# Preface

The development of wireless telecommunication and ubiquitous computing technologies has led to a growing mobile population and dramatically changed patterns of working and everyday life. A smooth and safe mobility is only possible when the mobile person is well-informed of the happenings in his ambient environments. Location-sensitive maps have proved a strong enhancement to what a mobile user can directly perceive from his ambient environments. Since ancient times the map has been the favorite communication language of spatial information. It is even more the case for mobile applications where brand-new maps can be wirelessly retrieved or generated in real-time. The upsurge of map-based services on mobile devices has raised a number of new questions challenging the conventional computer-assisted cartography.

*Map-based mobile services* provides a contemporary overview of research and development issues related to the design and the use of mobility-supporting maps. The book has been written for professional cartographers who are striving for extending their theoretical, methodological and practical knowledge to mobile mapmaking, for surveyors and geo-service providers involved in the development of intelligent location-based services, for software developers and cognitive scientists engaged in human-computer interaction, and for students and academics in cartography and geoinformation sciences.

The book was initiated by the multidisciplinary workshop “Design of map-based mobile services” within the frame of the conference “Human and Computer 2003 – Interaction on the movement” held in Stuttgart, Germany, September 2003. The enthusiastic resonance from workshop participants has encouraged the editors to invite further authors from outside Germany. Therefore, the book has become an international cooperation at the end.

The book covers the essential issues on theories in the first part of chapters, methods in the second part and implementations in the third part. Diverse case studies and application fields are discussed and demonstrated in each part. The empirical design rules and gained knowledge on mobile users reported in different chapters serve as a starting point for further elaborations. All chapters including colour images can be found on the accompanying CD-ROM.

Following the philosophy “cast brick to attract jade”, the book provides an insight into the design constraints and mobile user behaviour. The editors and authors hope to share their experiences, learnt lessons as well as new thoughts with the target readers and promote further considerations on the future development of ubiquitous computing and visualisation.

Liqiu Meng
Tumasch Reichenbacher
Alexander Zipf

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# 1 Map-based mobile services

Liqiu MENG and Tumasch REICHENBACHER

Department of Cartography, Technical University of Munich, Germany

**Abstract** This chapter gives a general introduction into map-based mobile services which are considered as value-added location-based services. Starting from an overview of digital map types, their rapidly growing affordances and required learning efforts, the natures and design constraints of offline screen maps, web maps and mobile maps are comparatively studied. The aspects of immediate usability are highlighted as a central thread drawing together the essential research challenges involved in the design process of user-centred mobile maps.

## 1.1 Background

The widespread Internet access since the 1990ties and the flourishing ubiquitous computing technologies in recent years have not only blurred the distinction between office and home, but substantially contributed to the increasing mobility of our working and everyday life. Handheld mobile devices (PDA and mobile phones) that have already exceeded traditional PCs in number (*Struss* 2004) are rapidly evolving from toys to tools. They tend to devour an ever growing amount of data transmitted on the basis of Internet protocols. Experiences hitherto have shown that maps remain the most popular communication language of spatial information also for mobile applications (*Kölmel* and *Wirsing* 2002, *Pammer* and *Radoczky* 2002, *Anand*, *Ware* and *Taylor* 2004), apart from the fact that more and more location-based services (LBS) are being integrated with the physical environments (*Gellersen* 2003), especially urban areas where computer chips are nearly omnipresent. Being equipped with mobile maps which have wireless access to Internet servers, modern mobile people are better informed of the events from near and far, past, present and future, can therefore get better prepared for their tasks than those nomadic tribes who have to heavily rely on their sensorimotor perception of the ambient environment.

