6 Adaptive Visualisation of Landmarks using an MRDB

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Abstract. Mobile navigation is one of the most popular applications for small electronic devices like PDA (personal digital assistants). In the last years the main focus of routing applications was on the use in car navigation systems. But with the increasing market and availability of small devices, a new user group comes to the fore: the pedestrian user. Because of the different needs and (technical) limitations of both groups, new concepts and implementations to improve the wayfinding process with routing instructions and their (visual) communication have to be developed. In our paper, we propose the generation of routing information targeted at pedestrians. We first describe the possibilities to extract the potential landmarks from existing datasets. For the visualisation of these landmarks in a map we propose to emphasize them appropriately in order to help the user in orientation and navigation. To this end we introduce maps containing more than one level of detail (LoD's). A multiple resolution database (MRDB) serves as a basis for these kinds of visualisation.

6.1 Introduction

In the last years the main focus of routing applications was the use in car navigation systems. But with the increasing market and availability of small devices, a new user group comes to the fore: the pedestrian user.

Technical constraints, but also different needs of both user groups demand for the development of new concepts and implementations to improve the wayfinding process with routing instructions and its (visual) communication.

In this paper, we propose the generation of routing information targeted at pedestrians. Humans prefer to communicate navigation instructions in a more natural way, namely in terms of landmarks, i.e. prominent objects along the route. Instead of announcing instructions like: "Turn left after 200 meters" the user gets route-information like: "Turn left after the church". Therefore, we enrich the routing directions with landmarks. To convey the navigation information via small display device appropriately, we use adaptive visualisation techniques.

6.2 Mobile Navigation

The technical components of mobile navigation systems include a processing and visualisation unit (like PDA or even only a mobile phone), a positioning unit (GPS as external device or internal card) and map data (as visual or textual descriptions). If the navigation system works "off-board", an online connection for the data request to the service provider is needed (e.g. via mobile phone).

6.2.1 Context-dependent mobile navigation

The general needs for navigation systems depend on different, situation-sensitive influencing factors, like user skills and experience, mode of movement, reason, time of day (see also (*Elias & Hampe* 2003, *Reichenbacher* 2004)):

1. Skills and experience:
   - experiences with maps, knowledge about signatures
   - abstraction ability (turning the map to north)
   - knowledge about environment
   - familiarity with map features
   - age, health
2. Mode of movement:
   - by car
   - by bicycle
   - as pedestrian
3. Reason of moving:
   - direct path to goal
   - tourist tour
   - shortest, fastest, specific distance, most scenery, secure or easy route (e.g. hiking)
4. Time of day/year:
   - 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 / night time (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)

6.2.2 Focus on moving mode

If we concentrate on the moving mode and especially focus on the pedestrian application of navigation, there are a few dependencies, like the route processing, selection of appropriate landmarks and the visualisation. For more details see (*Elias & Hampe* 2003).

Shortest Path Analysis
Processing of routes is based on weighted graphs. To adapt the routing to the moving mode, different 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 (one-ways, prohibited turnings, pedestrian zones etc.).

Usually, a cyclist has a few more options because of additional cycle paths – there are however also limitations, like the use of motorways. Pedestrians have the most possibilities for walking: they can use the complete open space and all directions to move. This needs an adaptation of the graph for the route processing for pedestrians, e.g. by changing the weights in the graph. In most cases, especially in city areas, the pedestrians will use the roads or food-paths along the roads. Because of the lack of adequate data, in our case the existing data for car navigation systems are used instead. The increasing degree of freedom of the different user types is shown in Figure 6.1.

Fig. 6.1. City plan (upper left); Graphs for route processing depending on moving mode: by car (upper right), by bicycle (lower left), on foot (lower right)

Characteristics of landmarks

There are two different kinds of route directions to convey the navigational information to the user: either in terms of a description (verbal instructions) or by means of a depiction (route map). According to (Tversky & Lee 1999) the structure and semantic content of both is equal, they consist of landmarks, orientation and actions. Using landmarks is important, because they serve multiple purposes in wayfinding: they help to organise space, because they are reference points in the environment and they support the navigation by identifying choice points, where a navigational decision has to be made (Golledge 1999). Accordingly, the term landmark stands for a salient object in the environment that aids the user in navigating and understanding the space (Sorrows & Hirtle 1999). In general, an indicator of landmarks can be particular visual characteristic, unique purpose or meaning, or central or prominent location.

