Location-based mobile pedestrian navigation services – the role of multimedia cartography

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Abstract. *In this chapter map-based location based services (LBS) are analyzed by describing the basic elements (positioning, information modelling and presentation, the user and questions of adaptation), the state of the art of current systems and the main fields of research. Selected results of experiences in terms of fundamental research (potential of cartographic presentations forms), in positioning (active landmarks), modelling and visualization (guiding and navigation for pedestrians) are given.*

Keywords: *Location Based Service, Pedestrian Navigation, Multimedia Cartography, TeleCartography,Cartographic Communiation*

1 Introduction

Telecommunication infrastructure (mobile network), positioning methods, mobile in- and output devices and multimedia cartographic information systems are prerequisites for developing applications, which incorporate the user's position as a variable of an information system. Imparting spatial information within such a system, normally cartographic presentation forms are involved. Thus, the resulting system can be called a map-based location based service (LBS). This chapter discusses the elements of a map-based LBS, outlines main research topics and describes some experiences in the context of conceptual design and developing map-based LBS.

2 Elements of Cartographic LBS

A system can be called a Location Based Service (LBS), when the position of the mobile device – and therefore the position of the user, is somehow part of an information system. The derivable types of applications in this context can be stated as heterogenous and include simple and text-based applications, which use the cell ID for a rough positioning ("Which petrol stations are there around me?") to map-based multimedia applications including routing functionalities. Independent from the level of complexity of the system architecture every map-based LBS needs some basic elements to handle the main tasks of positioning, data modelling and information presentation.

2.1 Positioning

The determination of the position of a mobile in/output device is a direct requirement for every system to be called LBS. Positioning has to be adequate to the service, that means in dependent relationship and adapted to the tasks. For various applications the necessary level of accuracy needed can be served by the cell-ID of a telecommunication network and the thus derivable position, which gives an accuracy of positioning between 50 and 100 meters in urban areas (see *Retscher* 2002). For navigation purposes – in particular in the context of pedestrian navigation – the accuracy demands increases to values of at least 25 meters and less (*Retscher* 2002, *Gartner & Uhlirz* 2001). For indoor navigation, the requirements for the position determination are even more increased (*Gartner et al.* 2003).

Various methods of positioning are available for different levels of accuracy:

- satellite-based positioning
- positioning by radio network
- alternative methods
- combinations

Nowadays for outdoor navigation, most commonly satellite-positioning technologies (GPS) are employed. Then the achievable positioning accuracies of the navigation system depend mainly on GPS, which provides accuracies on the few meters to 10 m level in standalone mode or sub-meter to a few meter level in differential mode (DGPS). If an insufficient number of satellites is available for a short period of time due to obstructions, then in a conventional approach observations of additional sensors are employed to bridge the loss of lock of satellite signals. This is particularily necessary for areas where the satellite signals are blocked like indoor or underground environments, or generally urban areas.

Deriving information to be used for positioning from parameters of a radio network – coordinative information of a cell or a base station – is a further method, which is immanent restricted by the cell dimensions. Measuring methods using elapsed time of signals in combination with cell identification, time synchronisation or differences of elapsed time can be used for improved positioning (*Retscher* 2002).

Alternative methods or improvements of already existing methods are shown by *Zlatanova and Verbree* (2003). They propose "user tracking" in combination with Augmented Reality (AR) to improve positioning in bad conditions (indoor/underground). *Kopczynski* (2003) describes an approach of using simplified topological relations to determine positions by sketch maps (sketch based input).

2.2 Modelling and Presentation of Information

The possibilities of transmitting spatial information in context of a determined position by various presentation forms is primarily restricted by the limitations of the used mobile device. The conditions of the cartographic communication process have to be fulfilled in any way, also in the context of map-based LBS: The cartographic model has to be clearly perceivable while it is permanently scale-dependent and has to present the task-dependent appropriate geometric and semantic information.

