huangpu river to the east, within outer ring road, including outer ring road tunnel, Xiangyin road tunnel, Dalian road tunnel, Xinjian road tunnel, etc and Yangpu bridge, Lupu bridge, Nanpu bridge, etc. Based on the urban traffic active safety demand for spatial information, the spatial data of this area is mainly made up of basic road network, point of interest, demonstration crossroads data, data of road intersection with a high incidence of accident and other basic terrain factors, as shown in the Tab.2. The entire map data not only includes the user travel basic information provided by the ordinary electronic maps ,but also contains professional traffic elements of the providing service intersection, such as the traffic signs, the traffic lights[12]and the mark lines, etc.

Table2. The urban traffic data features

	Category	Name	Description
Basic electron-ic map	Point elements	Accident monitoring sta-tions	Road accident monitoring
		Service road intersection	Selection of 10 service road intersection
		Dangerous road intersec-tion	Road intersection with a high incidence of accident
		Scenic	Famous tourist attractions
		Important landmarks	Government agencies
		Life service POI	Gas station,supermarket,etc
	Line elements	Road network	The center line of each grade road network
		Dangerous road	Ramp ,approach bridge,etc
	Polygon elements	The park green space	Urban green space
		Buildings	Block ,commercial buildings,etc
		Drainage	River ,lake,etc
		Administrative areas	Administrative division lines
Service road intersection map	Point elements	Arrowhead	Reflect the way Banks function in detail，indicate the specific function of indicating lane
		Traffic lights	Indicate traffic laws
	Line elements	Crosswalk	Indicate pedestrian croaawalk
		Shield wire	Located in the middle of the road，to play the role of a segregation to traffic
		Stop line	Vehicle stop mark
		Double amber lines	Isolation to traffic
		White full line、White Dotted line	Discriminate different lanes of the synthetic traffic，the former cannot be spanned，the latter can be spanned
		The road red line、the road green line、the road edge line	The lines associated with road design data
	Polygon elements	Green belts	To play the role of a segregation to traffic and vires-cence
		Safety island	The safety area for pedestrians crossing the road

5.2. Map publishment and optimization in demonstration area

This case of application is based on the requirement that provides location service online concerning active traffic safety to the urban vehicles. And the case aims at providing the traffic environment information of the front road to the drivers to prevent traffic accident that may happen. With the help of this application, users can get the information of the front road in advance, and then change the driving behavior in time. The server of this application will provide the service of traffic information published with ArcGIS Server. And the application on the mobile terminal is a kind of C/S structure based on ArcGIS Runtime SDK for ios.

The server of the application includes three parts: web server, database server, and map server. The web server is constructed with nginx and connects with database server and map server based on Ruby on Rails structure. The database server that consists of Oracle database can connect to the map server and transmit mass of data to it dynamically by using ArcSDE. The map server is used to publish geographical map and a series of GIS function. It can even be used to edit the map. This kind of application structure will improve the efficiency of map publish effectively. The structure of servers is shown in Figure 5.

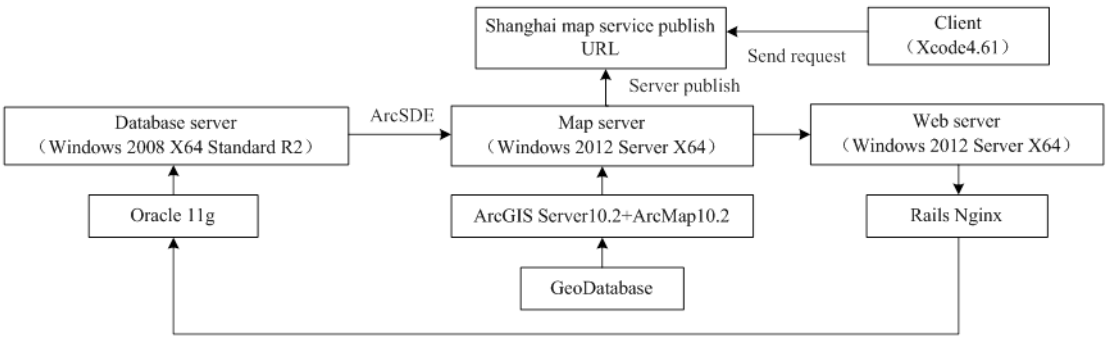

Figure 5. The server deployment mode of the Shanghai map release

In addition, the other way to optimize map server publishment is establishing the cache of the map beforehand. The database server doesn't store map data anymore, but stores the regular pyramid of tile data. The tile data makes the server so efficient that the server can transmit the map to mobile terminal nearly without calculation, and so do the terminal while displaying the map. The tile map can improve the transmit efficiency between the server and the terminal when compared with dynamic map. In addition, the tile map can be modified in advance and optimize the effect of display as much as possible.

5.3. Implementation of seamless expression based on IOS

The key to the seamless expression of map at a mobile terminal is to finish seamless switching among different levels of the cache map, judging by location. The main algorithm is shown in Fig.6. ArcGIS Server published 10 levels of cache map. The first nine layers are the ordinary road navigation display layers, and the tenth layer is the detailed intersection containing road drainage information in the service area. In the design, the service area is a 100 m radius circle with the intersection as the center. When a user enters the region, the location acquired by the mobile intersection held in the user will fall in the area, and the largest map hierarchy is level 9. When the user is not in the area, the largest map hierarchy is level 8, and display-level control is performed by getting terminal map scale. The effect of the final two map displayed on an iphone is shown in Figure 7.

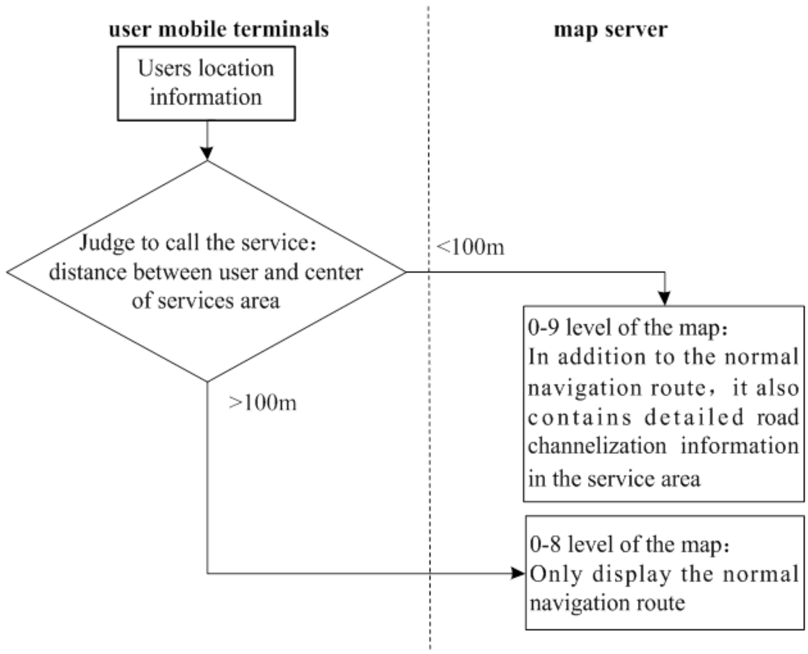

Figure 6. Map seamless switching algorithm based on the location

5.4. Feasibility analysis

In this paper, the achievement of seamless expression of mobile map method is based on the existing navigation softwares such as Baidu, Autonavi, etc. It is to be innovative by the effective integration of geographic information. From the aspect of theory and technology, this paper put forward a complete technical solution from the data processing, digital mapping, map publishment to the achievement in the mobile terminal. The method has been tested and achieved on iphone. In terms of data availability, in order to test the accuracy of the map data, we select a series of control points in road network. Then we use a GPS receiver to field measurements, with the distance between the map point and the actual point of about 3m. For the

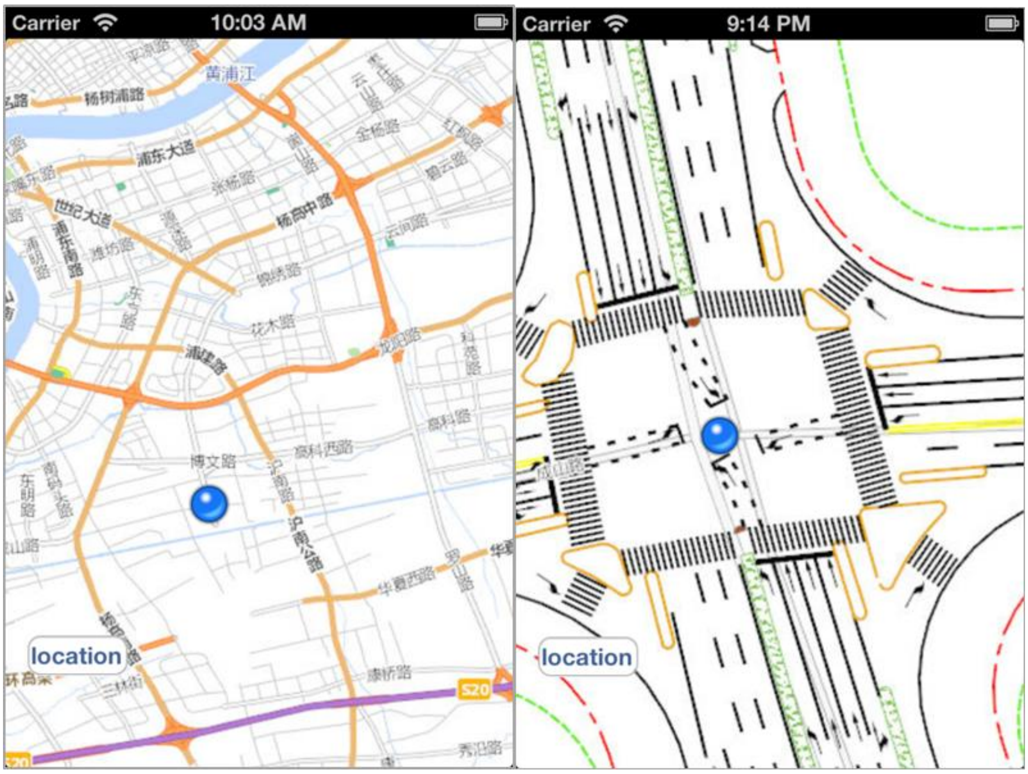

Figure 7. The effect map of road network and junction in the iphone

channelization intersection, we take the same method to measurement, the error is about 3 cm, and it met the required accuracy of the map. Therefore, the method of this paper could provide a good data foundation for high precision navigation and "car-to-car" collision warning services in future work.

6. Conclusion

This paper, based on the development components for the ios mobile terminal offered by ESRI corporation and ArcGIS Server,, realizes the seamless expression of the map on the mobile terminal by calling REST service. Since the REST structure supports caching mechanism, it can call the use of URL address and has made it much easier to develop mobile map and improve the development efficiency to a certain extent. Server distributed deployment plan design, making a large amount of data classification management, can effectively solve the network congestion problem caused by a large number of concurrent access, shorten the access time and improve the overall efficiency. After the map cached on the server, the switching between different scale maps on the mobile terminal can also be much smoother. So, when the user`s location changes, the map can change its richness according to the users' needs, allowing users to obtain more abundant visual experience.

The method provided in this paper is effective with the aid of the geographical position advantage and provides a new train of thought and feasible technical solutions for the realization of the map navigation. But the realization of the follow-up service of mobile map did not elaborate further, which remains to further study.

Acknowledgement

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Location Based Asset Management Application for Railway: AMS-R

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Abstract. Fundamentally asset management for railway infrastructure is about delivering the outputs valued by customers, funding partners and other key stakeholders, in a sustainable way, for the lowest whole life cost. In order to build an efficient asset management system, large amount of data is required in which location of assets plays key role. In current scenario various types of location based services are available, so using the concept of location based services, an efficient and reliable asset management system for railway is developed. In this paper the developed remote device application is presented. The developed application is running on android platform because of cost effectiveness of android devices. Various types of feature can be digitized manually or using inbuilt GPS, in android phone or tablet. Google maps API is used to integrate Google maps services for background maps and geocoding is used to digitize features manually. This paper describe the asset management framework, location based services, use of location based services in asset management system for railway infrastructure and the developed location based asset management application for railway which is used in remote device.

Keywords. Asset management system, location based, android, API, geocoding.

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1. Introduction

Location, which is the most essential context of an object, can be used to provide context aware services to users, which is called location based services (LBS). LBS is the recent concept in which the applications integrates geographic location information with the general notation of services. The concept of LBS presents many challenges in terms of research and industrial concerns. Location services are mainly used in three areas: emergency services, commercial sectors, and military and government industries (Schiller & Voisard 2004).

LBS requires five basic components:

- Service provider's software application.
- A mobile network to transmit data and requests for service.
- A content provider to supply the end user with geo-specific information.
- A positioning component.
- End user's mobile device.

According to law, LBS should be permission based. That means the end user must opt-in to the service in order to use it. In most cases, this means that installing the LBS application and accepting a request to allow the service to know the device's location. From the release of Apple's 3G iPhone and Google's LBS-enabled Android operating system, however, has allowed developers to introduce millions of consumers to LBS (Location Based Services 2014).

In LBS, location based asset management system is an important instance, in which, the type, quality, and positions of massive amount of assets can be managed. Asset management systems are used by many companies to keep track of their field installations and inventories (Cheng & Wei 2009). Asset management involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organizational objectives. Many definitions of asset management being used in different sectors. The most quoted definition of asset management is provided in PAS 55-1 which is as follows:

Systematic and coordinated activities and practices through an organization optimally manage its assets and their associated performance, risk and expenditures over their lifecycle for the purpose of delivering the organization's business objectives (BSI 2008).

Scope of asset management for railway can be categorized in to two categories, which are as follows:

- The physical assets to which the asset management process applies.
- Activities, decisions and processes for the infrastructure.

Physical assets of railway infrastructure consisting the following items:

- Ground area.
- Track.
- Engineering structures: tunnels, bridges, culverts and other overpasses etc.
- Level crossing.
- Superstructures: rails, grooved rails, sleepers, ballast etc.
- Access way for passengers and goods.
- Safety, signaling and telecommunication installations.
- Lighting installations for traffic.
- Electric power plant.