Furthermore landmarks can be divided into three categories: visual, cognitive and structural landmarks. The more of these categories apply for the particular object, the more it qualifies as a landmark (*Sorrows & Hirtle* 1999).

A study of Lovelace, Hegarty & Montello (1999) includes an exploration of the kinds and locations of landmarks used in directions. It can be distinguished between four groups: choice point landmarks (at decision points), potential choice point landmarks (at traversing intersections), on-route landmarks (along a path with no choice) and off-route landmarks (distant but visible from the route). A major outcome of the study is that choice point and on-route landmarks are the most frequently used ones in route directions of unfamiliar environments.

In our view, landmarks are topographic objects that exhibit distinct and unique properties with respect to their local neighbourhood. These properties determine the saliency of the objects, which in turn depends on different factors, like size, height, colour, time of the day, familiarity with situation, direction of route.

Selection of landmarks

The kind of landmarks used in routing instructions depends 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, Smith & May [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. These 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/s, 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 of 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.

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 and announce the turning instructions just in time.

6.3 Route-dependent generation of landmarks

The generation of landmarks can be divided into two different phases: the detection of potential landmarks in the digital database and the exploration of those that are relevant for a particular route (Figure 6.2).

The detection of landmarks is completely independent of the chosen route. It depends only on the general geometric and semantic characteristics of the investigated objects and the defined neighbourhood used for the analysis process. This computation step can be done in pre-processing and provides all potential landmarks in the chosen environment.

In a second step, those landmarks that are relevant for the particular route, are exploited according to route-specific criteria, such as visibility, distance to route, particular orientation of landmark to route and the uniqueness and reliable visibility of the landmark in its neighbourhood to avoid misleading.

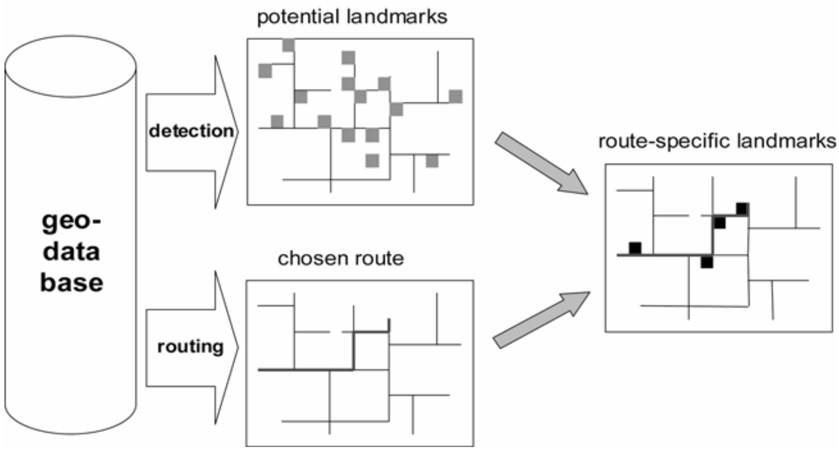

Fig. 6.2. Generation of route-specific landmarks

6.3.1 Existing databases for landmark detection

For an area-wide supply of landmarks we need an appropriate GIS database as a basis that contains information about objects which can be analysed automatically to determine the landmarks. In our approach we use the databases ATKIS (Authoritative Topographic Cartographic Information System) and ALK (Digital Cadastral Map) of the German national mapping agencies. The content of the ATKIS base-model of digital landscape model corresponds to the content of the Topographic Map 1:25.000. In addition, we use the building data of the digital cadastral map.

Landmarks can be different kinds of objects from different categories (e.g. parks, buildings, railroad tracks, subway stations), but for the beginning, we only consider one category of objects, buildings, for the landmark detection.