This fact in combination with restrictions in size and format of current mobile devices leads to different levels of solutions for presenting information within map-based LBS:

- Cartographic presentation forms without specific adaptions
- Cartographic presentation forms adapted to specific requirements of screen display
- New and adapted cartographic presentation forms
- Multimedia add-ons, replacements and alternative presentation forms

Rules and guidelines have been developed during the last years to adapt cartographic presentations to the specific requirements of screen displays (*Neudeck* 2001, *Brunner and Neudeck* 2002). A lively discussion about new and special guidelines for map graphics in the context of the very restrictive conditions of TeleCartography and mobile internet has brought up various suggestions and proposals (see *Reichenbacher* 2003, *Wintges* 2002, *Gartner and Uhlirz* 2001). In this discussion the main focus is laid on questions of graphical modelling, visualisations, or generally on questions of usability and application navigation (*Meng* 2002, *Wintges* 2002). First experiences and results have been made e.g. with the prototyping UMTS application LoL@ (*Gartner and Uhlirz* 2001).
Common rules or standards for cartographic presentations on screen displays are not defined yet, which is founded also on the permanently changing determining factors. Display size and resolution of state-of-the-art devices are permanently increasing, colour depth is no longer a restricting factor. Parameters of external conditions during the use of the application (weather, daylight) are hard to model. The needs of an interactive system have to be incorporated into the conception of the user interface, which includes soft keys, functionalities for various multimedia elements. As a general approach for including the various parameters within a model of map-based LBS the concept of adaptation has been brought up (*Rei-*

chenbacher and Töllner 2003, *Goulimis et al.* 2003), which aims to describe links or mutual dependencies between various parameters and connect this to impacts to the data modelling and cartographic visualization. Further more, new cartographic presentation forms have been introduced, taking especially in account, that a restricted and small screen display has to be used for transmitting cartographic presentations (see e.g. "focus-map" by *Klippel and Richter* 2003).

For the presentation of spatial information within LBS and on small displays additional multimedia elements and alternative presentation forms in general are increasingly seen as potential improvements. Methods of Augmented Reality (AR) link cartographic presentation forms (e.g. 3D graphic) to a user's view of reality, e.g. at applications like navigation systems. Cartographic AR-applications are based on the idea, that a more intuitive user interface can be reached (*Reitmayr and Schmalstieg* 2003). *Kolbe* (2003) proposes a combined concept of augmented videos, which realises positioning and information transfer by means of video.

2.3 Users and Adaptation

Experiences of developing LBS have led to various suggestions to take into account a more user-adequate system conception. Modelling parameters in the context of the "user" and the "usage situation" are seen as fundaments of more user-adequate attempts, which can be summarized as "concepts of adaptation". *Zipf* (2003) includes within his understanding of adaptation components of "adapting to a system", "to an user" and "to a situation".

The adaptation of cartographic visualisations in this context can be understood as e.g. the automatic selection of adequate scales, algorithms for adequate symbolization, or even the change to text-only output of information in case of inadequate graphic potentials of an output device. Adaptation to the user is for the time being limited to user profiles, selected in advance from a list or entered manually by the user himself to influence the graphical presentation (size of lettering, used colours) or to provide pre-defined map elements. Adaptation of the visualisation to the situation is including the current time of day (day/night) or takes into account the actual velocity of the user (this type of adaptation is realised in some actual versions of navigation softwares like TomTom©, which adapts automatically the map scale to the current velocity).

Various forms of adaptation are summarized by *Reichenbacher and Töllner* (2003) as "context-adapted Geovisualisation", where definitions of methods and algorithms to derive adequate cartographic presentation forms from influencing parameters for various output devices and different users in different situations are aimed at. This approach is challenging not only technical developments but also the questions of how to identify, define and model the main influencing parameters (e.g. "user", "user situation"). First attempts of empirical studies in this context have been made (*Zipf and Jöst* 2003, *Radoczky* 2003), while experiences of implementations are rare.

3 Research questions in the context of cartographic LBS

The elements of map-based LBS within their integrative context, as pointed out in chapter 2, are focused on in the main research questions: Positioning – Modelling – Visualisation – (Adaptation).