1.1. Asset Management Framework

The asset management framework always consists key components of asset management system, which falls into three categories and shows in figure 1:

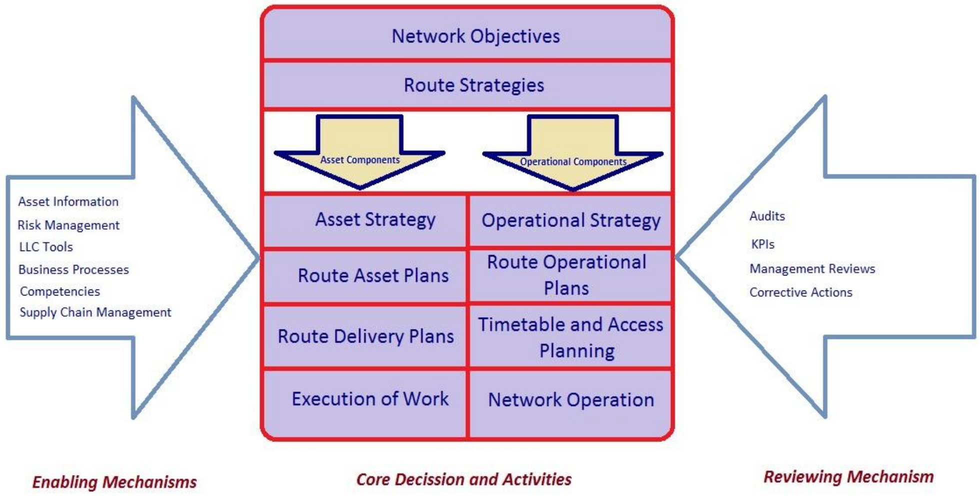

Figure 1 Asset management system framework (UIC, 2010).

1.1.1 Core Activities and Decisions

This is the spine of the asset management framework which defines the decisions and activities that link strategy to the delivery of work, including both work on infrastructure and operation of network.

1.1.2 Enabling Mechanisms

The effectiveness of core activities and decisions is influenced by many support mechanisms like, lifecycle of costing tools, asset information, business processes etc.

1.1.3 Reviewing Mechanisms

To monitor and improve the effectiveness of asset management system, reviewing mechanisms are required. These mechanisms deliver sustainable infrastructure outputs for the level of committed funds. These mechanisms provide continuous feedback for continuous improvement of the asset management system (UIC 2010).

To accomplish the above tasks the most essential part of information about an asset is location. So, this paper proposed a location based asset management application which provide essential information to decision makers about the railway infrastructure. The system has two parts one is central server and second is remote device.

2. Location Based Asset Management System for Railway

Railway organizations have massive amount of assets which have to be managed, reinstall, renovate and maintain properly. To accomplish these tasks an asset management system is required which provide necessary information about desired asset. Location is the key component of asset information. To obtain this location information about an asset and send this information to a central server, an Android based application is developed. The complete system is the combination of two applications one is server side application and second is remote device application. Here in this paper, only remote device application is presented. User can save location information of assets to external storage as well as in central server. If user wants to take photograph of an asset, user need to touch Ok button when alert ask to take picture while saving location information and feature details. The developed application geotag the captured picture of an asset and save it to an appropriate folder. When user touch any marker, line or polygon the related information is displayed in the information window and user can view picture of that asset.

2.1. System Architecture

Architecture of the developed system follows the client-server architecture. The client application is installed into an android based device which transmit location information of an asset to central server. The architecture of the system is illustrated in figure 2:

The client application works in two mode, first is offline and second is online. In offline mode, application doesn't use GPS receiver but in online mode it does. The server application is the combination of database and GIS server.

2.2. Methodology and Development of Remote device Application

Methodology of developed application is illustrated in Figure 3.

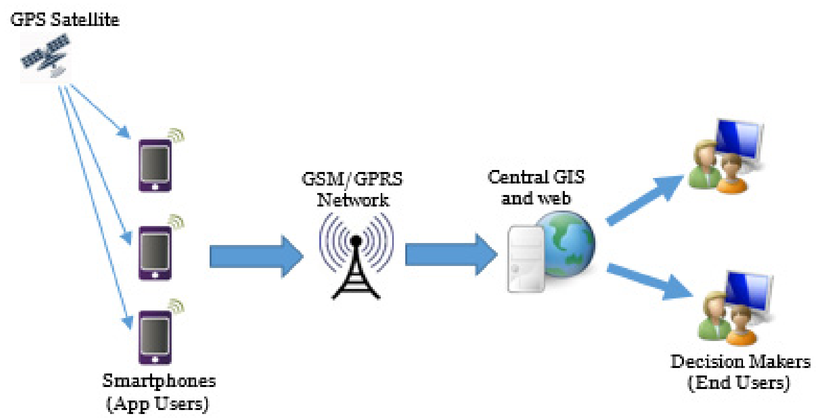

Figure 2 Architecture of location based asset management system for railway.

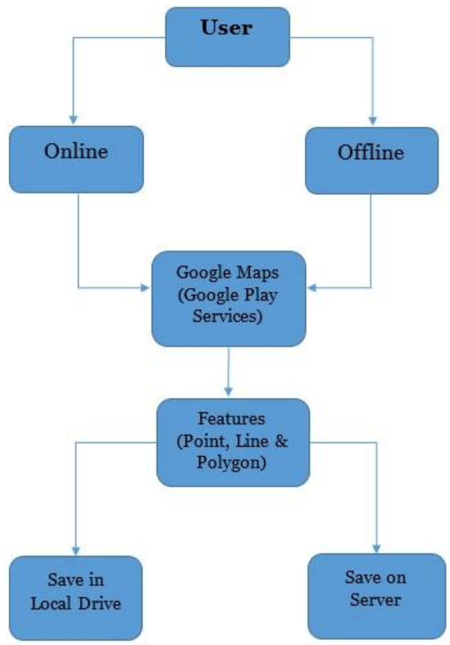

Figure 3 Methodology of developed system

As mention above in section 2.1, the system consists two applications one is client application and another is server application. The client applications is an android based application called AMS-R, which can be installed in any android based device like phone, tablet etc. Eclipse IDE is used to develop the client side application. Eclipse contains a base workspace and an extensible plug-in system for customizing the environment. By means of various plug-ins, Eclipse may also be used to develop applications in various programming languages like: Ada, ABAP, C, C++, COBOL, FORTRAN, Haskell, JavaScript, Lasso, Natural, Perl, PHP, Python, R, Ruby, Scala, Clojure, Groovy, Scheme and Erlang (Eclipse 2014).

AMS-R is configured to run on android versions between 4.1 and 4.4. Google Maps API v2 is used to integrate Google Maps with the developed application. Google Maps API is integrated using google play services. Google play services provide easy access to google services. For this, client libraries are provided by google for each service that let user implement the functionality. The client library contains the interfaces to the individual Google services and allows user to obtain authorization from users to gain access to these services with their credentials (Google Play Services 2014).

The developed application consists three main activities: DashboardActivity, AMSActivity and AMSOfflineActivity, other two activities: CameraActivity and ImageActivity are used to take picture when saving feature details to external storage and view desired picture respectively. Dashboard contains the main configuration functions of the application. User can create new project, open, edit and delete the existing projects. User can also configure project settings, location setting from this activity. After configuring the project user can start collecting data in two modes: Online and Offline. Figure 4a and 4b (refer to appendix) shows the dashboard activity and it's menu.

When user touch the Online mapping button the AMS activity is launched and GPS is enabled, so user can collect assets location information using GPS. The AMS activity is illustrated figure 5 (refer to appendix).

Before taking feature location information user need to select feature from menu and give the attributes to the selected feature like: id, name, feature code, description. After giving attribute information user can collect location information about an asset. Figure 6a and 6b (refer to appendix) shows the menu option and feature details dialog respectively. When user save the asset information by touching save button on menu bar, a dialog popup and ask to capture a picture of the asset. If user touch ok button in take picture dialog, the CameraActivity is launched and take picture of asset and geotag the picture with the asset (See appendix for figure 7a and 7b).

When user touch Offline Mapping button in dashboard activity, the AMS Offline activity is launched. In this activity GPS is disabled so user can collect asset location information by touching the map. User also have to select feature from menu and give attributes like AMS Online activity. Figure 8 (refer to appendix) illustrate the AMS Offline activity.

After completing the data collection, user have to tap on sync option in menu to sync collected data with the server (See appendix for figure 4b).

On the server side MySQL database is used to store data from remote device and PostGIS database is used to store spatial information. PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing location queries to be run in SQL

(PostGIS 2014). Data from MySQL can be extracted into ascii files and shape files can be generated from these ascii file by using third party applications. These shape files can be uploaded to Post GIS to publish spatial information online. For map service, GeoServer is used which allows user to display users spatial information to the world. Implementing the Web Map Service (WMS) standard, GeoServer can create maps in a variety of output formats. This is a Java-based software server that allows users to view and edit geospatial data. GeoServer allows for great flexibility in map creation and data sharing by using open standards set forth by the Open Geospatial Consortium (OGC) (GeoServer 2014). To publish maps and spatial information over the web Apache is used.

3. Benefits of the Developed Location Based Asset Management System

Location is the most vital information about an object and Location-Based Services (LBS) is a predominant term used to describe applications or services that identify the location of a person or object in order to provide some useful information. So in asset management system, location play a key role. Some benefits of location based asset management system are as follows:

- Location information about an asset can be updated to central server remotely.
- User can view all asset location information in the mobile device.
- Staking is very easy of an asset.
- Real time location synchronization of an asset.
- Cost effective.
- Very less training required.
- User can take pictures of assets.

4. Case Study

4.1. Study Area and Field Work

A field survey was conducted to collect the location information about roads, buildings, bridges, signals etc. The developed AMS-R application is used with Samsung Galaxy Nexus i9250 smartphone, which is running on Android 4.3.3 (Jelly Bean). Railway station at Roorkee and its surrounding was selected as a study area, which is located at 29°51'7.72"N and 77°52'30.01"E. Figure 9(refer to appendix) shows field data collection.

4.2. Results and Discussion

Figure 10a and 10b (refer to appendix) shows the collected railway asset information in the developed application. Figure 10a and 10b illustrates the data collection in online and offline mode respectively. The collected data was upload to a central server by selecting Sync option in menu of Dashboard activity (refer to appendix for figure 4b).

Here in figure 10a and 10b the red markers are signal position, green markers are level crossing and yellow markers are start and end of a bridge and red line shows the road, surrounding the Roorkee railway station in Online mode. In figure 10b, the blue markers shows the point on which the user touch to draw road or boundary (these are node points) after switching the application from Online to Offline mode. The yellow line and polygon shows the road and station respectively in Offline mode.

All the collected assets information is stored in the external storage as well as in central server also. After data collection if user wants to send collected data to central server, user need to select Sync option from menu of dashboard activity otherwise the data remains in the external storage of device.

5. Conclusion

In the context of the asset management system, location information is the most essential part of asset information. Railway have the massive amount of assets so the developed application is the suitable option for collecting location information of an asset. Android smartphones and devices are cost effective due to open source license of this software. So using developed application with Android powered smartphones of devices could be the cost effective solution for asset management system in railway industry. Previous studies shows that horizontal difference between smartphone and dedicated handheld GPS is 1 to 5 meter (Shoab et al. 2012), so where less accuracy is required, the inbuilt GPS receiver of smartphone can be used get asset location information. Offline mapping feature of the developed application make it differ from other location based applications. If a user unable to reach near the asset, user can identify that asset on the background map and digitize manually. This application have the capability bringing field and office activities into collaborative environment that can improve productivity and reduce cost.

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APPENDIX

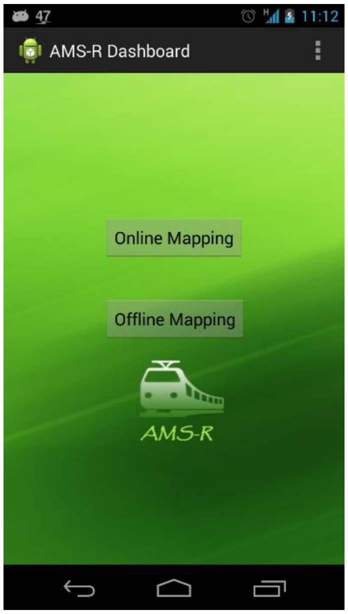

Figure 4 (a) Dashboard activity.