Besides the geometry of the objects, the digital cadastral map contains semantic information about the buildings like building use (residential or public) or building labels (name or function).

6.3.2 Extraction procedure of potential landmarks

To make an automatic analysis process possible, we use data mining techniques to detect the landmarks. Data mining methods are algorithms designed to analyse data, classify them or reveal implicit patterns in them (Fayyad, Piatetsky-Shapiro, Smyth & Uthurusamy 1996). Basic models of data mining are clustering, regression models, classification and so on. 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 potential landmarks, here buildings, has to be 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 collected in an attribute-value table. The idea is to determine an attribute or a combination of attributes that characterize a landmark. The advantage of this approach is the possibility that the selection of landmarks can be adapted to the availability of the attributes in a given context: for example, at night certain attributes of the objects will no longer be usable (e.g. colour). As this attribute then is not available, the dynamic landmark extraction procedure will not make use of it as discerning attribute.

For each potential decision point (i.e. 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 potentially are transferred to the data mining process to detect the object with distinct and unique properties with respect to all others. We used the well-known classification algorithm ID3 (Quinlan 1986) and the clustering approach COBWEB (Witten & Eibe 1999) for that purpose. For more details about the approach see (Elias 2003).

The result of the process is one or more potential landmark for the investigated junction. In Figure 6.3 the results of the processing with a modified ID3 algorithm are presented. On the left are the selected buildings for the data mining application, on the right the resulting potential landmarks. The large chosen building is the cafeteria of the University; it was chosen due to its unique function. The two small buildings have both a different building use compared to their neighbours which are predominantly residential buildings (one is a garage, the other is a bar).

Thus the different use was the discerning attribute that makes these objects distinct in their local environment.

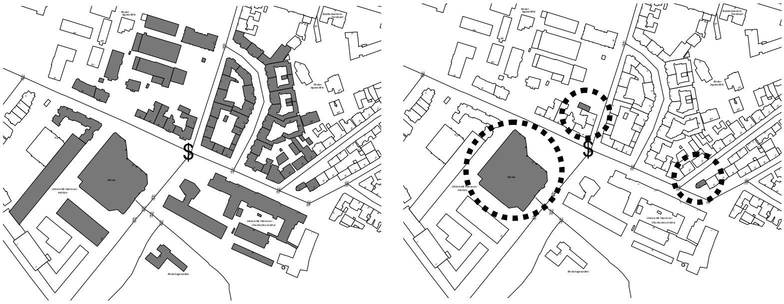

Fig. 6.3. Scene of Hanover (road network with decision points, buildings) – left: "local environment" around chosen decision point (created by a buffer), right: potential landmarks after processing (filled objects, inside circles).

6.3.3 Generation of route-specific landmarks

After processing the data mining it has to be checked, whether the chosen object is useful as a landmark in the particular routing situation. That means, the visibility of the object from the point of view has to be tested. To inform the user in advance about the navigation instruction, the landmark must be visible already while approaching the decision point. Therefore, the visibility has to be tracked during the entire approaching movement (Brenner & Elias 2003).

After that, it is possible to identify the time instance when the object comes into view and the point in time at which the user gets the instruction (time needed depends on the moving mode, see Section "Selection of landmarks"). In our case we use a DSM from laser scanning to track the visibility of objects along a trajectory. Therefore, virtual views of the trajectory are processed and plotted in one frame (see Figure 6.4). Such plots can be interpreted in the way that objects are better suited as landmarks when their visibility range (integral of visibility curve) is high. Also, it is possible to determine (depending on the moving speed) how much earlier the landmark is visible from the approaching direction and whether it is enough time to create an appropriate verbal instruction.