3.1 Integrative Positioning

Within the field of positioning, current research attempts focus on improving existing methods and especially in finding an integrating concept, which could include different types of observations and methods (satellite based methods, radio network, dead reckoning) for determining an appropriate position. In this case the combination of the advantages of the different methods being integrated can lead to a more applicable positioning system especially in urban environments. If for an application the accuracy of positioning is needed in the range of low meters (as for pedestrian or indoor navigation), either preparatory work of the network providers is necessary which can cause high costs and/or high efforts (synchronisation of run time signals, see *Retscher* 2002), or additional tools for the mobile device are essential (GPS-Jackets/Cards). Even assuming that satellite-supported solutions will become much less expensive, there will still remain some restrictions inherent to the system including especially the blocking of signals of various satellites in specific environments like cities. According to *Verbree* (2003) the combination of GPS- and Galileo-signals will lead to a significant improvement in this context, but will have still the restrictions of all satellite-based solutions (blocking of signals). The range of reachable accuracies will not be significantly improvable by combining various satellite-based positioning systems, but there will be an impact on the applicability. Alternative approaches like integrating video and augmented reality for improved and supported positioning, as proposed by *Zlatanova and Verbree* (2003) or *Kopczynski* (2003), are based on the usage of 3D-models or special semantic networks, which have to be derived from basic surveying data. The applicability of these approaches in operational conditions different from "ideal attempted" test areas are not yet proven.

3.2 Route Information Systems

Thinking about possible applications for map-based LBS, route information systems are in the centre of interest (*Sarjakoski et al.* 2003, *Lehto* 2003, *Hampe* 2003, *Gartner and Uhlirz* 2001). In the context of modelling routes for pedestrian navigation the main focus is given on the question of user-centred procedure (*Urquhart* 2003). An user-centred approach has to take into account existing knowledge about human wayfinding and human ways to communicate routes and navigation instructions. This includes also the question of differences in the actions and needs of map users and map-based LBS users. Does new behaviour in map use require new forms of cartographic information transmission development? And is the user of a mobile interactive cartographic information system able to gather all the information the system offers? This leads to the general question of the additional value or benefit of mobile cartography and cartographic LBS.

In order to answer these questions, knowledge about human behaviour in wayfinding is necessary as well as definitions of the potential of different presentation forms for navigation purposes. In this context potential means the capability of presentation forms to transfer a certain spatial information within a certain situation adequate in terms of geometric and semantic validity and convenient to the usage conditions. First basic studies have been made by *Reichl* (2003), who proposes a classification of the potential of different presentation forms in the context of route information.

3.3 Information Presentation and Visualisation

Symbolisation, visualisation and information presentation in general in the context of LBS can not be discussed without taking into account the restrictions of current mobile devices (size of display, data transfer rates, terminal access time, storage capacity, etc.). Although a rapid development in main technical parameters can be observed, the essential restriction of a small format of screen displays still lasts. To cope with this limitation is the goal of approaches where new cartographic presentation forms like "focus-maps" (*Klippel and Richter* 2003) are developed or map-related presentations (2,5D and 3D-presentations) and multimedia cartographic presentation forms (use of photos, videos or augmented reality) are applied. Prototype applications have proven, that there is a potential of integrating new and adapted presentation forms in cartographic LBS *(Gartner et al.* 2003, *Radoczky* 2004), although solutions for handling huge amounts of data, their automated acquisition and actualisation are missing. Finally, a discussion of possibilities of "on-the-fly" derivations of high quality presentation forms is not yet answered (*Gartner et al.* 2003).

Strategies for the optimisation of existing cartographic presentation forms in the context of LBS (adaptation of maps for small displays, development of new and use of alternative presentation forms) might become obsolet by technical innovations. Electronic paper (e-paper) is at the stage of prototyping, displays with characteristics of paper (thin, elastic, light) have been presented (*Der Standard* 31.1.2004), foldable and virtual keyboards are ready for use (*Der Standard* 14.1.2004).

4 Selected contributions to concepting cartographic LBS

Experiences and results in all fields of research on cartographic LBS, as described in chapter 3, have been made in various interdisciplinary projects at TU Vienna. In the following a selection of proposed methods and findings is given.