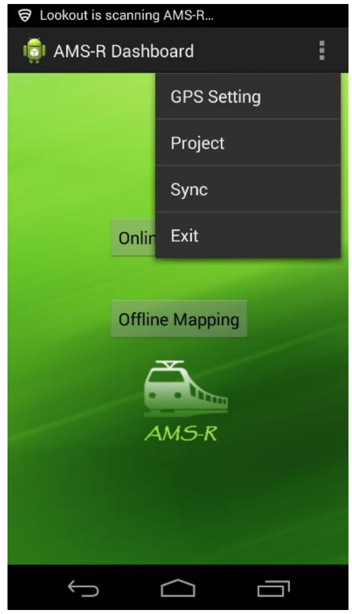

Figure 4 (b) Dashboard with it's menu

Figure 5 AMS online activity

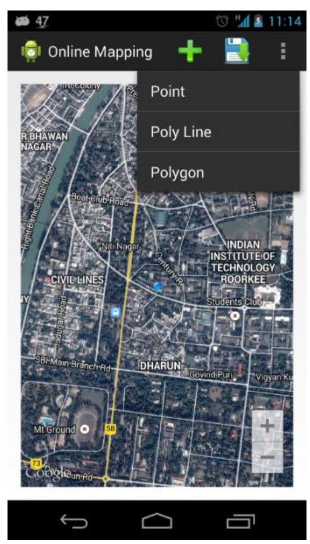

Figure 6 (a) AMS online activity with menu

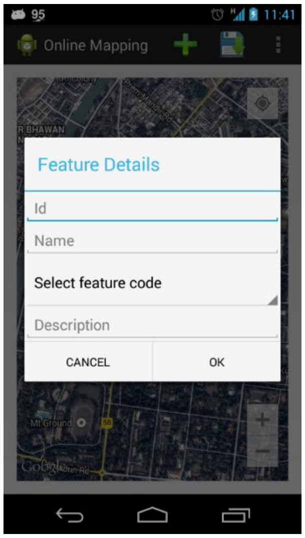

Figure 6 (b) AMS online activity with feature details

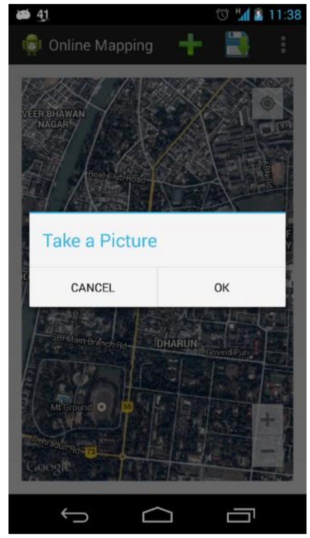

Figure 7(a) Take Picture dialog when saving asset information

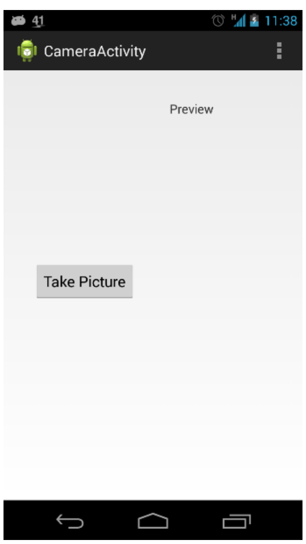

Figure 7 (b) camera activity for taking pictures

Figure 8 AMS offline activity

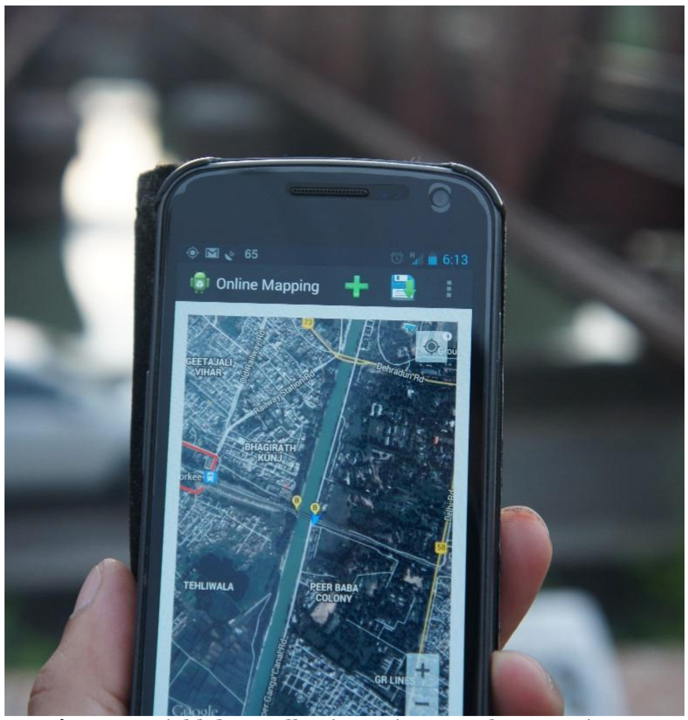

Figure 9 Field data collection using Google Nexus i9250

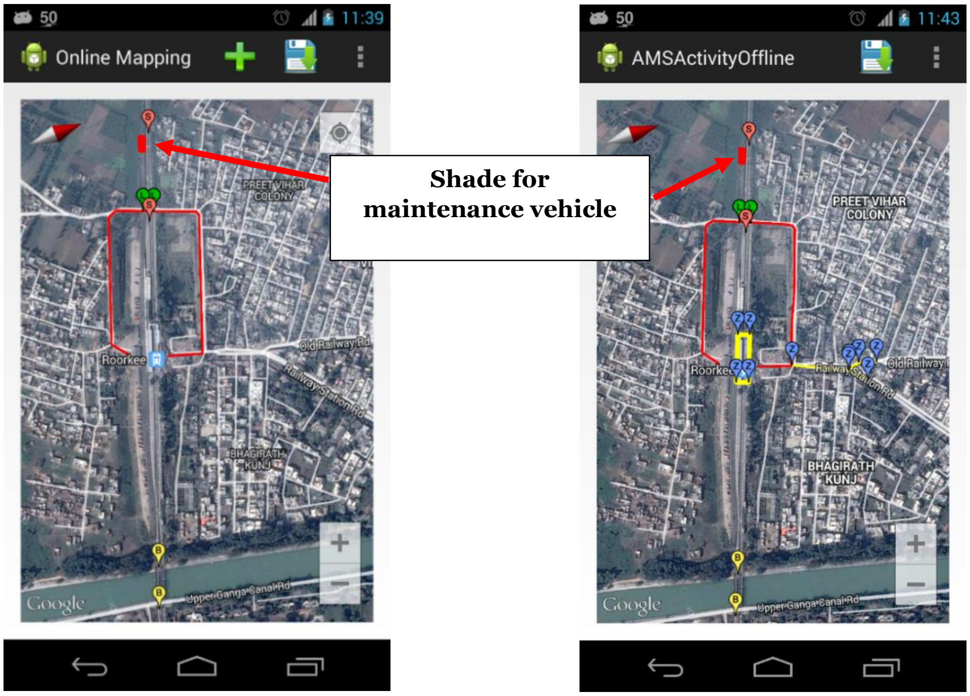

Figure 10 (a) collected railway asset information in online mode

Figure 10(b) collected railway asset information in offline mode

All You Need Is Content — Create Sophisticated Mobile Location-Based Service Applications Without Programming

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Abstract. Programming of sophisticated location-based service applications (LBS apps) for smartphones and tablets still requires knowledge in computer science and a lot of practical experience in the application of existing programming tools for the different operating systems. This means that only a fraction of possible LBS applications has been realized until today. In particular, smaller companies and organizers of one-time events cannot afford to buy custom developed apps; especially if one takes data-quality and maintenance cost of varying app content into account.

The presented AIONAV®-LBS app technology allows for creating offline-focused (but also online-capable) LBS applications without any programming skills and to publish them immediately. This is accomplished by a strict separation of content and user interface on the mobile device. The graphical user interface contains all the functions needed for general LBS applications, i.e. search functions, different graphical content presentation, but also highly advanced algorithms which are required for indoor and outdoor positioning, navigation, image recognition, communication, etc.

The multimedia content is stored within a database on the mobile device. This allows for an autonomous usage in case a connection to the web is not available. The creation of the database contents is done with the so-called LBS Manager PC-software, which provides the maps and allows for an arbitrary structuring of the data. Filling the database is simple by just using drag & drop, allowing everyone knowing how to use office software to create an own interest-specific, feature rich, offline-capable smartphone LBS app.

Keywords: LBS applications, LBS app generator, indoor positioning

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1. Introduction

Programming of sophisticated LBS apps is still a field for specialists. This has manifold reasons, which can be summarized, in two problem areas. First you have to master the basic technologies of LBS itself. These cover a wide field of theoretical knowledge, from cartography to navigation, from image recognition and processing to sensor technology up to the usability of mobile devices. Second, programming of mobile devices, despite extensive software libraries and development tools are available, is still very demanding and thus subject to computer scientists. In addition, sophisticated applications for various operating systems cannot be completely developed on a neutral platform yet, since the different operating systems do not support the same functions and level of access to internal resources.

This paper presents the AIONAV®-LBS app technology platform, which is designed to allow anyone to create an interactive, sophisticated LBS smartphone app of his theme of interest by just entering the appropriate content. The resulting user-customized app provides a rich, LBS-focused feature-set playing seamlessly together with the individual content.

Section 2 gives an overview about the characteristics of location-based service applications followed by an abstracted feature-description drawn from available LBS smartphone apps. In Section 3 the basics of the AIONAV®-LBS app technology are presented. In the following the smartphone app itself as well as the LBS Manager tool to model the app's content are discussed in detail. At the end a practical example shows the ease of use and the quality of the app for one typical LBS use case.

2. Location-Based Service Applications

Today using information concerning the domain of 'location' is a popular approach of applications to ease the daily life of consumers and professionals with modern technology. Such applications fall into the category of location-based services (LBS). These LBS applications are already an important part of the electronically augmented life of many people. As most people have already experienced, even "only" knowing one's own position is very helpful for various leisure and business use cases (e.g. car navigation).

To use a smartphone software application (app) as a personal access-point for LBS is an obvious choice, because it is the device a user naturally always carries around without having to think about an additional "LBS device"; this fact should increase the acceptance and usage of provided LBS. Additionally a smartphone has a serious amount of computing power and built-in sensors that are very favourable for the realization of desireable and user-assisting LBS.

2.1. Characteristics of LBS Applications

A reasonable usage application of an LBS smartphone app is for areas with a high density of different possible user-actions and/or -interest located within limited space next to each other. Typical areas are shopping malls, museums and alike.

LBS apps have to inform their users about things worth noting around the area they are located. Ideally, they help easen already present (location based) needs of users e.g. finding products, rooms etc. Therefore, one base functionality of LBS apps is a visualization of the location context around the user i.e. the map. That clearly helps a user at least in the way a paper map of that location would do.

Additionally to paper maps, an LBS app can improve the orientation purpose by marking the users position within the map; but doing that automatically and accurately is challenging within cost and convenience constraints of common consumer scenarios described in this paper. The reliability of accuracy is very important since a too (depends on the context) “wrong” indication of the user’s position is worse than no position regarding the given orientation purpose.

Further functionalities of LBS apps deal with enriching the location context with useful information. These classic location-based services are basically searching for and suggesting points of information (POI) for the user and visualizing a route to such POI.

It depends on the specific user how or why a POI is “interesting” and there will always be only an overlap of interest in a POI when talking to different stakeholders or users; so some kind of customization of information presentation has to be possible.

Stakeholders on one hand are users which consume or experience “products”. On the other hand, suppliers or creators try to improve the user experience of their offerings by using LBS. All parties have their own – often divisive – goals which however depend on the other party’s cooperation. So every LBS has to create a win-win situation somehow to be provided at first and also to be consumed at last – or in other words – to be successful at all.

POI in general are locations that someone could want to visit. An LBS app provides further information to the user regarding that POI (text, picture, video, sound, hyperlink etc.) and allows actions to be taken on that POI (routing to, communicate with, buy it etc.).

2.2. Feature Abstraction Drawn From Evaluated LBS Applications

There exist several LBS apps for indoor and outdoor usage. In principle they serve analog purposes but in different scope and application. So following stated examples could easily be translated to other use cases as well.

Most of the apps are focused on finding POI in the context of operation. One category of POI in that context always deals with user needs like finding restaurants, rest rooms or convenience like finding public transport, the parked car and leisure areas. These POI are not the reason one visits a location for, but for a person they are necessary and assumed or at least appreciated to be offered as sure infrastructure in such facilities/areas.

Another POI category deals with things, that users already wanted to find/buy before they came to that location or that are a reason for their visit. This category is the main topic for shopping malls or touristic regions and consists of consumer products or sightseeing hotspots. Additionally to known and wanted products/spots, a user could develop an interest in products/spots just while being around the initial location of interest. This behaviour could be triggered or influenced by sensing (seeing, smelling, tasting, hearing) products in a store, advertisement or tourist information boards. Available apps always consist of these POI.

Based on the creator and the app's purpose, the POI is structured into subcategories in a natural way. Translated to indoor-LBS, if one wants to find a certain product, he chooses the right store (thematically or by user preference), therein the right product category, down to specific product; this is the real-life shopping behaviour translated to a software app with the advantage over real-life of not having to walk during the (maybe only informative) search process.

Another real-life product/spot finding behaviour would be by asking shop staff or locals. This behaviour is ideally suited to be adopted/supported by a software-application because of obvious product database search functionalities. Both ways of finding something are implemented into these apps, reasonable and helpful to the user. Some apps extend these natural ways to look for products and present them as necessary goods for a specific context; especially meal suggestions and recipies lead to corresponding products (plus amount).

In most apps another key feature is "lists of POI". Such lists could be assembled by the LBS provider and could contain products currently on sale/discount, newly available products, best selling products, best italian restaurants etc. For convenience, a user can compose own lists of POI at home for a fast(er) access when needed while shopping/sightseeing; these lists collect needed products to buy (i.e. shopping lists), favorite products and shops as well as touristic hotspots to visit on a tour.

All these app-actions finally lead to one or more specific POI the user actually wants to walk to. All evaluated apps show the user a route to POI in the manner of a map/track representation or purely textual. These indoor LBS apps ask for manual user-input of the track start point or use some means of positioning technology.

3. The AIONAV®-LBS App Technology

All the typical features and characteristics of LBS applications are common, wanted and needed by users for useful LBS. But as mentioned before, it is not cheap to create sophisticated, full featured LBS applications from ground up as different expert knowledge is needed. A common and easy strategy to create an LBS smartphone application is to integrate popular web-based mapping services. These provide a programming framework and automatically fill-in the external map and context information. One's own information can be augmented on top of the provided layers of information in different ways. The easiest usage would be to just „pin" a wanted location to mark special interest. A more complex usage would be to draw additional polygons etc.

But with this approach one always needs a smartphone software developer who creates the overall business-relevant, functional smartphone app which also works soundly together with the mapping framework. Following this approach also includes the usual software development project risk, reasonable content quality concerns and difficulties with maintenance responsibility/cost as well as other imaginable factors. Further it is questionable if a user wants the LBS application to be always online as required by most web-based mapping frameworks. If online-restraints are not wanted (e.g. because of roaming charges for tourists), the question arises if a chosen software developer is able to produce an offline-capable LBS app, which in fact is considerable harder to do and therefore also more expensive.

The AIONAV®-LBS app technology aims to circumvent the outlined risk, cost, uncertainty and quality issues of a custom software development. This is accomplished by putting the focus onto the content during the app creation process, which is separated from the already done, generic, LBS-feature-rich, offline-focused app software development, which finally just „uses" the individual content. The app software development risks for a new app based on the AIONAV®-LBS app technology are not present anymore, because the app is finished and can be evaluated before a specific usage investment.[1]

The used generic LBS software and tools emerged from a location-provisioning framework developed during the last ten years and numerous research projects at the Institute for Building Informatics, Graz University of Technology, Austria. The research projects dealt with various aspects of the development of a disaster management system with a focus to build a usable mobile positioning system around a developed, patented inertial positioning algorithm for deployed forces (Walder et al. 2009, Walder and Bernoulli 2010). This has lead to demonstrator systems with mobile positioning and stationary control/command software components.

So this background formed a very solidly designed software framework which was extended to a complete LBS software framework in recent years (Krammer et al. 2013), assuring further, high quality, stable software applications. The developed software suite was partly commercialized under the common label AIONAV (*A*utonomous *I*ndoor *O*utdoor *Nav*igation). According to the intention of the paper the following sections focus on a description of the „LBS app generating“ aspects of the AIONAV system.

3.1. The AIONAV®-LBS App GUI

The AIONAV®-LBS app technology is characterized by the fact that the content of the app is strictly separated from the graphic user interface (GUI) with its functions for content manipulation and presentation. LBS app GUI as presented as the top layer in *Figure 1* is an operating system-specific mobile application that enables the interaction with the user on one hand and contains the algorithms to solve the typical LBS tasks on the other hand. These include information search and filtering, displaying maps and multi-storey floor plans, presenting and recording multimedia content, but also positioning and navigation according to different methods, either with the device-internal or external Bluetooth-connected sensors.

A concrete LBS app GUI has been implemented as an Android smartphone app directly using the Java-based LBS software framework. To be deployed to Apple devices, the Android app code has been ported to iOS in Objective C. The advantage of this approach is obvious. The platform-specific app development has to be done only once, regardless of the various LBS applications beyond. The porting of the extensive code base, whose development previously required several man-years, was carried out in a few weeks

[1] Several different apps based on the AIONAV®-LBS app technology are publicly available:
https://play.google.com/store/apps/developer?id=AIONAV+Systems+AG
https://itunes.apple.com/ch/artist/aionav-systems-ag/id917348430?l=en

thanks to the clear structure of the LBS framework. Porting to Windows Mobile and other operating systems is still waiting. However, the effort will be of the same order.