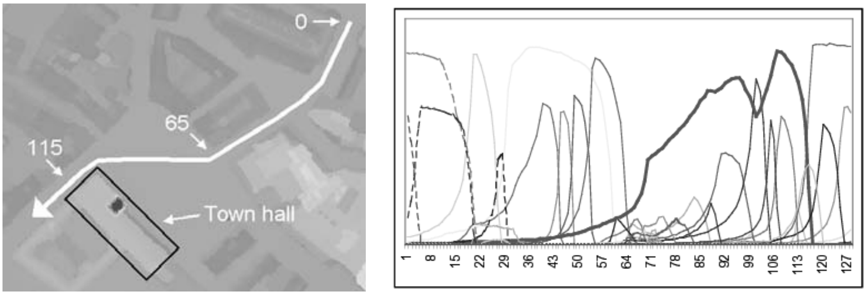

Fig. 6.4. Visibility tracking – left: trajectory approaching town hall, right: visibility plot of different objects, wide line: town hall (from (*Brenner & Elias* 2003)).

6.4 Scale-dependent visualisation of landmarks

Visualising a route using landmarks and other topographic objects on a small display faces the problem that too much information has to be displayed on too small space. Therefore, on the one hand a flexible zooming of information from overview to detail is a necessity. On the other hand, another option is a vario-scale presentation of the data, i.e. the integration of different scales in one representation (*Harrie et al.* 2002). In this section, we focus on this point and describe a method of flexibly integrating information from different scales in one presentation. The underlying multi-scale information is taken from an MRDB – a multiple representation database.

6.4.1 Generating multiple resolutions for the MRDB

An MRDB (Multiple resolution / representation database) 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, *Weibe*l *& Dutton* 1999). It can be understood both as a multiple representation database and as a multiple resolution database. In the following we use the MRDB in terms of a multi-scale data structure. 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

Two objects correspond when they represent the same real world phenomenon. Those objects are explicitly linked in the MRDB. The links can be exploited, if there is the need to change the appearance of a certain object or to "drill" for a more detailed information of the same objects in another scale.

It is the possibility of accessing different levels of detail that is the main advantage of an MRDB. An application falling back on the MRDB can choose the level of detail which is close to or matches the presentation that is needed for the given purpose. In the case of serving data for mobile applications an MRDB can support or supersede the time consuming process of generalising the spatial data to be presented in a certain scale. The MRDB maintains the data in all the necessary resolutions and stores the results of pre-computed complex generalisation steps.

The database is populated either by matching existing datasets (semantic and geometric matching) or by deriving a new dataset from existing ones - mainly using generalisation functions.

Concerning the first option there is the challenge to find the corresponding objects in the two existing datasets. In order to identify corresponding (homologous) objects and instantiate the corresponding links, two sets of geographical data must be searched for objects that represent the same real-world objects; methods for this purpose are subsumed under the term 'data matching' (*Badard* 1999, *Sester et al.* 1998).

Concerning the second option a new data set has to be derived from an existing one based on a given functional dependency. In the case of deriving a smaller scale dataset, generalisation functions can be applied. The function immediately establishes also the links between corresponding objects. Consider for example the aggregation of two adjacent parcels of land to a new combined parcel in the lower resolution data set: links will be established between the high resolution parcels to the newly created one (*Hampe et al,* 2003).

6.4.2 Adaptive visualisation of landmark objects by re-generalisation

Having the possibility to access different generalisation levels of spatial objects using the MRDB opens the way for new visualisation options. In the following we propose the option of both visualising details and overview in one presentation. We concentrate a spatial situation where landmarks have to be shown, and at the same time the overview of a larger part of the whole route has to be visualised as well. In our approach, we highlight or emphasize the landmarks in order to make them recognisable immediately and generalise the background information.

6.4.3 Emphasizing important objects

There are different possibilities for highlighting the important objects. A simple way is to overlay a landmark-symbol on the coarse background information. This would, however, hide the rest of the data, furthermore, it would make the recognition of the immediate surrounding of the landmark object difficult. Therefore we propose to present the object in its original shape – or even enhance it. This can be achieved using graphical variables or generalisation functions (see also (Sester 2002) or (Reichenbacher 2004)):

1. use colour to highlight landmark object,

2. simplify background objects and preserve original shape of landmark object,
3. enlarge landmark object and reduce background objects in size,
4. merge background objects while leaving the landmark object separate,
5. assign a height to the landmark object, and present background objects with decreasing heights with increasing distance.