"Putting yourself in the world and the world in your palm", however, does not automatically lead to an improved mobility unless both worlds can timely "melt" together in your brain. As a well-known fact, the synchronous interactions with the reality and its map that is usually not "life-like" exert an increased cognitive load on the part of users. Although the map is envisaged as a mobility-supporting artefact, it could very well become a mobility-impeding obstacle if not suitably designed. In order to keep the attention of a mobile user who can be, for instance, a driver, a cyclist or a walker, on his interaction with the reality, the map should be rendered and used non-intrusively. This requires, on the one hand, an intuitively operable mobile device of a nearly invisible size, on the other hand, a pervasive visibility of map symbols necessary for their immediate comprehension. Such a seemingly paradoxical requirement makes the design of map-based mobile services a challenging research topic.

## 1.2 Mobile maps and their predecessors

Map design, or cartographic visualisation, is a cognitive process that brings geo-objects, their relationships and processes into view on a usually 2D display surface. It involves a series of transformations. First, the 3D geographic space composed of spatial and non-spatial attributes will be "crushed" onto a flat surface. Second, the seamless real world will be folded up, scaled down and layered so that the mapping contents can be reasonably accommodated within the limited display size. Third, the various sensorimotor perception modalities of the real world will be trimmed to suit the dominating visual modality of maps. In spite of these inherent constraints, cartographers in pre-digital era had always found successful design solutions in form of maps which were occasionally complemented by map-like presentations. Since the introduction of computer the design flexibility has been dramatically expanded. Consequently, the scope of maps has been extended to include map-like presentations because of their booming quantities and importance for the spatial cognition. Depending on their intended usages, screen maps in pre-Internet times can be roughly divided into three major categories: view-only maps, analytical maps and explorative maps (*Meng* 2003).

### *1.2.1 View-only maps*

Like its printed counterpart, a view-only digital map serves as a storage medium and a presentation medium of geoinformation. It is mainly intended to transfer the knowledge of the map designer to his target viewers. In terms of viewing functions such as zooming, panning or scrolling, mouse pointer, integrated legend etc., the physical limitations concerned with display size and screen resolution are largely compensated. Moreover, multimedia solutions such as infographics, acoustic symbols, 3D graphics and animation can essentially improve the expressiveness of map symbols and open up many new perspectives and modalities of map perception (*Cartwright, Peterson* and *Gartner* 1999). However, the viewer (or listener) is supposed to be a passive information receiver. In principle, he has to "look at the maps long enough to get the messages they are giving" (*Triglav* 2004). How far a special viewer is able to distil the useful information for his application is largely dependent on his visual literacy, domain knowledge and ability to detect the visual cues embedded in the map. Since the reliability of the gained information from a view-only map can only be judged by its graphic quality, aesthetic aspects and geometric accuracy of map symbols are the major design concerns.

### 1.2.2 Analytical maps

An analytical map serves as a presentation medium and an interface that connects users with a geo-database. What it visualises can be both the geographic space and the associated hyper-dimensional information space spanned by the geo-database. Cartographers have a strong license to guarantee the legibility of an analytical map by intentionally adding artistic effects and inaccuracies to its individual symbols because the objectivity, accuracy and complexity of the underlying geo-objects are maintained in the database (*Poiker* 2003). Analytical operations such as clipping, highlighting, hiding, overlaying, searching, querying, and a lot of computing functions can further enhance the visual acuity of interesting data items. According to (*Gabbard, et al* 1999) there are two distinct domains that make up interactive system development - the behavioural domain representing the view of the user and the user's interaction with the system, and the constructional domain representing the view of the system developer and the overall system. In an analytical mapping system, these two domains begin to touch each other. Excellent examples for such an interactive phenomenon can be found in multimedia atlas information systems (*Hurni* 2001). However, users as active information receivers have to spend an increasing learning effort on the extensive interactions with and through the map. Analytical maps in current GIS tend to be disconnected to their design elements. A majority of them are merely a graphic transcription of their object geometry or topology. The usability of an analytical map is often limited to the pragmatic aspects which, for instance, can be measured in terms of effectiveness and efficiency of a typical user in completing typical tasks for typical goals. It can be argued whether the plain-looking and emotionless maps are really more favoured by users than elaborated design solutions, and how far both roles as presentation medium and interface could be fairly united in analytical maps.