Special attention was paid to ergonomics and user friendliness of the app's GUI. Extensive usability testing for development projects and demo apps in various fields of application (shopping (Krammer et al. 2013), museums, didactics, etc.) yielded iteratively to a user interface, which can be operated intuitively, despite its powerful functionality.

Parameterization of the GUI

The need for a unified and easy operation of the app conflicts with the requirement of potential providers of LBS apps to give their apps an individual appearance and features. This concern is met by the fact that the generic app is highly parameterized and automatically adjusts appearance and capabilities according to the used and defined LBS content (see Figure 2). The hierarchical structure of the individual app provider's content may be defined arbitrarily as wanted.

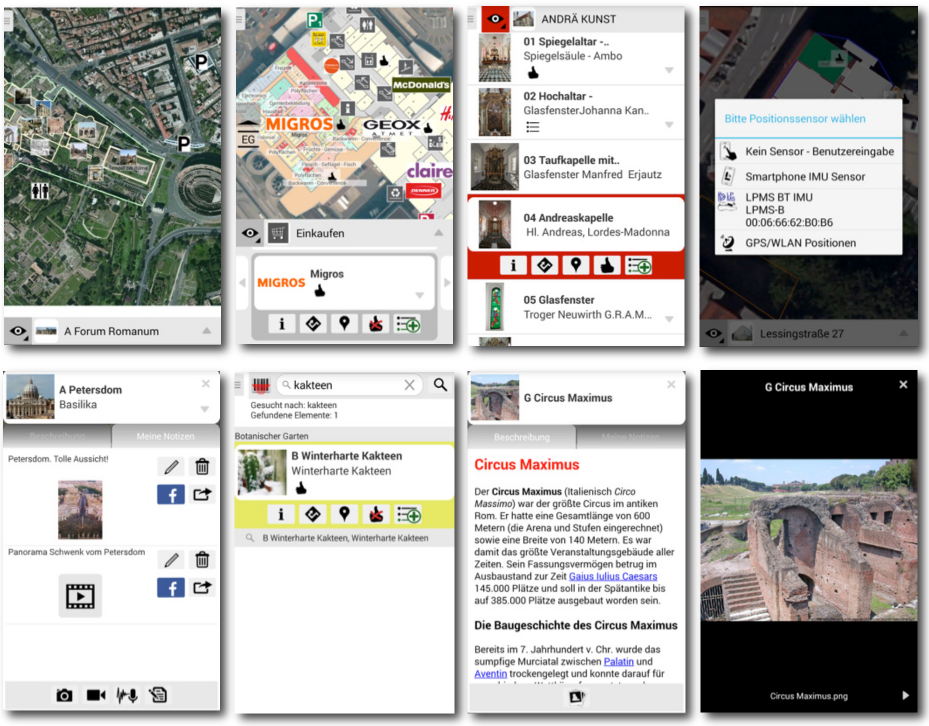


Figure 2. LBS app screenshots: Different applications and possible app features packed with one generic app.

Interactive Use

A particularly popular feature is the linking of the app content with user-created notes. This includes text, images, movies or sound recordings. Initially they are stored on the mobile device locally and can be integrated into the app with the LBS Manager later as well. These private notes can be shared on social networks or be sent by mail immediately as wanted by the user.

The practical applications of this are innumerable; from a travel diary to record keeping of a site visit, from the documentation of a design process to the observation of nature or complementing teaching contents with comments and observations of the student.

Positioning and Navigation

Since the LBS app emerged from a specialized research used in various navigation projects at Graz University of Technology, the LBS app contains all methods developed in this regard, particularly for autonomous indoor navigation. In addition to the usual positioning aids such as GPS and Wi-Fi, which achieve only a very limited accuracy, the patented algorithms for positioning with a foot-mounted inertial measurement unit (IMU) and positioning based on video content analysis (VCA) technology are available.

Positioning based on inertial navigation has been designed for professional first responders (fire fighters, police, etc.). In these applications it is important to determine and track positions in unknown or already heavily damaged environments without any external aid (Foxlin 2005, Walder

Figure 3. Navigation aid for blind and visually impaired people

2012). The method is suitable also in civilian environments, such as monitoring services or sensitive inspection missions.

The VCA method allows for a determination of the user's position along a route with the help of previously recorded images of the environment. The challenge was to code the complex algorithms in a way that they can run on a smartphone in real-time. It was mastered in collaboration with the University of Lucerne. The final goal of this feature is the navigation of blind and visually impaired people in urban areas. Thereby the navigation commands will be transmitted either via headphones or onto a bracelet with vibration sensors (Groves 2013, Bernoulli et al. 2011).

3.2. AIONAV®-LBS Manager

The LBS Manager is a PC-software used to structure/model an LBS app's content and to link multimedia content to a location. The latter is not compelling; often it is just a need to bring structured, multimedia content to a smartphone quickly (e.g. teaching content, procedure plans, manuals, etc.). All information is stored within a database; the hierarchical structure can be freely defined by the user. The LBS Manager runs on a PC locally or can be accessed via the Internet. Similar to the operation of the LBS smartphone app, the LBS Manager is self-explanatory and explicitly developed to be operated by laymen.

The app content is divided into information categories, which are structured hierarchically. The structure of the content can be freely defined. A new category may be defined at any point within the tree of categories. By creating this structure, the later appearance in the LBS app GUI is defined too.

The multimedia data itself is assigned to so-called points of information (POI). POI locations are represented by a polygon that is either filled or outlined on a geo-referenced pixel-based map or a picture and optional vector-based floor plans. A category can contain several POI, such as several sales areas of the same product in a shop or infrastructure facilities of the same type at different places.

As can be seen in *Figure 4,* POI information can further consist of texts, images, movies, sounds or links to different on- and offline sources of information (other apps, web pages, etc.). The text is stored offline within the database in HTML format, but one can embed links to all other common information on the web as well, resulting in flexible on-/offline app content as desired. In addition direct access to the functions of the mobile device is available and as already mentioned, direct links to social networks are possible.

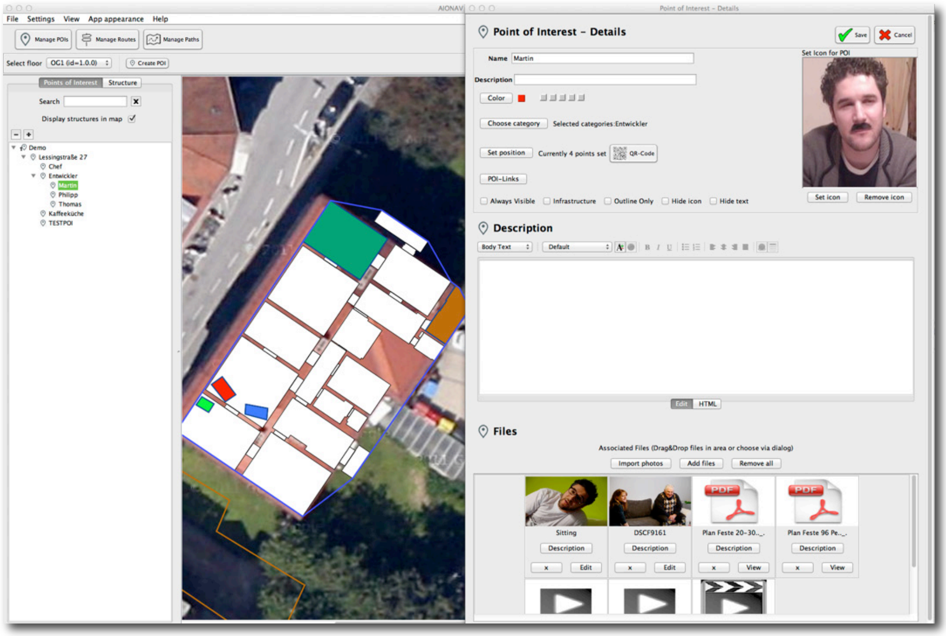


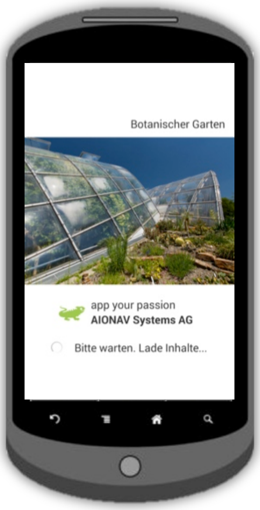
Figure 4. LBS Manager: POI as element for structure, spatial and multimedia information

Since pictures are often not available in the required size or format, the LBS manager provides a simple image editing tool. Entering styled text is facilitated by an integrated HTML-WhatYouSeeIsWhatYouGet editor. Additionally to the LBS Manager, simple tools are available to download maps from Open Street Maps, Google Maps or World Wind, as well as for the import and structuring of floor plans.

To publish the generated app in an app store, its database gets coupled with the generic LBS smartphone app to form a specific LBS app for that content; because of the automatically content-adjusted app features, icons, app name etc. an app user will not be able to tell that the final app was not specifically programmed for that use case e.g. a specific museum's information/guiding app.

So the content provider is able to generate an app by entering and maintaining the data solely via the LBS Manager. This approach reduces cost and development risk as well as enables self/expert-controlled content quality and flexible content management over the app's lifetime as wanted by the content provider, i.e. the app creator.

Starting from template databases for a variety of use cases can further accelerate the LBS app creation process. The possibility to directly import POI from existing databases, such as corporate or telephone directories is envisaged.



4. Creating an LBS App for the Botanical Garden Graz

The Botanical Garden Graz[2] is one of the oldest botanical gardens in Austria; with around 14,000 plants it is one of the most renowned gardens in Europe. It is affiliated to the Institute of Plant Sciences at Karl-Franzens University Graz.

The garden is accessible to the public free of charge whereupon the spectacular architecture of the greenhouses is an attraction by itself.

The requirements of an app for the Botanical Garden Graz were widespread, but showed a clear need for an LBS focused app. Also easy maintenance of plant data within the app was a requirement, because entering plant information is an expert task and plant inventory changes are common. Further the app should serve three very different groups of users:

- Visitors to the Botanical Garden,
- Students at the Institute of Plant Sciences and other institutes of the university (e.g. pharmacy with the medicinal herb garden),
- The employees of the garden.

Creating an app should be as simple as possible; before starting the POI creation process within the LBS Manager software, it's important that some considerations are made: To whom the app is primarily addressed, how it will be structured and how its GUI should look like. Therefore it is necessary that the information contents, i.e. the texts and images, are previously procured in the right formats and made available digitally. At the Botanical Garden a printed guide for visitors exists, so the structure of the app has been modeled on that basis.

Figure 5 shows some features of the final app[3] of the Botanical Garden Graz. In the following it will be described how it was done to get that feature rich LBS app by just entering data into the LBS Manager.

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[2] For further information see http://garten.uni-graz.at

[3] App publicly available:
https://play.google.com/store/apps/details?id=com.aionav.lbs.spot.botanischerGartenGraz
https://itunes.apple.com/ch/app/botanischer-garten-graz/id921183231?l=en&mt=8

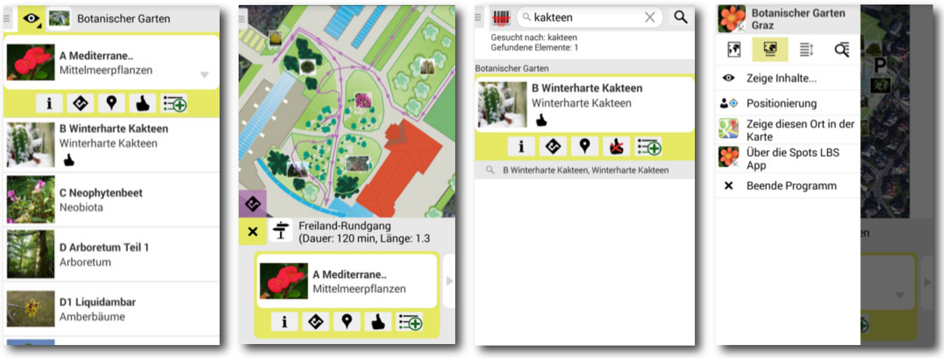

Figure 5. LBS app screenshots: Different features of the final Botanical Garden Graz LBS app

4.1. Structuring and Entering the Content

According to the printed guide the app was not structured by botanical order principles, but accordingly to the geographic occurrence of plants, i.e. by continents and regions, which in turn has its counterpart in the compound of the garden. As a basis for the local context representation served a painted plan, that was embedded in a geo-referenced satellite image of the environment.

The hierarchical structure of the app has been deliberately kept flat in order to enable the visitor a rapid overview of the whole garden:

Botanical Garden

- plant species by region of origin
  - sub region
    - plant
- greenhouse
  - climate zone (for example, tropical house)
    - plant species by region of origin
      - plant
- general information
  - Botanical Garden
    - activities
  - environment
    - parking
    - public transport
    - restaurants
    - etc.

