Integrating topographic information and landmarks for mobile navigation

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Abstract

To help a mobile user navigating and finding his or her way in a foreign environment there are nowadays more possibilities than only using a paper map, namely using small mobile devices. But nevertheless, there is need for research and development before using these new technical possibilities in an ideal manner and replacing the traditional paper map. small mobile devices in terms of location based services

The optimum would be to pass the user the most actual data within a few seconds, representing the data in an understandable, uncomplicated and clear way, meeting the user's needs by personalising the visualisation and filtering the unimportant information. To satisfy all these claims different steps of research are necessary.

The *institute of cartography and geoinformatics* deals with two research tendencies related to this field of mobile cartography. One of these projects investigates the needs of a mobile user in different navigation situations. The most widespread navigation systems are in-car systems, navigating with instructions like: "turn left after 300 metres". But user, not only restricted to the car, but also navigating as pedestrian or by bicycle would prefer navigation information that works more human-like using landmarks for the wayfinding process: "turn left behind the church ...". Research work deals with extracting these landmarks from existing geodata sets and finding a more natural form of navigating the user, adapted for example to his mode of moving.

Another research project, the EU-project *GiMoDig*, aims at serving up-to-date geodata, derived from the topographic databases of the European national mapping agencies as well as additional data from other data sources. This project aspires on implementing a user portal which receives a request from a mobile user, collects all the necessary data from different data sources, combines and processes these data for presenting it on the mobile device (PDA, smartphone etc.), depending on the users needs.

The partners involved here work on different sub objectives like harmonising the different datasets, processing the data for coordinate transformation and data generalisation as well as developing a system architecture for this kind of service. Furthermore the needs and demands of the potential users will be investigated.

1 Mobile navigation

The technical components of mobile navigation systems include a processing and visualisation unit (like PDA or even only a mobile phone), in general a separate positioning unit (GPS as external device or internal card) and spatial data (as visual or textual descriptions). If the navigation system shall work “off-board”, an online connection for the data request to the service provider is needed (e.g. via mobile phone). Another possibility would be to store the necessary data on the mobile device, but two disadvantages are connected to this solution. On the one hand there is the limited memory capacity of mobile devices and on the other hand the lack of up-to-dateness of the stored data.

The EU-project GiMoDig, which is partly described on the following pages, assumes such a mobile user and serves topographic data via internet connection. The user should be able to state his actual needs and requirements. Because of the limited display size and resolution it is important to transmit only the required information to the user. This will include the selection of the desired objects and features as well as the desired resolution of the presentation. Due to these requirements, one sub-objective of the project is the development of methods for generalising the graphic representation of geospatial data in real-time, to be suited for display of the data at varying scales on small, mobile devices. The presentation on the mobile display will be dependent on - and adaptive to - the special user requirements i.e. data resolution and content as well as special circumstances like the time of the year etc. These ideas are described in detail by Nivala & Sarjakoski (2003).

1.1 Context-depending mobile navigation

The general needs for navigation systems depend on different, situation-dependent influencing factors, like user skills and experience, mode of movement, reason for moving, and time of day (see also Elias & Hampe (2003)). If the influence parameters are determined, a concept for adaptive visualisation (following Reichenbacher (2003)) can be established:

- Skills and experience:
  - experienced with maps, knowledge about signatures
  - abstraction ability (turning the map to north)
  - knowledge about environment
  - familiar to features of map (typical symbols for features, e.g. churches)
  - age, health
- Mode of movement:
  - by car
  - by bicycle
  - as pedestrian
- Reason for moving:
  - direct path to goal (shortest, fastest path)
  - tourist tour (specific distance, most scenery, secure or easy route (e.g. hiking))
- External factors:
  - rush hour, traffic jam, accidents, holidays
  - road restrictions (pedestrian zone may be used by cyclist in the evening hours, road use is prohibited to defined hours)
  - daytime/nighttime (objects cannot be seen in the dark, special objects are illuminated at night)
  - summer/winter (restricted visibility because of trees and bushes in the summer time)