4.1 Active Landmarks

4.1.1 Question

Experiences from former projects like LoL@ (*Gartner and Uhlirz* 2001) lead to the development of the concept of so called "active landmarks". This is based on the idea, that pedestrian navigation systems (PNS) inherently need specific elements, including methods and techniques to determine a position (positioning), to model a suitable route (route modelling) and to derive an adequate presentation form (route communication). Current methods of positioning seem to be - especially for the most applicable areas of PNS (urban areas, mixed indoor/outdoor environments) – still inadequate for these fields of application, even when using satellite based methods like GPS. But routing instructions for supporting human wayfinding need definitively high accuracy of position determination, in order to be able to communicate routing information in and about an urban street network clearly and without ambiguity. The concept of permanent tracking and deriving positions of a mobile user in narrow inner-urban street networks on a high level of accuracy seems to prevent a satisfying solution per se. Therefore the authors propose a concept, where the location of fixed short-range sensors, so called "Active Landmarks", is used for deriving a position of a mobile user.

4.1.2 Relevance of Landmarks

Various studies have discussed, that navigation instructions should not only consist of street names and directions but have to be improved by additional indications of landmarks. In an empirical study the participants complain about the absence of landmarks in routing instructions (*Denis* 2001), other studies requested the participants to build route instructions on their own. Nearly all answers included additional descriptions – landmarks – beside the routing instructions for better orientation (*Elias* 2002, *Tversky and Lee* 1999). The user feels more comfortable finding his way when supported by additional information like landmarks (*Elias* 2002).

4.1.3 Definitions of Landmarks and Active Landmarks

Landmarks are prominent objects, which act as marks for places and can be used as reference points. They own special visual characteristics, are singular concerning their function or meaning, are situated in a central or exposed position and therefore helpful for users in situations of navigation and spatial understanding (*Sorrows and Hirtle* 1999, *Elias* 2002, *Raubal and Winter* 2002) .

Landmarks can help pedestrians in navigational problems and serve as decision support for turnarounds or as confirmation for a decision (*Denis* 2001, *Elias and Sester* 2002).
Active landmarks can, but do not necessarily have to, have the same characteristics and qualities as landmarks described above. The main function of active landmarks is to build up an ad-hoc network or link with a mobile device via an air interface in a short range and to enable identification by the user. Therefore the user has not to actively try to identify landmarks, but can remain passive until he has entered the applicable area of an active landmark, where his position can be determined as "being within the range of the active landmark" and new route or other information can easily be transmitted. The short-range environments to be aimed at in this concept should not exceed 20-100m.

4.1.4 Infrastructure Requirements

A main problem of this conception is the necessity of enough active landmarks with the potential of building up ad-hoc networks or data transfer connections. Commercial, legal or other aspects for realisation can not be answered from a today's point of view. From the technical point of view only a short range sensor is needed, including the possibility of data storage, data transfer, short range data transmission and an adequate client.

The connection between the sender and the receiver has to be built up spontaneously and without user interaction. This can be done currently e.g. by Bluetooth or WLAN[1]. Bluetooth offers a transmission range from about 10 meters, WLAN from about 100 meters. In both cases an appropriate interface at a mobile device is necessary. Directional air interfaces (infrared) are not useful, because of the needed precise justification of sender and receiver.

4.1.5 Realisation

The proposed concept of active landmarks has been implemented for a test area at the Vienna city centre (Karlsplatz) during a research project, sponsored by the Hochschuljubiläumsstiftung of Vienna (*Brunner-Friedrich* 2003). The results proved the applicability of the concept, but some questions on sender optimisation, short range data transfer and system optimisation for PNS in general have not yet been answered and will be discussed in future research projects.