Reordering an existing structure is very simple and possible at any time in the app creation and maintenance process. An element of the structure tree with all its sub-elements, can be easily inserted to any new location by drag and drop. (see *Figure 6)*

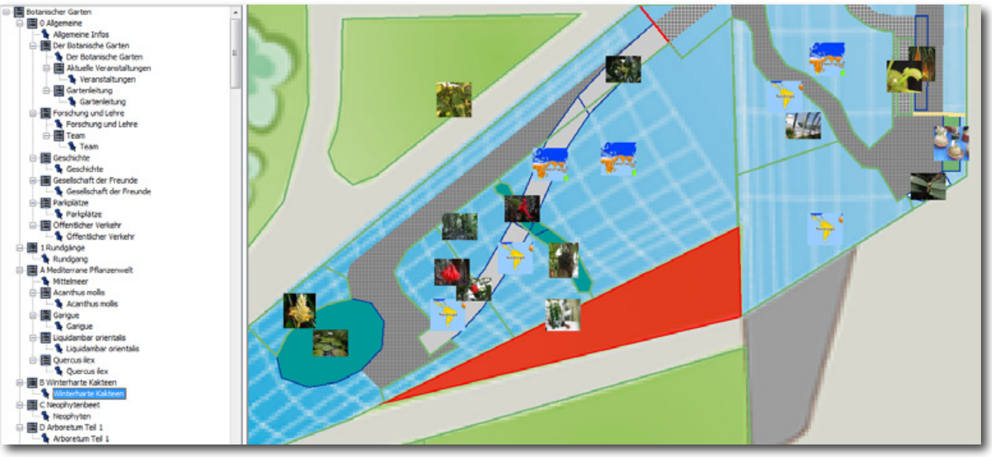

Figure 6. LBS Manager screenshot: POI structure tree of the Botanical Garden app's content

4.2. Routing

As the footpaths are not automatically recognized as such on a pixel image, the map is augmented with an invisible network of paths implemented as a 3D routing graph. The creation of the paths is done graphically and very simple within LBS Manager; it consists of a network of nodes and corresponding connections. Attributes, such as priorities or one-way directions, can be assigned. The created path network allows for an automatic point-to-point routing within the smartphone app. (see *Figure 7, left)*

4.3. Guided Tours

If you want to guide visitors through the garden or, e.g. specify a thematically organized round trip for the students, the software allows the definition of tours. A tour basically consists of a subset of POIs, which can be ordered in a user-defined, tour-specific sequence following an arbitrary walk path. (see *Figure 7, right)*

4.4. Search and Navigation

Searching for information is done via alphanumeric input of a search term or, depending on the ability of the smartphone, also by voice input. All search results are listed subsequently. If you want to navigate to the desired

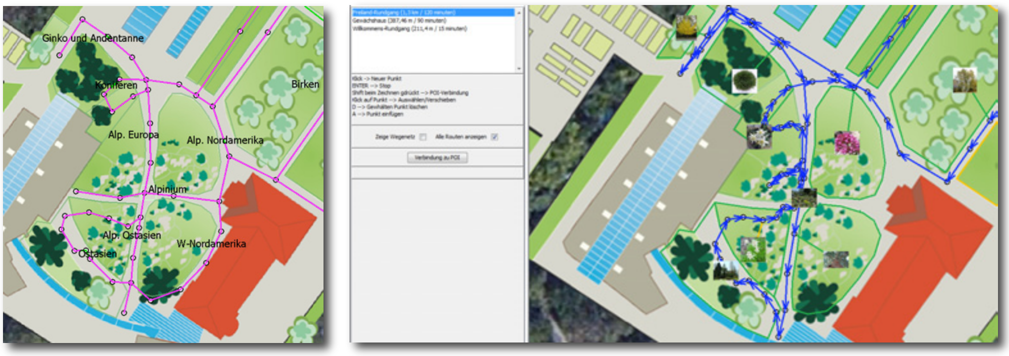

Figure 7. 3D routing graph (left); Definition of a specific tour with linked POI (right)

POI, the shortest route to the POI is displayed on the map. The own position can be the current GPS location or a manually entered point on the map, if no GPS is available. In addition, ad-hoc positioning by scanning of (LBS Manager generated) QR-codes on site is available and very suitable for museum-like use cases.

If you move to the intended POI, your position can be tracked continuously, if GPS or Wi-Fi positions are available. In environments without such positioning options AIONAV® inertial positioning and navigation can be used.

4.5. Linkage with External Sources

Undoubtedly it is a great advantage if all core functions of an app can be used without connection to the internet. It saves not only roaming charges, but is a must at many occasions when no network connection exists. In addition the LBS app can start other apps on the mobile device without leaving the context of the LBS operation at hand.

If an internet connection exists, it can be used in many ways, either through the imposition of hyperlinks in the texts of a POI or by calling web pages directly from the information window or scanned by appropriate QR-codes.

5. Conclusion and Future Development

Without a doubt the simple and rapid creation of sophisticated mobile applications with the tools mentioned above will increase the availability of LBS applications. In particular, applications only needed for a single event or dedicated to a very limited group of users are possible now.

In schools novel opportunities now exist to disseminate interesting and attractively presented course contents via the scholar's smartphones.

A further increase of acceptance of the new technology will be achieved, as soon as POI that are commonly used, such as the nearest restaurant, surrounding attractions, etc., can be downloaded directly from existing databases, such as telephone directories, websites and specialized information providers. A good example is Wikipedia, which allows for integrating their contents in various formats into other applications. A certain standardization of information formats will be necessary to get full access to a wide variety of sources.

Another major goal is to develop LBS solutions also for blind and visually impaired people. Here it is especially important to increase the safety of navigation and to define a 'language' for vibration-bracelets which goes beyond simple commands for directions.

Additionally to further increase the inherent possibilities with the AIONAV®-LBS app technology it is planned to define an easy-access LBS-service interface. This will allow third party software to access basic LBS functionality from information collection to arbitrary positioning services to use them within their context of application. This decoupling of expert tasks should enable arbitrary business applications to implement needed offline LBS functionality easily and future-proof, without loosing focus on their core business application. A first application regarding the development of an environmental context-service interface, which was evaluated within a construction workflow application, is presented in Krammer (2014). The envisioned easy-access location context provisioning strategy concept for third party applications is presented in Krammer et. al (2014).

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Providing Emancipation through Maps

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Extended Abstract

There is a growing number of works, not only in geographical environment, responding to the spatial needs and claims of the disabled. Disability is a broadly discussed concept, based particularly on two aspects: on the physical, health status and on the social situation of the individual (Mowl and Fuller, 2001 or Gleeson, 1999). It is generally understood that some kinds of physical condition, or rather the lack of them, of a person may lead to his or her social inferiority, which may be a gateway to further oppression.

In our aim - to study and describe the accessibility of city space - we cooperate with a group of disabled, above all on wheelchair, who have considerable navigation difficulties. This cooperation, lasting for more than four years, resulted in a number of real applications, such as a wheelchair map of Brno city, the second largest settlement in the Czech Republic.

However the process of creating suitable spatial representation appears to be a lot more sophisticated than just to “draw a map”. Current IT development may lead us to the impression of relative ease of such process, but the results may be confusing.

Accordingly, we decided to base our aims on profound cooperation with the disabled. In order to empower them, there has to be a gradual change of the status and roles of people involved in the research. The geographers should pass the role of spatial experts to disabled people and rather assist during this process. In other words, the experience of disabled was the main constituting element of research itself and its outputs (more about this in: for example Imrie, 1996).

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The possibility to identify and define spatial priorities by users themselves resulted in a succession of surprises on both sides of this process – the researchers and the partners (more on this in: Jaňura, Toušek, 2012). For example, the city centre is naturally barrier space, but for each of the research partners there is an individual net of ways to navigate through. The orientation of a person may be based on very specific entities, such as church towers. In general, most of research partners do have serious orientation difficulties rising from their life experience (typically: significant part of their young life spent behind the gates of various medical institutions) and socio-cultural position (wheelchair users often experience the status of "different" or "less" human). And finally, the wheelchair cannot be presented as a uniting element of a social group; rather it should be understood as a part of individual's life story.

Thus, as indicated "normally designed" map frequently appeared to be insufficient and far from the ideal representation of city space. This may lead us to important points on the cartographical side of the research.

At first, wheelchair users represent a heterogeneous group of map users. Therefore the need for different types of information is apparent. Although a number of cities, including Brno, produce detailed accessibility maps, anybody may feel that the information about the accessibility is limited because the map literacy may be limited too – thus, this factor is worth serious consideration.

For that reason, the accessibility maps should be as intuitive and easy-to-understand as possible. The optimal visualisation method seems to be the usage of special map signs combining the qualitative information, i.e. the type of location, with quantitative information, i.e. the level of accessibility (Otrusinová, Řezník, 2013). Such method of creating accessibility maps would be optimal for paper or simple on-line maps.

However, the ongoing research, i. e. Mulíček, O. (2013) showed that many wheelchair users prefer other ways of presenting reality as they perceive space differently than people without impairment. This may be quoted by one of the members of the focus group who stated that there should be "something as a barrier-free Facebook" (Jaňura, Toušek, 2012).

Nowadays, such applications begin to appear, i. e. the Czech web application "Vozejkmap" which works as a simple social network with users enabled to share the accessibility data. There is an obvious advantage of this application over paper map: the possibility to run it on mobile devices. On the other hand, the information about accessibility is presented by a map so there is no other option of representing space and spatial relations.

The solution leading to the establishment of a barrier-free network of streets and locations in the city centre could be a mobile map application based on a social network which works with adaptive visualisation. Other components of such service would be the exact destination of an individual and the target destination, his or her individual requirements (such as no crooked surface on the trail, etc.) and particularly the database of accessibility data.

All the users could actively participate in the mobile application. More information about participation is described in i. e. Arstein 1969, Connor 2007. It would also enable to adapt the product for every single person and their special needs. An individual can read a map displaying the accessible points in the city; other one may view pictures from the particular places while someone else could hear the information. All of this is advancing the philosophy stated before: to base the product on the needs of users and help them to shape the result.

This information – accessibility of a place or of a part of space (street, etc.) may be used further. The service filled and controlled by the users is going to carry the primary accessibility information, but in a broader view, such device (application, service...) is going to be capable to collect a large sum of accessibility data. It is beyond doubt that these data – generalised, periodically evaluated and confronted with the official structures – are able to tell the story of city progress and reflect the emancipative power of such device.

The resulting device may open the new spaces for a large number of people and enforce them not only in the spatial but also on the socio-political level of life. The stated principle of “bottom-up” work appeared to be effective and regardful attitude towards accessibility mapping. These assumptions lead us to further work and cooperation on the research for accessible (city) space.

The process of building a social network which includes the map application and works with the position and individuality of the user is broadly related to location based service. Our aim is to create socially responsible service and continue with the development in further research.

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Outdoor LBS – relationship between users, providers, and place.

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Extended Abstract

An increasing number of local decision-makers are commissioning smartphone applications to promote their city, often including LBS features. Although more and more resources are invested in this, it is difficult to quantify how often these applications are used; most of the information currently published concerns successful applications, while the systematic review by Nielsen (2014) showed than many attempts had been unsuccessful. Considering leisure and tourism activities in the outdoor, smartphone apps have the potential to improve the outdoor experience of users but also to inform the provider (e.g. municipalities, tourism offices, or private companies) on the use of places.

Focusing on the outdoor use of the LBS apps, we identified three actors: the *provider* of the application, the *user*, and the *place* that relates both together. We also identified possible interactions between these actors, with information being exchanged from the user to the provider or from the provider to the user. These interactions are tightly related to the place, and therefore the applications facilitate them. We believe that modelling these interactions enables a better understanding of mobile apps potentials, and therefore that considering them is crucial to the development of relevant mobile applications.

Our model defines four types of communications: **Information** is a mode of interaction where the user receives localised data from a provider relevant to a place. Considering the mirroring communication exchange, from user to provider, **Feedback**, corresponds to users giving information to a provider about a place. Adding the possibility of users to communicate with

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each other, **interaction**, is when the users share information with each other about a place. Finally, applications where provider and users exchange information relevant to places, consist of **participation**.

The impact on users is different depending on each application; either increasing the sense of security, making places more real, or giving a sense of ownership (Farrelly 2012). Depending on the intention of the provider, either mode of communication should be used. Reflections on these communication styles would support providers of smartphone LBSapps to design adapted smartphone applications that efficiently promote businesses.

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Ethical and Political Responsibility in Location Based Services - The Need of Implementing Ethical Thinking in Our Research Field

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Abstract. Rapid technical developments in Location Based Services (LBS) lead to new applications and possibilities in many personal and institutional sectors. LBS became a powerful instrument in predicting consumer behaviour and preventing crime. The dichotomy between privacy and security leads to new ethical issues that have to be addressed. We are willing to reveal our personal data at many occasions to get a small benefit or more convenience in daily life. Although we are always lagging behind the latest developments in respect to data protection and the privacy issue, the politics constantly has to adopt the law with regards to LBS, privacy and anonymity. The trend is towards continuous localisation and tracking of certain people or even the whole population. Users of electronic devices should get the right to withdraw their consent for transferring location based and other personal data at any time. They also should get clear and comprehensive information when and for what they give away their personal data and location and their further use. The LBS research community should keep privacy and ethical implications in mind from the very beginning of their research projects and already ongoing research activities. Meanwhile LBS influences every individual's life, hence ethical issues have to be debated within the research community and taught our students. Technical Universities and especially the developers of LBS can no longer keep their credibility without cooperating with ethical experts or an ethical committee.

Keywords. Privacy, Values and Norms, Ethical Committee, Politics

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1. Introduction

When we talk about LBS most technical researchers imply that it is mainly about further enhancing technologies and algorithms including the development of new advanced Apps to improve personal navigation and to deliver location oriented information just in time to a single person or group of users. Technical developments of GNSS and other ubiquitous positioning methods can become a very powerful tool when tracking an individual or a whole population based on automated algorithms. Ng-Kruelle et. al. (2002) elaborate it to the point in their paper "The Price of Convenience: Privacy and Mobile Commerce" that due to technical developments users are often only vaguely aware of the fact that they transmit their current location and trajectory to navigation and guidance service providers while at the same time receiving aggregate information based on data transmitted by other users. In the following we pick up current developments with regards to ultimate users and the LBS community where we question if the researcher and provider have taken privacy and data protection into account adequately.

For instance, in emerging Intelligent Transport Systems (C-ITS), the positions of all road users have to be transferred to and used by the service provider in order to improve road safety and efficiency of the road network. New technologies, such as cooperative positioning (CP) (or also referred to as collaborative positioning) of a group of users (see e.g. Grejner-Brzezinska and Toth, 2013) are developed in particular, to deliver more robust positioning performance and to increase positioning quality using shared information between the users that operate within a defined neighbourhood (Kealy et al., 2014). Such developments show that user's privacy frequently is exchanged for convenience. Ng-Kruelle et. al. (2002) state that individual consumers of such navigation services must always balance costs (e.g. loss of privacy pertaining to personal location and driving speed) against benefits obtained (e.g. navigational support, improved road safety, collision avoidance, etc.).

Apart from commonly employed standard LBS services and the provision of navigation support, several worldwide researchers are focusing on the analysis of the movement behaviour of pedestrian users using cellular phone data. Typical examples of investigated application fields include the determination of commuting patterns for downscaling of movements in road or street canyons, tracking of large crowds at mass events, studies of tourist behaviours, shoppers, public transport users, etc. Here it is often stated that the anonymity of the users is or shall be guaranteed. Researchers in Estonia (see e.g. Saluveer and Ahas, 2010) are using passive cellular phone data from a major provider for their studies. In contrast to active mobile positioning where the location of the cellular phone is asked following a specific query, passive positioning data is automatically stored in memory or log files of mobile operators (i.e. billing memory, hand-over between network cells, home location register, etc.) to the precision of network cells. The database of passive positioning data used in the studies is the locations of all 'calls out' (calls initiated by the respondent, not received calls) (see Ahas et al., 2010). The assigned random ID, generated by the operator, which is not related to phone or SIM card number, but remains constant for every phone, enabled them to identify the calls made by one person.

Hence, this possibility enables the researchers to link the person's calls throughout the whole study period. In this case the ultimate consumer has no choice to give his informed consent to put his data at disposal or to disagree, since he doesn't even know that his data is being used to analyze several aspects and to be turned into a source for population statistics. Such a course of action poses a severe threat for cellular phone holders as the random ID assigned to them keeps constant over a whole study period. Mobile operators can then aggregate personal and private geographical data from log files, such as location points or movement vectors. Mascetti et al. (2007) argue that "in general, the association between the real identity of the user issuing an LBS request and the request itself, as it reaches the service provider, can be considered a privacy threat. [...] Simply dropping the issuer's personal identification data may not be sufficient to protect user's privacy". Therefore it should become mandatory to inform LBS users when and what for they are giving away their personal data and location information but that they also have the right of refusal.