	Routing	Selection of landmarks		Presentation			
Mode of Moving	**Degree of freedom**	**Speed**	**Visual field**	**Display / Output**	**Interaction**	**Attention for map**	**Additional information?**
Car	Tied to road network, limitations (oneways, forbidden turnings, pedestrian zones)	50(-100) km/h (15 m/s)	Front shield (+ side windows, driving mirror), predominantly straight forward ca. +/- 60° in driving direction	Voice output (because of distraction) simple graphics, also maps	No interaction while driving (hands on driving wheel), only when car stops	Very poor	Not while driving, restriction to essentials; demand for further information, when car stops.
Bicycle	Roads and cycle paths, additionally: forest and farm tracks, Openings of oneways and (partly) pedestrian zones	20 km/h (6 m/s)	Predominantly in moving direction, take a look in other directions is possible ca. +/- 90° in driving direction	Voice output/ map	No interaction (hands on handle bar)	Eye contact possible	Need increases
Pedestrian	Free in all directions (footpath and roads), Pedestrian under- and overpasses	5 km/h (1,5 m/s)	Directed in moving direction, but in general +/- 180° in line of vision	Map	Hand-operating /-input / -selection possible	Absolute attention, eye contact and interaction possible	Need for additional information and features exists
Conclusion:	**Different data sets for appropriate routing necessary!**	**Different amount of time to look out for landmarks**	**Different visibility analysis for landmarks needed**	**From: dissect complete route in single instructions to: map**	**From: automatic process to: interaction**	**From: simple graphic (arrows) to: detailed map**	**Extend features**

Table 1: *Components of mobile navigation (depending on moving mode)*

1.2 Components of mobile navigation

In our investigations we concentrate on different ways of navigation. If we single out one factor, for example the mode of moving, there are a few dependencies following, like the route processing, selection of landmarks and the appropriate presentation for the user. The following sections are compiled to an overview in table 1.

1.2.1 Generation of routes

Processing of routes is part of graph theory and needs a linear network to calculate for example shortest paths. To fit the routing to the moving mode, adapted graphs have to be used, because the degree of freedom to move in the environment depends on the mode of moving. If the user is going by car, he is tied to the road network and traffic restrictions (oneways, prohibited turnings, pedestrian zones etc.).

Usually, a cyclist has a few more options, because of additional cyclist paths. (One limitation is the use of motorways). A pedestrian user has the most possibilities to move: he can use the complete open space and all directions to move. (In fact, there are some limitations for this user group like buildings and motorways.) But from this it follows that it is necessary to remodel the graph for the route processing for pedestrians. This can be achieved by assigning weights or possible directions to the graph. Because of the lack of adequate data, the existing data for car navigation systems are used instead. The increasing degree of freedom of the different user types is shown in Figure 1.

Fig. 1*: Graphs for route processing depending on moving mode (by car, by bicycle, on foot)*

1.3 Selection of Landmarks

The landmark-based navigation is the most natural concept to navigate for humans. Landmarks are prominent, identifying features in the environment of the wayfinding human, which enable him to locate himself in his surrounding. In this context, a landmark may be defined by its particular visual characteristics, by its unique purpose or meaning or its central or prominent location (Sorrows & Hirtle 1999). In our view, landmarks are topographic objects that exhibit distinct and unique properties with respect to their local neighbourhood.

The kind of landmarks used in routing instructions depend on the moving mode of the user. Usually, car drivers move much faster through their environment than pedestrians and have a more limited visual field because of the car they are sitting in and the attention paid to the driving. Therefore, different (specialised) ontologies have to be used for different activities (Winter 2002).