Figure 6.5 visualises these different options.

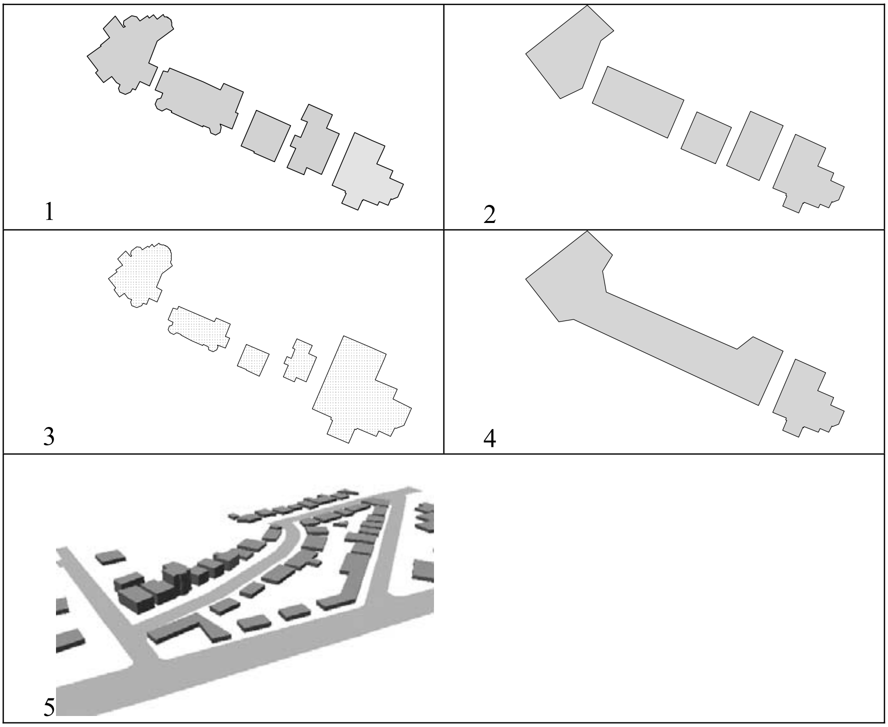

Fig. 6.5. Visualisation of different possibilities for enhancing individual objects: use colour, simplify background objects, enlarge landmark object, aggregate background objects, use height as indication for importance (from (*Sester* 2002)).

Such visualisations can be generated by adequate generalisation operations (see e.g. (*Sester* 2000)). Since these operations have to be applied only on a very limited number of objects in the immediate environment of a landmark, they can be executed very fast, in real-time.

6.4.4 Using MRDB for emphasizing important objects

The data structure in terms of the MRDB easily allows to integrate different representations of the data in different resolutions. The general schema for the multi-scale visualisation is as follows: a coarse representation of the scene is given; only in the vicinity of the landmark the coarse information has to be re-generalised (see Figure 6.7), taking the presence of the landmark into account (see Figure 6.6).

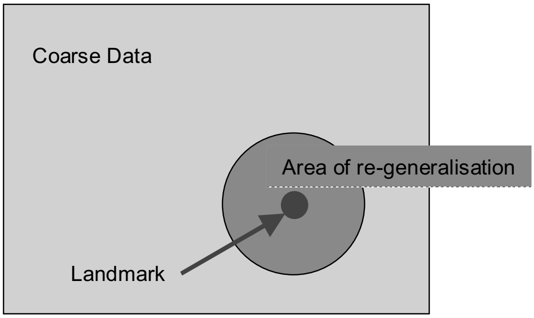

Fig. 6.6. Schema of re-generalisation in vicinity of landmark.

The different data sources are provided in the MRDB. The flowchart in Figure 6.7 shows the sequence of necessary accesses of the MRDB in order to get the relevant information and generate an appropriate visualisation.