The remainder of the paper is organized as follows: The price of convenience which LBS users pay is elaborated in section 2 followed by a brief discussion of adopted anonymisation strategies for privacy protection in LBS in section 3. The struggle between maintaining privacy versus security is discussed in section 4. Then in section 5 legislative and political activities in the context of maintaining and protecting user's privacy aspects are reviewed. In the concluding remarks (section 6) the need and postulate for the establishment of ethical committees at Technical Universities and/or the cooperation with social scientists is raised.

2. The Price of Convenience

The publicist Frank Schirrmacher (Quarks & Co, 2014) argues that we are almost unperceived navigated on the internet. For instance, advertisements that are placed on the result page of a search engine, a book recommendation on an online booksellers start page that might be interesting, or a personalised add sent home by a discounter in dependence of changing shopping habits of users due to changes in their life. An example would be a reaction to pregnancy of a user. This happened to 16 year old girl in the US whose parents found out that she is pregnant because of all kind of baby advertisements suddenly were addressed to their daughter (Quarks & Co, 2014). Every day more and more data is collected from us, turning us into specific usable 'profiles'. Meanwhile every one of us is registered in several profiles, whether it is shopping habits at the discounter, buying tickets for cultural events on the internet, search terms in search engines, cookies from web pages, surveillance cameras in public, and so on.

The population is beginning to get aware of that. More or less conscious and with an astounding indifference, many people are willing to give away and to disclose their data for a small benefit or convenience. They negate the fact that all their data is collected. There is a possibility that we may be intercepted, monitored and tracked. 74% of the Europeans see disclosing personal information as an increasing part of modern life (European Commission, 2011).

"Digital technologies are setting down the new grooves of how people live, how we do business, how we do everything" (Lanier, 2013). Quite a lot of LBS are and certainly will be based on that life style. "We want free online experiences so badly that we are happy to not be paid for information that comes from us now or ever". Lanier (2013) and many researchers for LBS strive for a future where..."In a world of digital dignity, each individual will be the commercial owner of any data that can be measured from that person's state of behavior".

One application of LBS ended up in that parents track their children enforcing them to answer their phone call, otherwise they can remotely deactivate their mobile device. These children are socialized in being tracked down all the time and we do not know how this will change the next generation's habits and understanding on privacy. Justice Louis Brandeis, cited in Lanier's Book "Who Owns the Future", (2013) gives us a rather radical definition of privacy. It is the "right to be left alone". It is up to us to set limits and to initiate a broad discussion on the use of our data with regards to our privacy and its ethical and political dimensions. Values shape people's decisions, which in turn, determine human destiny. Any influence on human values is a potential influence on the future (Sperry, 1983).

What we define as privacy and intimacy today is far from 100 years ago. Our research outcomes are shifting and shaping common standards, constantly influencing political and social structures as well as decisions, no matter if we come from the 'hard' or 'soft' sciences.

3. Anonymisation Approaches for Privacy Protection of LBS Users

Several researchers raise major concerns for the protection of personal location information of LBS users. Damiani et al. (2009), for instance, described an approach where the user's privacy is protected based on forwarding the LSB provider a coarse instead of the actual user location. This strategy is termed as 'obfuscation'. Commonly employed techniques for privacy preservation are spatial cloaking methods or spatial generalisation and they are briefly introduced and discussed in the following.

Spatial cloaking is extensively applied to provide spatial k-anonymity. In general, k-anonymised means that each record is indistinguishable from at least k-1 other records with respect to certain identifying attributes. As defined by Kalnis et al. (2007) this concept means in the context of LBS: "given a query, guarantee that an attack based on the query location cannot identify the query source with probability larger than $1/k$, among other k-1 users". In order to prevent privacy violation, the LBS user can avoid providing his exact location and, instead, send to the service provider not his personal data but a generalised area that includes his location and the location of other k-1 users. The LBS provider then replies to this generalised request with the queried result which is the closest one to any point of the generalised area. Hence, the ID and exact position of an individual is replaced by an anonymising spatial region (ASR) (also termed as cloaked region CR) containing the client that issued the query and k-1 other users, while the privacy metric is defined by the probability $1/k$ of identifying a user in the respective ASR. In other words, then a set of candidate results that satisfy the query condition for any possible point in the ASR is sent by the anonymiser to the LBS user.

Damiani et al. (2009) used the example that a person's health problems may be revealed if the person is currently inside or very close nearby to a hospital. A hospital defined as ASR is obviously a sensitive place for certain users. The authors demonstrate and argue that "privacy breaches may occur because existing obfuscation techniques are unable to protect against the inferences made by linking the geometric information with the semantic location which, depending on the perceptions of users, may represent sensitive information. Thus protection of sensitive location information requires techniques that are able to take into account the geographical context in which users are located, in particular the semantic locations and the spatial distribution of population, as well as the users' privacy preferences". Hence, using such comprehensive techniques for the protection of location privacy against location inference attacks the LBS subscribers can specify location privacy preferences about the places that they consider sensitive as well as the desired degree of privacy protection.

Spatial generalisation is comprehensively discussed and assessed in Mascetti et al. (2007). The typical scenario assumes the existence of a so-called Location-aware Trusted Server (LTS). The server stores precise location data of all *k* users, using data directly provided by them. Hence, the LTS has the ability to efficiently perform spatio-temporal queries to determine which or how many users are in a certain region. Then the LBS provider fulfils user requests and communicates with the user through the LTS. The answer from the service provider is routed through the LTS to be redirected to the specific user with a refined result (Kalnis et al., 2007; cited in Mascetti et al., 2007). The three main goals in such an anonymisation approach are: (a) to guarantee the user's privacy by ensuring that a sufficiently large number of potential users are not distinguishable from the issuer; (b) to preserve the quality of service by minimising the size of the ASR area; and (c) to be efficient, since it must be computed online (Mascetti et al., 2007). As the first two goals are somehow contrary to each other regarding the size of the ASR and therefore are partly difficult to be achieved at the same time because of limited processing time and power, a LBS query result may not be very precise and satisfy the user when he receives too many search results which are not relevant to his current location. Considered that only a few other users are present at one time and they are spatially far apart from each other, the ASR will be quite large. In this case, the user will only receive imprecise results from the service.

Kalnis et al. (2007) identified other challenging problems associated with such generalisation algorithms. In cases where a user issues continuous similar LBS queries it is difficult to preserve anonymity when the same query from successive locations is asked. Then it is likely that an attacker can disclose the identity of the querying user. Further problems may arise when the attacker has additional information about the preferences of a certain user. The following example is used by Kalnis et al. (2007): when a rugby fan is asking for the location of the nearest rugby club and his ASR contains only other female users in addition to him, the attacker may infer him as query source with higher probability.

As can be seen from the examples described above anonymisation approaches have several shortcomings and are not able to completely guarantee the anonymity of a LBS user. "In practice, users would not be reluctant to access a service that may disclose their political/religious affiliations or alternative lifestyles" said Kalnis et al. (2007). Especially users currently located at sensitive places, such as in a hospital (see example from Damiani et al., 2009), normally are not willing to reveal their precise location and give up their privacy completely. Hence, further research and developments are required for privacy protection of LBS users followed by an investigation about the users' willingness to give away their data. In the following section the ambivalence between maintaining privacy of a person versus security is discussed.

4. The Strive for Maintaining Privacy versus Security

Beresford and Stajano (cited in Kido et al., 2005) point out that location privacy is "the ability to prevent other parties from learning one's current or past location" thus the "protection of location privacy is one of the most significant issues of LBS". Location technologies developed over the years, such as GNSS, cellular location-based solutions, indoor positioning systems, etc., have resulted in new services that make use of both location-based and context-awareness. Enabled by modern telecommunication technology, convenient services promote changes of lifestyle, thus 'total' privacy is increasingly difficult – perhaps impossible – to maintain. The benefit offered by each 'convenience' is in general associated with a loss of privacy – that is, services can only be effectively provided when the service provider has access to the consumer's location, personalisation data, or both (see Ng-Kruelle et al., 2002).

Meanwhile LBS are much more than every one of us can imagine. It is possible to retroactively track an individual by creating its movement behaviour and profile. It is a highly fractured scientific field where one research group, e.g. technical or social scientists, geodesists, geographers, cartographers, App developers, etc., sometimes only vaguely knows the results of other research teams, not taking into account that their results in conjunction with the results of another team can be used to create a totally new and questionable tool. Nowadays LBS data became part of a lucrative business for trusts like Google, Apple, Samsung, etc. They are of striking military interest and of equal interest for intelligence services. LBS data can be turned into a powerful instrument, when e.g. at the first sight harmless data and tools that have been developed in LBS research projects are brought together and merged. Politicians and police departments are using LBS generated data for controlling parts of cities and suspicious citizens. The collection of big data and data mining are wide spread and most of us do not know when and which data of us is collected. That also happens with data we generate and track for LBS. It seems likely that within the next following five to ten years, when looking at the sky, we might see five Unmanned Aerial Vehicles (UAV's), three of them are delivering parcels but the other two are following us at every move we make turning us into suspects. This scenario is an example for how important it is to critically consider and to question the technology that we develop with regards to political and social effects, not to mention their liability for abuse. This implies the need to discuss potentially negative effects within our own research community and with social scientists to publish our warnings. We argue that it needs a further step towards an ethics committee to investigate together with social scientists the social, political and ethical dimensions of a new research project and its possible outcomes.

What can be seen from Figure 1 is one and the same part of a city with four different data sets such as social structure, crime rate, unemployment rate and former detainees that can be merged for a certain district. In the U.S., such programs are already in use in some cities. In Chicago, the forecast is derived from analyses of social networks and the criminal files of recent years. The police computer creates a so called ‘heat list’ with the 400 most dangerous citizens of the city. The list specifies who may be involved most likely at the next shooting or major crime. The police visits these citizens for prevention purposes and warns them not to commit serious crimes. So on one hand the population in such high crime hotspots loses a part of their privacy, on the other hand the police can grant more security. In fact due to this measures in Chicago the crime rate dropped by 38% (Quarks & Co, 2014).

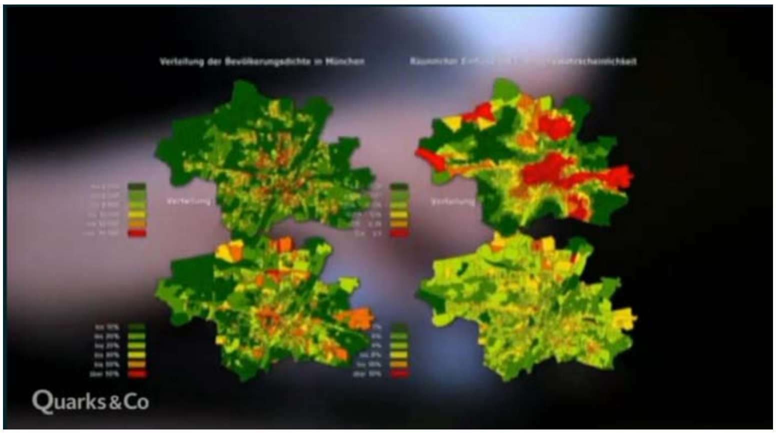

Figure 1. Merging different data sets for crime prediction (Quarks & Co, 2014).

On a national and international level public policy, law and regulation continually have to strive for politically defensible positions involving protection of individual rights and collective security (Ng-Kruelle et al., 2002; Perusco and Michael, 2007).

The EU research project CAPER (2014) will go one step further. It is planned to investigate all of us at an unprecedented scale. All available data on the network of a person such as photos, videos, sounds, other files are planned to be tracked and evaluated by computers. The goal is to make impending crime of a person predictable in order to thwart them. Public surveillance cameras are used for screening unusual behaviour of passers-by. “We slowly recognise that science and technological progress at best can cause that more people can live a better life. However, this is achieved only for a certain time until new boundaries appear on which the same and in addition other problems arise that might even be bigger” (compare Sperry, 1983). At the moment streetlights are equipped with surveillance cameras. Hence it becomes very cheap and efficient to combat crime. In the future, it is likely that completely automated UAVs with cameras and location sensors including GNSS and inertial sensors (see Figure 2), can merge datasets, such as judicial rulings, police protocols and will be able to create movement profiles and can detect conspicuous behaviour of any suspicious person. Whereas electronic surveillance clearly was seen as an intrusion on personal freedom, today, many in the US would be willing to accept privacy restrictions and allow the government far “greater liberty to use surveillance technology to combat terrorism” (Olsen and Hansen 2001, cited in Ng-Kruelle et al., 2002).

Figure 2. Tiny UAV equipped with a camera and location sensors (RIANOVISTI, 2014).

5. Legislative and Political Activities

On the webpage of the German government commissioner for data protection and freedom of information, Schaar (2014) informs about using LBS but there is no regulation, law or ethical standard and guideline relevant for App developers, LBS researchers, providers or users. Schaar promotes that providers should comprehensively inform users of LBS in advance about which data is collected and how and to whom they are sent. The data protection law is a mandatory requirement for the transfer and use of location data with the subject's consent only. The users should have the possibility to withdraw their consent at any time. Furthermore, the customers of LBS would be able to turn off the location temporarily or permanently. Schaar argued that "the consideration of data protection is in the interest of the seller. Without adequate protection the expected success of LBS will be denied". He pointed out that the European Directive on privacy and electronic Communication contains detailed rules concerning LBS that will be implemented in the ongoing revision of the Telecommunications Act in Germany. The data protection supervisory authorities will ensure that these requirements of the companies are respected. From the perspective of data protection, significant new risks may arise, said Schaar. There is a risk that data can be passed on to third parties including movement profiles, personal lifestyle and consumer behaviour. In this way data pools may arise that are no longer controllable (Quarks & Co, 2014).

In 1950 Article 8 para 1 of the European Convention on Human Rights ensures and claims for a person to respect his private life, his family life, etc. Several European countries included this article in paraphrases in their Basic Law. 1974, a resolution on the processing of personal data has been adopted as a non-binding appeal to the Member States. The EU's data protection rules, introduced in 1995, are outdated and need a comprehensive reform to strengthen individual rights and tackle the challenges of globalisation and new technologies. In 2010 a comprehensive survey was conducted on "Attitudes on Data Protection and Electronic Identity in the European Union". The results show that European Internet users feel responsible for handling their personal data but 90% would prefer equal protection rights across the EU and regulation should be introduced to prevent companies from using people's personal data without their knowledge. Such companies "should be fined (51%), banned from using such data in the future (40%), or compelled to compensate the victims (39%)" (European Commission, 2011). In March 2014 the EU Commission announced progress on the long awaited EU data protection reform. The EU Parliament voted for an upcoming regulation that will establish a single, pan-European law for data protection, replacing the current inconsistent patchwork of national laws (European Commission, 2014).