Depending on the way of moving a human user chooses different types of objects as landmarks for the navigation description. The study of (Burnett et al. 2001) reveals, that in applications for car navigation the "road furniture", such as traffic lights, pedestrian crossings and petrol stations plays a vital role as landmarks. In contrast, according to the research of (Michon & Denis 2001) wayfinding instructions for pedestrians include objects like roads, squares, buildings, shops and parks. This results can be interpreted as a consequence of the dependencies between moving speed and limitations of the visual field: a car with 50 km/h covers a distance of 15 m per second, while a pedestrian moves only the tenth part of it in the same time. Thus, the pedestrian has considerably more time to perceive his environment and salient features in it than a car driver. Additionally, the driver is confined to the visual field of his front shield (plus side windows and driving mirror). Because traffic and driving actions need most of the drivers attention, only landmarks located near or on the road are observed precisely and fast. Advertisement signs of a shop attached to buildings may be hardly visible for drivers, whereas pedestrians are able to turn round and watch out for the landmarks given in the wayfinding instructions (see overview in Table 1).

According to this, it is necessary to adapt the selection of landmarks to the moving mode. Therefore, the visibility of objects and the duration of it has to be determined to display/announce the turning instructions just in time.

1.3.1 Presentation mode

The form of presentation of the routing with landmarks depends on the available attention of the user: a car driver is mainly occupied with driving the automotive and paying attention to the traffic. There is only a small amount of concentration and time to spend on reading a complex map. Therefore, the presentation for car drivers has to be in a very basic form with quickly perceivable graphic or even as mere audible instructions. In general, there is no interaction with the map/device (while driving) possible and the need to get additional information is very limited (and in case, focused on traffic information about traffic jams, accidents etc.).

As a bicycle user a restricted interaction with the device is possible, as well as an occasional glance towards the map display. Because the driving speed is relatively slow and the attention towards the map is higher, it is possible to convey the routing via a map possibly enriched with additional features (e.g. points of interest, restaurants with opening hours).

The pedestrian is able to spend the most of his attention to the route description. A detailed map helps him to locate his actual position on the map. Because of his slow motion it is advantageous for him to interact with the device. The supply of additional features (different map scales, 3D-views) is possible (see Table 1).

The statements given here are a first approach to categorise the different needs on mobile navigation. Alternatives to the general behaviour depicted here are conceivable (e.g. presentation of complex maps to car drivers via head-up displays).

2 Data processing

2.1 The available datasets

The basic geospatial data can be titled as a part of the geodata, which describes the landscape (topography) and the cadastral information of the earth's surface in an relatively application independent way. These geospatial base data serve as the basis for all possible applications related to spatial context. These data are maintained by the National Mapping Agencies and are available as paper maps or orthophotos and satellite images as well as in digital form. In this context, we talk about geospatial vector data in digital form stored in geospatial databases.

One example of such data is the German *ATKIS* (Authoritative Topographic Cartographic Information System) product. In addition to the traditional topographic map series of the states (Laender) of the Federal Republic this project aims at the provision of digital models of the earth 's surface suited for data processing. In this way ATKIS constitutes a data base for computer-assisted digital processing and analog output forms, but also a base of spatial reference for the linkage to and combination with technical geothematic data. It can therefore be described as a geobase information system (AdV 2003).

Fornefeld et al. (2003) state that these data serve as a basis for the clients applications but have only a minor benefit for the user. Nevertheless in connection with additional data, like navigation information or landmarks, these data get useful for the client.

Because of meeting the claims of all possible users it is necessary to provide geobase data as well as additional data and to combine these data individually in one application. The base data, for example topographic maps, are produced for general applications. The user has to pick up the information, which are relevant for him or her. But if these data are customized and enhanced with additional valuable information with spatial reference, the users will be supported in his tasks. The geobase data gain in importance.

Because of this, an application for mobile navigation consists of these three categories of provided data and services:

- Providing geobase data,
- Providing additional data with spatial content,
- Providing user applications using these geodata

2.2 Extracting landmarks

Landmarks are topographic objects with distinct and unique properties. These properties determine the saliency of the objects, which in turn depends on different factors: size, height, colour, time of the day, familiarity with situation, direction of route, etc. Our approach uses the existing data sets ATKIS and the digital cadastral map (ALK) to extract these salient objects automatically and provide them for navigational purposes. At the moment, we focus in our research on a single object group: the buildings from the ALK.