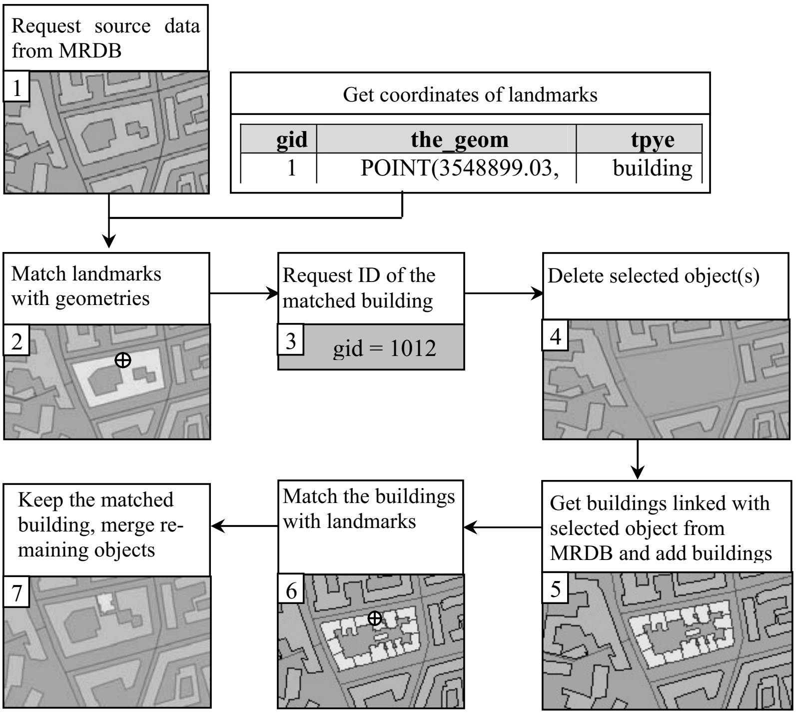

Fig. 6.7. Workflow for visualising landmarks using original shape of buildings.

First of all the map data and additionally the location of the landmarks will be requested from the database. To find out which objects are representing the landmarks, matching procedures will be applied. In our case the landmarks will match the buildings in the map. Because this object may be a generalised object with less information than available at the given level of detail there is the need to find the representation of the same object with a higher level of detail in the database. The key attribute for those links are the ID's (Identifier) of the objects. The linked objects are requested from the database and the matched objects will be exchanged by their representation with a higher level of detail (steps 4, 5).

As shown in the example the buildings have been combined to one object, that means that more than one object is linked with the representation in the lower level of detail. Because only the building representing the landmark should be presented in its original shape the other buildings have to be aggregated again (steps 6, 7).

The workflow presented above shows how the objects in the vicinity of the landmark have been aggregated, whereas the landmark object itself is presented in its original form. As an alternative, buildings located in the immediate neighbourhood of the landmarks can also be shown with all their details to facilitate the recognition of the surrounding, too. Details could degrade with increasing distance from landmark object.

A way to select the possible options of emphasizing a landmark is to use those attributes that have been determined as crucial (most discerning) in the extraction process described above. If, e.g. the height of a building has been the most discerning attribute, it is very obvious to use this property also for enhancing the object for visualisation. The same holds for other geometric properties like size or distance to neighbouring objects. This implies that this discerning feature is used for presentation – it can even be enhanced in order to make it more clear.

6.5 Summary and Outlook

In the paper a very important problem in the context of location-based services (LBS) has been tackled: personal navigation based on landmarks using a small mobile display device. The limitations of small displays enforce the development of intelligent methods for efficiently communicating spatial information. We proposed to firstly extract the important information for navigation using methods from data mining and spatial data interpretation. Secondly, we used adaptive visualisation techniques for presenting the important information to the user. A multiscale presentation is used in the way that the important object is shown in high detail, whereas the background information is given in a coarse presentation. The fast generation of such presentations is facilitated by the use of a Multiple Representation Database structure.

Future work will focus on the integration of walking direction and visibility on the selection of landmarks. Concerning the MRDB, we will develop schemas for adaptively selecting appropriate base scales for given contextual situations.

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