4.1.6 Discussion

The concept of active landmarks aims to turn around the idea of positioning – not the mobile user is located but the user moves from one known position to the next known position, that are the active landmarks. The mobile device is always in the status of searching for active landmarks. Being successful by entering the range of an active landmark, a spontaneous connection is built up via air interface and identification data can be transferred to the device. Each active landmark owns unique coordinates. That enables sufficient positioning of a pedestrian, if the range of the active landmark is short (20-100m). A multi-sensor-fusing model as proposed by *Retscher* (2002) enables the combinations of different positioning methods from different observations. Positioning by satellite-based methods or by radio network methods can be completed by observations from active landmarks. Cartographic visualisation of the position around the landmarks area allows easy orientation and verification of the current position. Advantages for the users are furthermore the automatic presentation of the landmarks surroundings when moving into a sender area (*Brunner-Friedrich* 2003).

Additional information (like graphics and descriptions) beyond the identification and positioning data can be transmitted easily (see fig. 1). The local storage of the data (there is no central database for all active landmarks of an application to be maintained and actualised) could force easy handling and greater actuality, because each single active landmark, that means each sender situated on a building, shop or advertising space is in one's own responsibility concerning maintenance and actualisation.

Using the conception of active landmarks will influence the single elements of LBS as well as the whole system. A server independent architecture of a LBS that enables new perspectives for acceptance, confidence and security seems possible now because of the therefore not needed central identification and storage of positioning data. (*Gartner and Brunner-Friedrich 2003*).

4.2 Presenting routes by various presentation forms

To communicate route information most efficiently as proposed by the conception of adaptation (see chap. 2), knowledge about presentation forms and their applicability and potential for route information systems is necessary and has to be analysed. In principle various presentation forms could be used to present routes, including all cartographic presentation forms (maps and map-related presentation forms) but also other forms that are suitable for spatial-relevant route information like text (written and spoken), graphics, video, animation or combinations (*Reichl* 2003).

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[1] Wireless Local Area Network

Reichl (2003) analyses the connectivity between user situations and user groups in this context and proposes a "matrix" that gives possible dedications of the applicability of different presentation forms. These dedications have been founded by an empirical study, where a finding, beneath other results, elucidated, that communicating route information by maps leads to significant "more complete" topographical knowledge and understanding than not map-based information transmission. Transmitting route information without maps can enable the user to build up topological correct mental representations, but will lack a chorographic understanding of topography (see Fig.1). The study has been based on a procedure, where participants, after having been navigated by different presentation forms, had to answer a questionnaire and to draw a sketch map from memory. The experiences of this study of text-based vs. map-based information communication had been valuated by *Reichl* as map-based information communication leads to a better reproduction of the geometric information and better distance estimation. This conclusion is equal to that of a similiar study perfomed by *Thakkar et al.* (2001). Further research is necessary, in particular in analysing similarities between various presentation forms for human route communication; in the adaptation to different styles of learning (*Kienberger* 2004); and the derivation of route information from one single data set to different presentation forms.

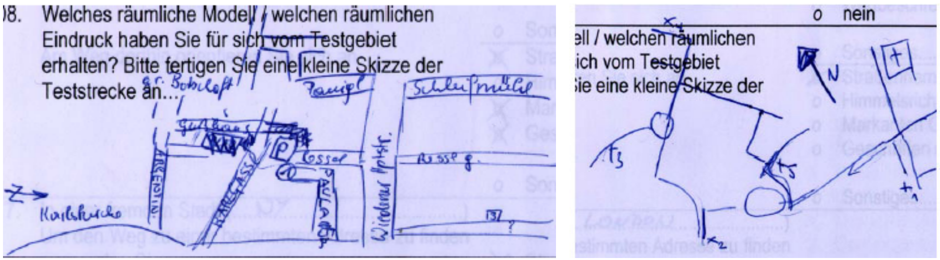

Fig.1 „Sketch Maps" drawn after navigation by textual instructions (left side) and by map –based instructions (right side): creation of a topological mental map model vs. a topographical mental map model (*Reichl* 2003)