We differentiate between two phases of landmark extraction (see Figure 2). First the data base is analysed automatically to detect all potential landmarks existing in the data. In a second step the route-depending aspects such as visibility of the landmarks from decision point (junction), approaching direction, duration of visibility and orientation of landmark towards route has to be investigated.

The procedure to detect the potential landmarks is analysing the data set with data mining techniques to discover unique objects. Data mining methods are algorithms designed to analyse data or extract from data patterns into specific categories. Basic models of data mining are clustering, regression models and classification (Fayyad et al. 1996).

These procedures can be applied to data sets consisting of collected attribute values and relations for objects. For that purpose, all existing information about the buildings are extracted: information about semantics (use, function) and geometry of the object itself (area, form, edges), but also information about topology (e.g. neighbourhood relations to other buildings and other object groups (roads, parcel boundary etc.)) and orientation of the buildings (towards north, next road, neighbour) are compiled in an attribute-value table.

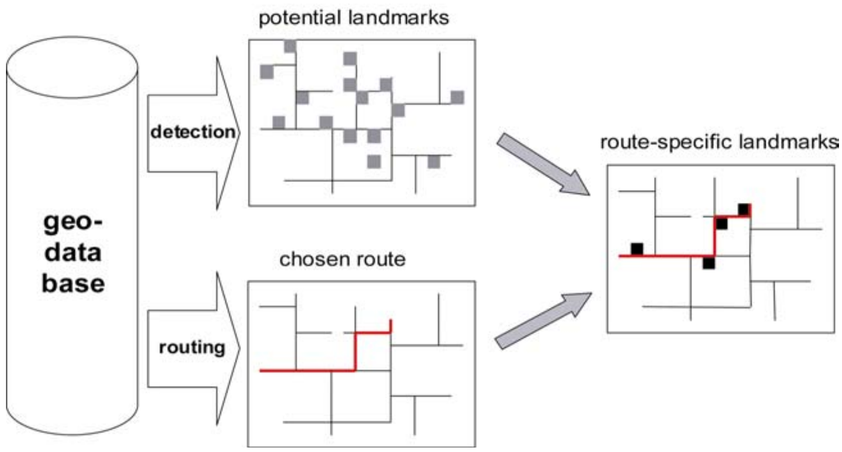

Fig. 2*: Determine route-specific landmarks*

For each potential decision point (that means each junction in the graph network) the local environment for the investigation is determined by means of a simple distance buffer or a 360 degree visibility analysis to determine which objects are visible from that point of view at all. All selected buildings (creating the local environment) are fed into the data mining process to detect the object with distinct and unique properties with respect to all others. For more details about the approach see (Elias 2003).

The result of the process is one or more than one potential landmark for the investigated junction (see Figure 3). If there is no object that fulfils the requirements, a return of no potential landmark

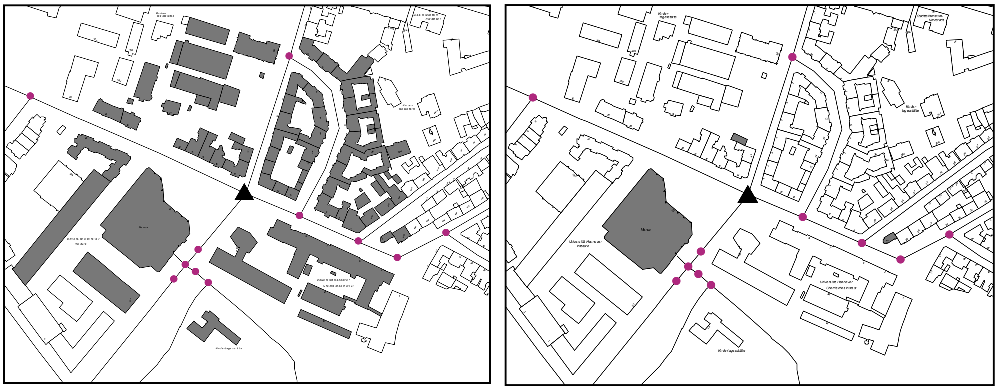

Fig. 3: *Scene of Hanover (road network with decision points, buildings) – left: "local environment" around chosen decision point (created by a buffer), right: potential landmarks after processing*