6. Conclusion

"We are moving into a world where your location is going to be known at all times by some electronic devices. [...] It's inevitable. So we should be talking about its consequences before it's too late", said Smarr in 2003, Funder of NCSA (National Center for Supercomputing Application) and now director of California Institute for Telecommunications and Information Technology. There is a lot of research and development going on in developing algorithms to keep ones data and search request in private. Questions arise like: How often is our research community thinking about values and ethical responsibilities? Are we aware of the social and ethical dimensions with regards to research activities and possible future implications? Already or in the near future does the lack of consciousness or failing to disclose ethical considerations have an effect on the credibility of LBS research? We are certain that a lot of us do think about ethics, norms and values but only few of us articulate and address this issue within their department, in public or when publishing research results. "The future of the exact sciences is highly dependent on whether or not the public in general is attesting them a competence in the realm of values" (Sperry 1983).

From the very beginning of the research process technical researchers, which are only working on the improvement of ubiquitous positioning to achieve a higher availability, integrity and reliability in any environment and more precise location determination, should include the issue of the user's privacy. Obviously it is not enough to develop new, innovative technologies and to take the lead. It is time to think not only in technical terms, but also its potential danger in our newly created knowledge. Moreover, the research results must have a positive impact on our society and the future.

In his Book "Who Owns the Future" Lanier (2013) argues: "This is what diverse cyber-enlightened business concerns and political groups all share in common, from Facebook to WikiLeaks. Eventually, they imagine, there will be no more secrets, no more barriers to access, all the world will be opened up as if the planet were transformed into a crystal ball. [...] The Problem Is Not the Technology but the Way We Think About Technology". In this regard we apparently cannot expect of the politics not only to surround itself with technical but also with social science and ethical advisors. For researchers and developers, this means that they have to self-regulate and set limits on their own. They need to scrutinize and control themselves. Ethical counseling at Technical Universities would be a first step in this direction, the implementation of an ethics committee the second.

An ethics committee does not mean to say no or forbid LBS research projects. This is not the implicit function of an ethics committee on University level. It will first discuss and consult research proposals amongst them and then provide a platform for a researcher or research team to examine the implications of the ethical impact of research projects and its possible research outcomes.

In social sciences it is mandatory that, ethical questions have to be considered and addressed, not only when conducting data collection but also for the ethical and moral impact of the expected results and consequences for its individuals, users or population. Over the past decade LBS developed very fast in many research directions. Hence, it becomes more and more influential in everyone's daily life privacy. Social scientists and scientists in the health sector have one advantage, when it comes to difficult questions with regards to ethical responsibilities and implications. They can or even must state their research proposal to an ethics committee. We think that it's time that no longer only medical and social science faculties have an ethics committee to support and counsel their researchers. We have shown that also on Technical Universities the integration of the dimensions like ethics, values, morals and political responsibility become a serious necessity to be included in their research and teaching activities.

And as a final conclusion the authors are claiming:

1. Privacy and data protection has to be openly and formally considered in every LBS research project from the very beginning.
2. Ethics and research ethics as a subject have to be taught at every Technical University.
3. Every Technical University has to implement an ethics committee or to cooperate with another (Technical) University that has an ethics committee.
4. Privacy and data protection has to be part in every country's Basic Law and as academics we are responsible for promoting it.

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GIS Liability Issues – by Example of US and Polish State of Play

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Abstract. The field of activities associated with Geographic Information Systems is a constantly growing one. The ever increasing number of GIS users constitutes the Geoinformation society, which derives from Information Society Concept. As spatial information is widely used in decision-making in both public and private sector, quite a few thoughts are being spent upon not only development of GIS, but on legal aspects arising from the use of spatial information, such as: access to public (geo)information, copyright ability of spatial data and databases, licensing system policy, privacy rights policy, and liability policy. One shall note the necessity to minimize the risk of the users of spatial information on the one hand and to set the transparent principles of the liability in the use of the information on the other. Neither much ink has been spent on these issues nor is there an established case law in that regard yet. However, we may still attempt to foresee possible legal consequences of providing an erroneous geospatial data or dataset basing on traditional legal theories and concepts at hand. The presented work outlines situations in which liability may incur, as well

[1] This text is a translated and shortened draft of a chapter from the author's book about legal aspects of GIS, which is still being prepared (in Polish). Elements of this text have been published as the chapter "LIABILITY IN THE USE OF GIS IN US LAW - shall Poland learn from the experienced players?“ in the Monograph: Adamczyk T., Begović V., Bieda A., Bielecka E., Bugaj P., Dawidowicz A., Džunić I., Gajos M., Jankowska M., Kereković D., Krukowska K., Kryszk H., Kurowska K., Parzych P., Rahmonov O., Schrunk I., Wójciak E., Źróbek R., SPATIAL DATA IN WIDE GEOSPACE. Nacionalna knjižnica, Zagreb 2014. ISBN 978 -953-6129-43-0. This text has been prepared in the course of the research on the liability for digital maps that the author is conducting in 2014/2015 thanks to ministerial grant for young scholars. The grant let her pay the study visit to Max Planck Institute in Munich in May/June 2014 and to present her research at GIS Odyssey 2014 in Crkvenica.

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as examines existing Polish contract law and tort law in order to shed some light on pitfalls and shortcomings that might incur in the course of using GIS in our country. In particular, the analyzed concepts include negligence, breach of warranty and the product liability concept, which falls under tort law regime.

Keywords: geoinformation, liability, tort liability, product liability, maps, liability of surveyors

1. Introduction

It is quite clear that most citizens would find it quite hard to maintain their daily routines without reaching (consciously or unknowingly) for spatial information. It should be noted that the scope of geographic data used by an average person grows every year, as does the awareness of the importance of this type of data. Surveys conducted in Poland in the year 2004, 2006 and 2009 (Adamczyk 2007; Gajos 2009) one after another paint a fine picture of what kind of needs intricate the use of geodata and encounter the change of attitude of users to geoinformation over these years. This citizenry which uses the spatial information accessed by generally available services of geoinformation infrastructure has been described by the term “Geo-information Society”, by J. Gaździcki (Jankowska & Pawełczyk 2014).

The basic legal act on the European continent referring to aspects of using and accessing spatial information so far is the Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE), which entered into force on the 15 May 2007[2]. The Directive addresses 34 spatial data themes essential for environmental applications. The INSPIRE Directive by all means has served as a good trigger for many institutions to start opening their datasets and sharing them with others, both with institutions and private persons (Cetl, Tóth, Abramić & Smits 2013). However this is not a commonly known fact that the idea of updating, coordinating and making geographic data available was developed a long time ago in the United States and seems to be as old as 100 years old (Robinson 2008). It has been observed that hadn’t it been for the technical shortcomings the geographic databases would have been launched in US

[2] Official Journal of the European Union, L 108, 25 April 2007.

decades ago. Ones of first to understand the potential of geographical information were President Theodore Roosevelt who as early as in 1906 signed the Executive Order creating the U.S. Geographic Board and President Woodrow Wilson who in 1919 signed the Executive Order establishing the Board of Surveys and Maps (Robinson 2008).

In fact, the United States, with its astonishingly well-established jurisprudence in that regard, seem to be one of the first countries to understand the potential (and the threat) of the geographical data. In US legal issues surrounding the consequences of using spatial data seem to spark much more attention than on the European ground. The increase in the number of geographic information (GI) related cases that came on trial before the courts in US must have driven the necessity for deeper analysis of law regarding GIS. Conclusions that have been made before US courts may be a good point of reference when analyzing the possible evolution of GI laws in Poland or other countries.

2. The US Legal Experiences with GI

2.1. The Case of Inaccurate Data on the Map

The case of Murray v. United States[3] came on for trial before the court on 4 May 1971 and regarded the air crash of a plane, Cessna 206, carrying the pilot and two passengers on board. The accident happened on 8 November 1969 after the plane had arrived at the Bryce Canyon Utah Airport at night and there had been no runway lights on. United States of America was the defendant because the agency the Federal Aviation Administration was the operator of the government Flight Service Station at the airport. In this case it has been concluded that this is the elementary knowledge of all airmen recognized in many government publications and acknowledged as a customary practice that a night pilot either without the radio or with a radio that has gone dead shall in the event of approaching the airport, which the runway lights are not on, circle the field in order to get those lights turned on. One of the witnesses testified before the court that the plane before crush has been seen circling the field and blinking its landing lights. The court referred also to maps and information concerning airport available at the time of the accident. According to the U.S. Government Flight Infor-

3 Mary Jean Murray et al., and Nancy Jeanne M. Droubay et al., Plaintiffs, v. United States of America, Defendant, 327 F. Supp. 835 (D. Utah 1971), available at: https://www.courtlistener.com/utd/8qUG/murray-v-united-states/, as of 16 May 2014.

mation Publication "Enroute Low Attitude U.S.", in effect on that date, the airport had a Flight Service Station and it had available runway lights at night. The legend of the map indicated that "L" with an asterisk meant such runway lighting was available on prior request. At the same time the information given for the mentioned airport was a plain "L" with no asterisk. Also, according to another government-published aeronautical map, that was in effect at that time as well, the information given without asterisk indicated that the runway lights were on from sunset to sunrise or could be obtained by request, either by radio or by circling the field. It has been proved that the FAA Facility Management Manual puts an obligation on the facility chef of the FAA Flight Service Station to review and update data given for his facility on aeronautical maps as well as to put effort keep the information "accurate, complete and current". Therefore the court concluded that "The defendant United States of America had a duty, in connection with its publication and dissemination of aeronautical charts and airport directory information, to truly and accurately represent the runway lighting available at Bryce Canyon, Utah, and the circumstances under which those lights would be on or would be turned on at night. The defendant United States of America negligently published and disseminated certain aeronautical charts and other information which falsely indicated that either the runway lighting at Bryce Canyon was available throughout the night without request or that it was available to a night-flying pilot who circled the field as a means of requesting such lighting. Such negligence on the part of the United States of America in publishing and disseminating false aeronautical information regarding the available runway lighting at Bryce Canyon, Utah was also a proximate cause of the subject air crash, and the ensuing deaths of the pilot and the two passengers"[4].

The court found that the accident gave rise to the governmental tort liability under Federal Tort Claims Act (28 U.S. Code Chapter 171). It shall be noted that pursue to 28 U.S. Code § 2674 the *United States shall be liable, respecting the provisions of this title relating to tort claims, in the same manner and to the same extent as a private individual under like circumstances, but shall not be liable for interest prior to judgement or for punitive damages. If, however, in any case wherein death was caused, the law of the place where the act or omission complained of occurred provides, or has been construed to provide, for damages only punitive in nature, the United States shall be liable for actual or compensatory damages, measured by the pecuniary injuries resulting from such death to the persons respectively, for whose benefit the action was brought, in lieu thereof.* At the same time court examined whether the defendants' acts of negligence did not arise out of the exercise of any discretionary functions within the

4 Ibidem.

discretionary functions within the meaning of 28 U.S.C. Section 2680 (a) and (h). The section states that the provisions of this chapter [...] *shall not apply to –*

(a) Any claim based upon an act or omission of an employee of the Government, exercising due care, in the execution of a statute or regulation, whether or not such statute or regulation be valid, or based upon the exercise or performance or the failure to exercise or perform a discretionary function or duty on the part of a federal agency or an employee of the Government, whether or not the discretion involved be abused [...]

(h) Any claim arising out of assault, battery, false imprisonment, false arrest, malicious prosecution, abuse of process, libel, slander, misrepresentation, deceit, or interference with contract rights: Provided, That, with regard to acts or omissions of investigative or law enforcement officers of the United States Government, the provisions of this chapter and section 1346 (b) of this title shall apply to any claim arising, on or after the date of the enactment of this proviso, out of assault, battery, false imprisonment, false arrest, abuse of process, or malicious prosecution. For the purpose of this subsection, "investigative or law enforcement officer" means any officer of the United States who is empowered by law to execute searches, to seize evidence, or to make arrests for violations of Federal law.

In that case, as well as in the others cited in this paper, the court did not found the application of these exceptions and found the map provider (in this case the United States of America) solely responsible for the suffered damages.

2.2. The Case of Improperly Marked Data in Question on the Map

The case of Reminga v. United States[5] was brought to court after the accident that happened on 17 November 1968, when a plane, a Mooney M-20C single engine four seat aircraft, crashed after flying into a guy-wire of a tall television broadcasting tower located near Rhinelander, Wisconsin. The light plane carried two men on board. The court found out that only the center part of the television broadcasting tower was lit, while the guy-wires we neither lit nor marked. The tower was not standing free, but was supported by guy-wires that extended in three directions from near the top of

5 Gertrude REMINGA, Executrix of the Estate of Thomas H. Reminga, Deceased, and Barbara Sue Breeden, Executrix of the Estate of James Robert Breeden, Deceased, Plaintiffs, v. UNITED STATES of America, Defendant, 448 F.Supp. 445 (1978), available at: http://www.leagle.com/decision/1978893448FSupp445_1808.xml/REMINGA%20v.%20UNITED%20STATES, as of 16 May 2014.

the 1720 foot tower to anchors approximately one-half mile away from the base of the tower. The court further also found that the location of the guy-wire was inaccurately depicted on the 1967 Green Bay Sectional Chart disseminated by the United States Government. The chart depicted the tower as being west from the town of Starks and south of the railroad tracks, but as a matter of fact it was north from Starks and north of the railroad tracks. This fact was of a relevance because it is common for pilots flying by visual flight rules (VFR) to use railroad tracks as reference points. As it was proven, the location of the guy-wire on the map was the location initially planned, which has been subsequently changed because the Airline Pilots Association objected to it, pointing out that it would be extremely hazardous to erect the tower in such vicinity to railroad tracks. Not going into too much detail this shall be noted that the plaintiffs based their claim on five different grounds, among which one of them referred to the erroneous placement of the tower on the chart:

(1) The United States was negligent in that it improperly marked the tower in question on the official sectional air map.

(2) The government failed to issue a Notice to Airmen (NOTAM) warning pilots of the alleged misplacement.

(3) The government improperly granted permission for the construction of this tower.

(4) The government failed to issue a NOTAM warning that the tower in question had "unusually long" guy-wires.

(5) The Federal Air Administration (FAA) and the Federal Communications Commission (FCC) failed to require proper marking of the television tower.