4.3 Cartographic support for wayfinding

Based on the description of the potential of various presentation forms for transmitting route information (cp. 4.2) the range of applicability can be tested. In this context the combination of different presentation forms for certain situations (e.g. in mixed indoor/outdoor environments) is particularly interesting. *Radoczky* (2004) has analysed the shortcomes of existing LBS applications in this context and proposed – by using the theory of multi encoding (*Lovelace et al.* 1999) - concepts for supporting the communication of route information via map-based LBS in terms of integrating multimedia add-ons and enhancing the user support by various means, including the use of maps, graphics, photos, text, video, panoramas, animations and all kind of combinations. The audio channel is used for additional support by means of speech, music and audio-signals. In order to improve the use of the presentation form "map" various supportive concepts have been proposed, including animations (e.g. for supporting the understanding of a change of map scale), map-relevant presentation forms as floor plans, bird's eye views, video clips or VR-scenes. *Radoczky* (2004) focuses especially on the relevance of support when changing presentation forms and proposes some conceptions in this regard, based on general theories of multimedia cartography. The relevance of the proposed conceptions has been proved by implementing the concept on a mobile input/output device and by an accomplished feasibility study (sample: 22). By summarizing the results it could be stated, that the determined trends are similar to comparable studies (*Zipf and Jöst* 2003). *Radoczky* (2004) indicates, that some conceptions and functionalities have been found as helpful, independent from sex, age or educational background for all tested situations (day time, weather conditions):

- General considerations:
  Overview maps for a general presentation of the whole route and information about distance and estimated time of walking have been found indispensable. An acceptance of 64 % of all participants, being "always sure to be on the right way" by using the overview, has been stated.
- Automatic scrolling:
  Automatic adaptation of the presented map section to the position of the user has been found indispensable.
- Egocentric mapview:

86 % of all participants preferred a “track up” oriented map, that means the map is always adapted to the user’s direction of move, only 9 % preferred “north up” orientation.
- Multi encoded navigation instructions, in particular the integration of photos in case of decision points for better decoding the map’s information turned out to be helpful (73 %). Panorama photos (73 % of male, 36 % of female participants), combinations of maps and spoken or written text for route information communication (82 % argued that this combination is the most helpful of all combinations) have found high acceptance.
- Supported change of scale:
  To enhance the understanding of the effects of a change of scale (in terms of changing from one scale dependent cartographic presentation to another) support can be useful. The change can be done abruptly, step by step or animated. Indeed, 55 % of all participants did not need supported change of scale.
- Presentation forms for indoor environments:
  For indoor navigation (test case: University of Technology Vienna) different presentation forms have been used: floor plans (accepted by 82 % of the participants as “supporting navigation by finding the way immediately”), bird’s eye views (64 % acceptance, by 36 % acceptance of male persons and 91 % acceptance of female persons) or animated 3D graphics (55 % acceptance).

The following conceptions have been stated as only partly acceptable/helpful:
- Speech interaction:
  There has been no confirmation to the theory that mobile users could prefer speech commands instead of graphic-haptic interfaces. 68 % of the participants preferred a written menu for selection of destinations instead of speech commands.
- Photo realistic presentations:
  The use of photographs or 360°-panoramas has been stated as not useful in the context of small displays and pedestrian navigation, although the specific use of photos and panoramas for landmark identification and as support for decision points seems has found positive acceptance (photos: 73 % “yes, helpful for decision making”, panoramas: 55 %).
- Change of presentation forms in mixed indoor/outdoor environments:
  In the case of changing presentation forms by transit from outdoor to indoor navigation, changes supported by dynamical zooming between maps and floor plans have got the highest acceptance to all other combinations (intermediate steps, changes from 2D graphics to 3D graphics and vice versa).

Radoczky (2003) has shown with her studies that the chosen presentation form and the effort of supporting cartographic methods is decisive for the acceptance of pedestrian navigation systems. Adequate methods can accelerate the process of way finding and avoid uncertainties of the user.

5 Summary

In this chapter major aspects of concepting map-based LBS are discussed: integrative positioning, context-adapted data modelling and multimedia route communication. As a result the pre-requisites for positioning, data modelling and information communication are analyzed. Findings and results from research projects, accomplished at the University of Technology Vienna, have been presented. Results have been discussed, that lead to further developments and questions concerning the integration of positioning sensors, handing over positions seamless between indoor and outdoor navigation, modelling context-dependent communication forms for route information communication and to enable and to enhance map-based LBS, pedestrian navigation systems in particular.

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