at all is possible, too.
The selection has to be narrowed down by route-dependent aspects. For example the visibility of the objects from the walking direction has to be checked. Therefore, a visibility analysis on basis of a DSM from laser scanning data combined with building polygons has to be calculated (Figure 4). As a second step, the visibility of the objects can be tracked while approaching the decision point to determine the advance visibility of the landmarks (Brenner & Elias 2003).

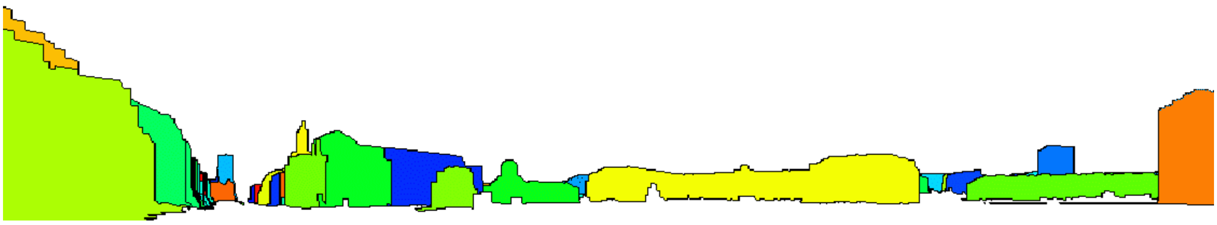

Fig. 4: *Visibility analysis for a point of view (Brenner & Elias 2003)*

2.3 GiMoDig: Providing topographic datasets in different scales

As mentioned in chapter 2.1 the combination of topographic data and additional information, like landmarks, help the user to navigate. The content of this combinated data is of course dependent on the user, as mentioned in chapter 1. In the case of a pedestrian or bicycler, topographic information supports the user while navigating and orienting.

The EU-project GiMoDig aims at serving these topographic data to the mobile user and additionally tries to integrate third party data like navigation data, points of interest or landmarks on top of these topographic data. The main vision of GiMoDig is a mobile user, travelling within an European country and receiving on-line information of his or her environment on the mobile device, allowing him/her to flexibly inspecting data by zooming in and out.
In GiMoDig a *Multiple Resolution Database* (MRDB) with pre-generalised levels of detail of topographic datasets is established. The main goal is to allow for a realtime zooming from overview information to details and vice versa. The MRDB is populated with topographic information, as provided by national mapping agencies. For adaptation, however, often also

additional information has to be included. This leads to the problem, that also this additional information has to be generalised in the different levels of detail. So the challenge is to introduce additional information into an already existing MRDB on the fly.

In our investigations we tackled the problem of introducing Points of Interest (PoI's) or landmark information into an MRDB-dataset. Here the problem is that for such additional information possibly other resolutions or levels are adequate. Therefore, the idea is to consult the MRDB to generalise the area around the landmark object and present the landmark in a higher or its original level of detail.

3 Visualisation of data for navigation

3.1 Individual maps dependent on the user-situation

If we concentrate on the possibility to navigate the user with the help of a map on his mobile device one can think that there is no need for investigating the map design because there are already numerous experiences in producing maps. But the rules for producing paper maps and even digital maps cannot be transferred to the maps used on mobile devices. On the one hand constricting features of a mobile device like a smartphone or PDA are the limited size and resolution of the display, compared to ordinary computer screens or paper maps. On the other hand the capacity of memory and the possibility to transfer the data to the client are limited. Because of these reasons solutions should be found to compensate these limitations and to serve an understandable and clear map for the user. It is one aspect in the above mentioned GiMoDig-project to investigate and develop new possibilities to visualise spatial data on small displays (Nissen et al 2003).