The suit was brought under 28 U.S.C. § 1346 (of the Federal Tort Claims Act), which in point (b) (1) reads that subject to the provisions of chapter 171 of this title, the district courts, together with the United States District Court for the District of the Canal Zone and the District Court of the Virgin Islands, shall have exclusive jurisdiction of civil actions on claims against the United States, for money damages, accruing on and after January 1, 1945, for injury or loss of property, or personal injury or death caused by the negligent or wrongful act or omission of any employee of the Government while acting within the scope of his office or employment, under circumstances where the United States, if a private person, would be liable to the claimant in accordance with the law of the place where the act or omission occurred[6].

6 Available at: http://www.law.cornell.edu/uscode/text/28/1346, as of 16 May 2014.

The court recognized that **"the United States has a duty, when publishing and disseminating aeronautical charts, to accurately represent those features it attempts to portray. Where such information is inaccurately and negligently indicated, and such negligence is a proximate cause of plaintiff's injuries, the government is liable for such damages as are caused** [...]it has been determined that that map was copied from the Governmental Sectional Map for Green Bay, and thus the tower misplacement which it contained was carried over into the state map. **Hence the United States Government is directly responsible for any error in the Wisconsin map because of their original and continuing negligence in misplacing the tower on the Sectional Map**. The erroneous marking of this tower on the aeronautical maps normally used by pilots constitutes a real danger to pilots flying according to landmarks, and this was especially true in this particular case. It is common knowledge among pilots that light aircraft flying under visual flight rules use landmarks for navigational purposes. Therefore it is certainly foreseeable to the Government that an error in the placement of this tower would constitute a substantial and unreasonable danger to the pilots, such as these decedents, who use the Sectional Map. In summary, the United States Government is found to be negligent in its distribution of the Green Bay Sectional Maps containing an error in tower placement as described in the findings of fact [...]. Further, I determine that this negligent action resulted in an unreasonable and foreseeable risk to pilots such as decedents, and that this negligent action therefore was a substantial and proximate cause of the accident".

2.3. The Case of a Defect of the Graphic Depiction of the Data on the Map

The case of Aetna Casualty and Surety Company vs. Jeppesen & Company[7] referred to the accident of a plane that happened on 15 November 1964 when a Bonanza Airlines plane flying from Phoenix, Arizona, crashed in its

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7 Aetna Casualty And Surety Company, a Connecticut Corporation, et al., Plaintiffs, v. Jeppesen & Company, a Colorado Corporation, Defendant, 463 F.Supp. 94 (D. Nevada 1978); 642 F.2d 339; 1981 U.S. App. LEXIS 14149; 31 Fed. R. Serv. 2d (Callaghan) 811; 16 Av. Cas. (CCH) P17,644, available at: http://www.leagletax.com/decision/1978557463FSupp94_1536.xml/AETNA%20CAS.%20&%20SUR.%20CO.%20v.%20JEPPESEN%20&%20CO and http://courses.ischool.berkeley.edu/i205/s05/Aetna%20v.%20Jeppesen.pdf, as of 16 May 2014.

approach to Las Vegas. The claims arising from the death of the passengers were settled by Bonanza's insurer, Aetna. Jeppesen produces instrument approach charts aiding pilots in making instrument approaches to airport. The court found that Jeppesen makes its landing charts not only for every commercial airport in the United States, but it also makes navigational charts for every commercial airport in the world, therefore the liability of the map producer is a matter of special concern. The map in question portrayed graphically two views: the "plan" view and the "profile" view. The defect of the map regarded the graphic depiction of the profile which covered a distance of 3 miles from the airport and appeared to be drawn to the same scale as the graphic depiction of the plan, which covered a distance of 15 miles. Aetna's claim was based on the theory that the crash happened due to pilot's reliance on the fault in graphics and that there was a nonconformity between the data and the information delivered in graphics and in words. Jeppesen disputed this claim by proving that that was the custom to draw the profile and the plan view to the same scale and that they have never heard of any pilot complaining about that. The court found that "for every hour of every day there are literally thousands of passengers and crew members of planes which are dependent for their lives upon the Jeppesen charts being accurate in what they purport to represent, being quickly legible and readily comprehensible. The chart here failed in all three respects. The failure of Bonanza to exercise any supervision over the distribution of the charts to, or the receipt by, the pilots, of the many charts (67) contained in Bonanza's Manual of Landing Charts must be considered as a failure on the part of Bonanza to exercise the highest degree of care which it owed not only to the pilots but to the passengers of its planes as well. The evidence was that the custom was for Bonanza to provide a manual of charts but that the corrections and changes and insertions of new ones were sent to the pilots individually from Jeppesen leaving it up to the pilots entirely, not only to examine them carefully before using them, but also to note additions and changes and peculiarities. [...] the difficulty in reaching a conclusion is as to comparative fault between Jeppesen and Bonanza, but the Court concludes from all the evidence and testimony that the evidence preponderates to the conclusion that Jeppesen was 80% at fault and Bonanza was 20% at fault"[8].

[8] Ibidem.

2.4. The Case of Defective Data Portrayed on the Map

The case of Saloomey v. Jeppesen & Co.[9] concerning liability for maps that brought Jeppesen to court regarded a private plane Beechcraft Sierra with a pilot and two other passengers on board. The accident happened on 31 August 1975 when the pilot attempted to land at the Martinsburg, west Virginia airport. In general, the court found that Jeppesen's area chart was defective in designating Martinsburg as having a full instrument landing system by adding a notice ILS to it. At the same time court found that Jeppesen was negligent in the manufacture and in inspection of that chart, but negligent was also the pilot of the plane on the operation of the plane. But it has been proved that the pilot's negligence was not the proximate case of the plane's accident. The court had to decide on the basis of the claim, in other words whether Jeppesen was liable on the product liability basis. It has been noted as a matter of fact that **"Appellant's position that its navigational charts provide no more than a service ignores the mass-production aspect of the charts**. Though a "product" may not include mere provision of architectural design plans or any similar form of data supplied under individually-tailored service arrangements, see Gibson v. Sonstrom, 2 Conn.L. Trib. No. 103, at 3 (Super.Ct. Hartford Cty. 1976), **the mass production and marketing of these charts requires jeppesen to bear the costs of accidents that are proximately caused by defects in the charts**. See Halstead II, supra, 535 F.Supp. at 791; K-Mart Corp. v. Midcon Realty Group, 489 F.Supp. 813, 816-19 & 818 n. 7 (D.Conn.1980); Restatement (Second) of Torts § 402A comments c, f (1965)"[10]. The court accepted, without discussion, that the Federal Aviation Administration flight data drawn on the chart was a product for strict liability purposes and that Jeppesen has taken the special responsibility as the seller. More than that the court observed that Jeppesen is entitled to treat the burden of accidental injury as a cost of production and therefore it may be covered by liability insurance. There was no doubt for the court that Jeppesen shall bear the costs of the accidents when the proximate cause of the accident is the defect on the map.

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[9] Katherine H. Saloomey, Administratrix, Estate of Willard Vernon Wahlund, Deceased, Plaintiff-Appellee, v. Jeppesen & Co., Defendant-Appellant. Peter C. Halstead, Administrator, Estate of Erik F. Wahlund, Deceased, Plaintiff-Appellee, v. Jeppesen & Co., Defendant-Appellant; 707 F.2d 671 (1983); available at: http://www.leagle.com/decision/19831378707F2d671_11242.xml/SALOOMEY%20v.%20JEPPESEN%20&%20CO, as of 16 May 2016.

[10] Ibidem.

2.5. The US Experience Summarized

As it has been shown on the aboveIt has been observed that the liability regarding maps might be discussed under three theories of liability:

1) negligence,

2) breach of warranty (the implied or the express ones),

3) strict product liability.

The cases discussed above mostly relied on the third concept of liability though other theories sparked much attention not only of the courts but in the literature as well (Raysman 2002, Larsen, Sweeney & Gillick, 2012). More than that, in 1994 Congress exempted the former U.S. National Imaginery and Mapping Agency (currently the National Geospatial-Intelligence Agency) from a liability for maps, charts and publications containing geo-data (Larsen, Sweeney & Gillick, 2012). The exemption, made in 10 U.S. Code § 456, reads as follows:

(a) Claims Barred.— No civil action may be brought against the United States on the basis of the content of a navigational aid prepared or disseminated by the National Geospatial-Intelligence Agency.

(b) Navigational Aids Covered.— Subsection (a) applies with respect to a navigational aid in the form of a map, a chart, or a publication and any other form or medium of product or information in which the National Geospatial-Intelligence Agency prepares or disseminates navigational aids.

However, when the private sector of creating and providing data is involved it has to be stressed that a chart meets the premises to constitute a "product" under the US regulation for defective products and therefore falls under Restatement (Second) of Torts § 402A, pursuant to which:

(1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or to his property, if

(a) the seller is engaged in the business of selling such a product, and

(b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.

(2) The rule stated in Subsection (1) applies although

(a) the seller has exercised all possible care in the preparation and sale of his product, and

(b) the user or consumer has not bought the product from or entered into any contractual relation with the seller.

The producer of a map may be found responsible on the basis of the breach of warranty as well. Under the US law there is a concept of an implied and the express warranty. These are to be found in Uniform Commercial Code 2:313 and 2:314 (see Onsrud 1999).

3. The Polish State-of-the-Art in GI

Similarly to all other EU Member States, Poland is obliged to implement the INSPIRE directive. As it is, the directive is likely to bring about some concern as it comes to the issue of legal liability for disseminating defective data and information, most of all in form of maps. The Polish law is lacking jurisprudence on the liability of map providers. So far we may find judgments and regulations that expose surveyors to legal liability for disseminating defective data on the maps. Pursuant to the verdict of Voivodship Administrative Court in Warsaw enacted on 13 July 2005[11] "the organ shall indicate the premises for choosing the sort of the punishment, having in mind the degree of the fault of the acting person, the kind and the character of the violation [...] in case of questioning the due care of the surveyor it shall be indicated how the due care should look like as well as why it has not been performed. Also, it shall be measured to what degree the punished person's behaviour was culpable (intentional fault or negligent fault), the kind of the fault is always of importance when deciding about the sort of punishment". In other words, the surveyor falls under the Law on Geodesy and Cartography of 17 May 1989[12] regime as well as under the Polish Civil Code of 23 April 1964[13] regime (both tort and contractual liability).

[11] Verdict of the Viovodship Administrative Court in Warsaw of 13 July 2005, sign. IV SA/Wa 316/05.

[12] Law on Geodesy and Cartography of 17 May 1989, Journal of Laws (Dz.U.) of 2010 No. 193 Item 1287, with further changes.

[13] Polish Civil Code of 23 April 1964, Journal of Laws (Dz.U.) od 2014 Item 121, consolidated act.

Dissemination of geodata involves the discussion whether we are willing to expose the data providers to all sorts of liability or if there are reasons behind imposing legal limitation on the traditional regimes of liability. If we look into the scope and specificity of collecting and providing geoinformation as a result of implementing INSPIRE Directive it seems that we are still about to face these legal questions US did some time ago. It has been raised in the US literature that too strict regime of liability for providing defective geoinformation may limit the scope of the data disseminated or make geodata even more costly. If one had to compare the benefits flowing from the disseminating of data and holding data providers liable it seems that the first one prevails the other. With this in mind US Congress introduced the immunization in that regard for the National Geospatial-Intelligence Agency in 10 U.S. Code § 456. So far Polish law does not provide any exemption of this kind.

If we take a glimpse at the tort liability under Polish law it has to be pointed out that there are at least a few basis worth further analysis, which due to the length of this paper, will be provided in other place. The general rule of liability regulated in the Article 415 of Polish Civil Code states that *whoever by his fault caused a damage to another person shall obliged to redress it*. Considering that many of the bases are being disseminated by governmental and local authorities some more attention shall be brought to Article 417 which in § 1 states that *the State Treasury, territorial self-government unit or another legal person exercising public authority by virtue of law shall be liable for a damage inflicted by unlawful activity or cessation thereof which occurred in exercise of such authority*. According to Article 417 § 2 of Polish Civil Code *where the performance of public authority tasks is mandated, under an agreement, to a territorial self-government unit or another legal person, a joint and several liability for a damage inflicted shall be borne by the contractor and territorial self-government unit mandating such tasks or by the State Treasury*. The responsibility arising from the regulation is based on the principle of risk, contrary to the regulation of Article 415 of Polish Civil Code which introduces the liability based on the principle of fault.

The regulation of the product liability is to be found in the Article 4491 of Polish Civil Code and the following. As there are quite a few details to it is important to note that pursuant to Article 4491 of Polish Civil Code:

§ 1. One who produces within the scope of economic activity (a producer) any hazardous product shall be responsible for any damage caused by such product to anybody.

§ 2. The product shall mean any movable thing, even if it has been attached to another thing. The product shall also mean an animal and electric energy.

§ 3. A hazardous product shall be any product which does not provide safety one may expect while using such product in a normal way. Circumstances of the introduction of a product to trade, in particular the way of presenting it to the market and information offered to a consumer on properties of the product shall decide whether the product is hazardous. One may not maintain that a product does not provide safety merely because a similar product in an improved form has been introduced to trade.

According to Article 4492 of Polish Civil Code *the producer is responsible for a damage caused to another person's property only where a thing having been damaged or impaired can be regarded as a thing commonly designed for personal use and when the sufferer has used it mainly for such purpose*. More than, pursuant to Article 4497 § 2 of Polish Civil Code, that the indemnity for a damage will be due only if the damage exceeds an amount equal to EURO 500. These two provisions introduce limitations on liability for damage caused to person's property. However liability for the damage caused by the product to a person finds no limitation and general provisions shall apply.

Due to the high risk of bearing liability for dissemination of the defective data many providers escape liability by attaching in the license agreement a disclaimer, though this is questionable whether that contractual stipulation will as a matter of fact clear the provider of all the liability. Under Polish law it is possible to escape the liability on the basis of the Article 473 of Polish Civil Code which reads as follows:

§ 1. The debtor may assume by contract the liability for the non-performance or improper performance of the obligation due to specified circumstances for which he is not liable by virtue of statutory law.

§ 2. The stipulation that the debtor is not liable for a damage which he might do to creditor intentionally shall be null and void.

The regulation in question will likely be a subject to greater concern once we are to decide in a case involving the disclaimers of the GI providers, especially as to the question whether it is possible to exclude tort liability by a contract (in favour: Popiołek 2009, Wiśniewski 2007, Gawlik 2010, Rzetecka-Gil 2011; against: Zagrobelny 2006).

4. Conclusions

The country of Poland is still in the midst of facing issues concerning liability in the use of GIS. These are certain to arise if we consider the strong pursuit to implement the INSPIRE Directive. The standpoint of US law reveals the complexity of legal regulations finding application in the case of disseminating defective information. If we pay attention to the case law related to the use of maps under US law we will easily get a fine picture of what to expect in future.

Therefore the stand of Polish law needs examining as well as deciding whether the implementation of the INSPIRE Directive shall not be followed by any statutory immunization of liability, especially of public authorities.

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