In cartography the ordinary way to solve the problem of limited space while presenting spatial data is to generalise the data. Generalisation means to simplify the geometries and to visualise only the necessary data for the user to navigate. The user gets the possibility to specify the information he needs for his purpose or he specifies his purpose and the system selects the necessary data and leaves out unimportant details. This is one aim in the GiMoDig-project. Because of this the resulting map contains only the relevant information without any dispensable details.

3.2 Maintaining multiple representation in a database

But generalisation means more than just selecting a certain subset of the available data. There is also the need for manipulating the way how to visualise the objects. In smaller scales geometries have to be simplified, amplified, merged etc. One possibility to serve these different representations of the objects is to maintain certain levels of detail in one database.

An MRDB can be described as a spatial database, which can be used to store the same real-world-phenomena at different levels of precision, accuracy and resolution (Devogele et al.1996, Weibel & Dutton 1999). It can be understood both as a multiple representation database and as a multiple resolution database. In an MRDB, different views on the same physical objects or phenomena can be stored and linked. This variety can stem from different views of the world, different applications, as well as different resolutions. These lead to differences in the objects as such, i.e. in the semantics and in the geometry. Also the graphic representation can be taken into account, leading to geometric, semantic and graphic multiplicities (Bedard & Bernier 2002).

There are two main features that characterise an MRDB:

- Different levels of detail (LoD's) are stored in one database and
- the objects in the different levels are linked.

As mentioned in chapter 2.3 the GiMoDig-service uses such an MRDB-structure to store different levels of detail of topographic data. But the MRDB-structure also allows for new possibilities to visualise additional information, e.g. vario-scale presentations (Harrie et. al

3.3 Visualisation of PoI and landmarks using an MRDB

The representations stored in the MRDB can also be used to emphasize important objects like points of interest or landmarks. The ordinary way would be to present the landmark as a point-symbol on top of the map or to highlight the matching objects with an eye-catching colour. The user gets less information of the landmark objects the lower the level of detail of the map is chosen. For example in Figure 5 and 6, the relevant object represents a generalised building consisting of a block of 15 buildings. Instead of presenting generalised objects the landmarks and other objects which should focused by the user can also be presented with its highest level of detail stored in the database. This helps the user to find these objects easily on the map and also supports in recognising the buildings in the reality more easily. In this way, both detailed information (the landmark object) and overview (the wider environment of the settlement area in terms of building blocks) is visualised in one presentation.

Fig. 5*: Two possibilities to visualise landmarks: point presentation(left), detailed building object within generalised environment (right)*

The workflow for generating these kinds of visualisations can be followed in Figure 6. The relevant object, i.e. the landmark, can be matched with its actual representations on the map in the target scale by using the coordinates of the landmark. Using the links in the MRDB the relevant object can then be exchanged by its representation in the highest level of detail. The objects not matching the landmark can be presented in a lower level of detail than the landmark itself.

The possibilities of many different scales or generalisation modes in order to emphasize objects graphically has been investigated by (Sester 2002). Here, the detailed information from the large scales is combined with the course information from the small scale. In order to do so, first the original object is loaded up via tracing the links in the MRDB (step 5), then the landmark object is preserved whereas its neighbour objects are re-generalised again, i.e. aggregated.

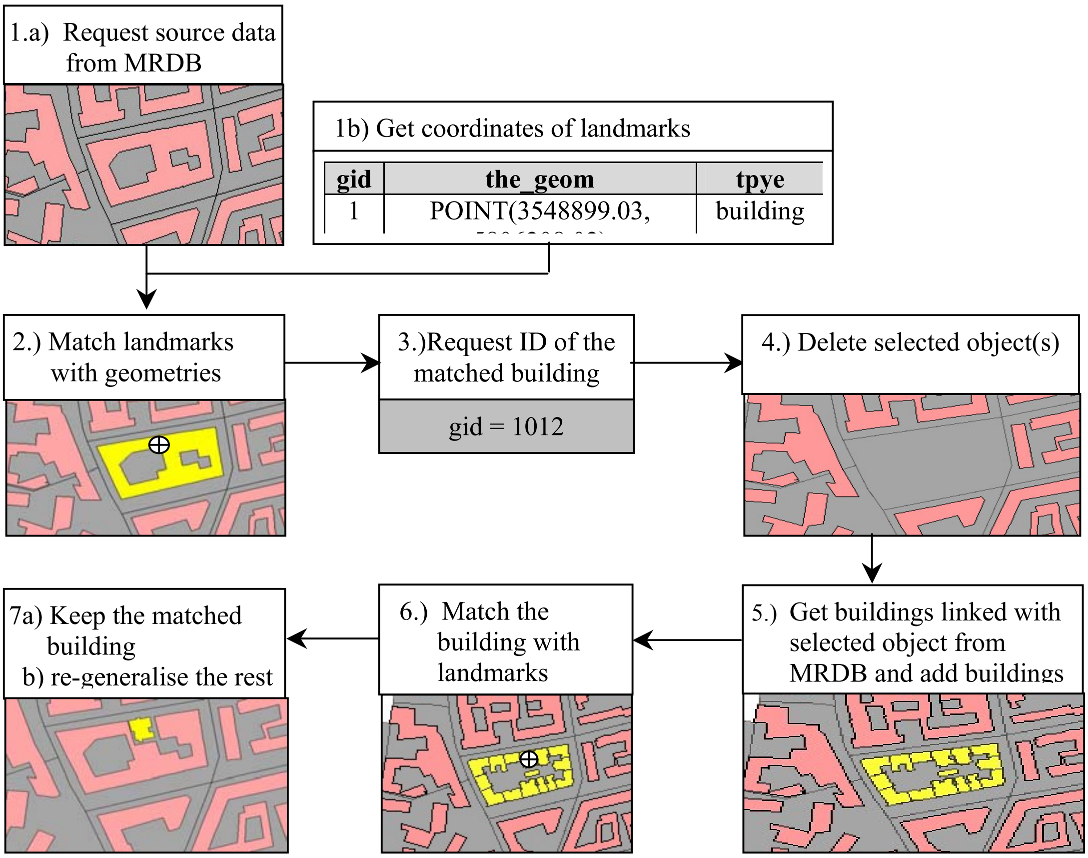

***Fig. 6**: Workflow for visualising landmarks using original shape of buildings*

4 Conclusion

This article gives an overview of the needs of mobile users while navigating. It shows possibilities to extract landmarks from existing datasets and visualise these objects in an environment of topographic data on a mobile device. Navigating and orienting with the help of mobile devices differs from navigating with ordinary paper maps. The mobile digital version needs and offers at the same time new ways of visualising spatial data and supporting the user while finding the way. We propose possible solutions to derive and serve these data for mobile users and also present the feasibility to integrate landmarks in a topographic map.

The digital mobile maps can be customised, depended on the individual needs of the different types of users and his position. It is possible to serve topographic data in combination with integrated additional data and also visualise these in a way to combine different scales in one presentation. This is one solution to integrate and visualise additional data into an existing topographic dataset designed for a other scale-ranges than the third-party data.

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Mark Hampe (Dipl.-Ing.), born in 1973, studied Geodesy at the University of Hannover and obtained the Masters degree (Dipl.-Ing.) in 1999. His master thesis was about animated maps and their advantages for the user. Between 1999 and 2001 he attended a trainee on public service. Since 2002 he is a scientific assistant at the institute for cartography and geoinformatics, University of Hannover. His primary exercise lies in MRDB related to the EU-project Gimodig.

Birgit Elias (Dipl. –Ing.), born in 1973, has studied Geodesy at the Universities Brunswick and Hanover till 1998. Afterwards she did the internship for the state examination and started at the ikg in the summer of 2001on a research project with the LGN, the national mapping agency of Lower Saxony.