### 1.2.3 Explorative maps

An explorative map serves as a presentation medium, an interface and a thinking instrument that visually supports its users to confirm or generate hypotheses, detect hidden concepts and value-add the underlying geo-database. Multiple expressions that stress different aspects of the same dataset and their multimodal access are typical design strategies to facilitate the exploration (*MacEachren* and *Kraak* 2001, *Andrienko* and *Andrienko* 2004). Users are provided with not only the viewing and analytical tools, but also a maximum freedom to manipulate the mapping contents by means of editing operations such as translating, rotating, morphing, inserting, removing and generalising or even redesign the maps. In an explorative mapping system the behavioural domain not merely touches the constructional domain, but gets interwoven with the latter. With the utmost visual exposure of a geo-database, the user strives for the acquisition of the highest possible level of intelligence along the hierarchy "knowledge → comprehension → application →

analysis → synthesis → judgement" according to Bloom's taxonomy (*Arleth* 2004). The explorative interaction is indeed a process of mutual information gain in the sense that it allows the user to discover and define hidden knowledge based on his insight into the geo-database and at the same time makes the geo-database regenerative. However, the maximum user freedom in using explorative maps is coupled with the maximum learning effort and the maximum risk of getting "lost" in the infinite design possibilities. For this reason explorative maps are not intended for one-time use or real time tasks. Moreover, their usability, even when only the pragmatic aspects are concerned, remains difficult to measure since tasks and goals of knowledge discovery are often ill-defined (*Marsh* 2004). Many usability tests so far have been restricted to applications where the exploration tasks have been a priori defined by users or qualitative evaluations are desired (*Andrienko*, et al. 2002, *Slocum, et al.* 2003).

### 1.2.4 Web maps

The emergence of Internet as a giant "information trade centre" has revolutionised the distribution of screen map products. Meanwhile, the web-based screen map or web map has been assigned with two new roles: as a metaphor to spatialise the information space and as a collaborative thinking instrument shared by spatially separated users. Nevertheless, the web design including web map design proves a more complicated process due to the accessibility of worldwide spanned data sources and the changed user behaviour. A web map behind which distributed processing technologies are wrapped and hidden look spectacular and refreshingly simple (*Kuhn* 2004), yet its open-ended nature makes it more fragile than a closed mapping system. In addition to all the design elements applied to a non-web map, the web map as well as its individual symbols can be treated as hyperlinks leading to various sorts of virtual places in cyberspace. Statistic investigations have revealed the fact that about 50% of web interactions are hyperlink actions (*Weinreich, et al.* 2003). This means that both the web designer and the web user are confronted with a cognitive overhead associated with the encoding and decoding of hypermedia information. Although the designer is able to make full use of audio-visual variables to distinguish the hyperlinks from other symbols, inform the user of the hyperlink type (e.g. textual or graphic association, sound, video, action, another map etc.) and provide necessary navigational guide, he has little control over the linked contents and their design parameters. As soon as the user decides to click on a recognised hyperlink, he runs certain risk of invoking unexpected change of the web page appearance, losing his task and gained information from the vision field, getting irritated by erroneous links or cryptic message, landing nowhere or finding no way back. The erratic characteristics of hyperlinks are so far a major barrier that hampers the usability of web maps in terms of both the activity-oriented pragmatic quality and the self-oriented hedonistic quality (*Hassenzahl, et al*. 2003, ISO 9241, *Nielsen*, 1993, *Preece et al.* 2002). As a whole, a web map is a rather intrusive and "thick" interface. Being bound to stationary computers it usually occupies the entire vision field of the user, thus demands his exclusive attention. Moreover, the unpredictable reaction time of hyperlinks always reminds the user of the “thickness” of a web map.

### *1.2.5 Mobile maps*

The realisation of wireless Internet access has finally brought web maps back to mobile environments where they are most needed. Along with the triumph of unification of two open-ended systems - the real and virtual world, however, cartographers are facing a number of more acute design constraints. The miniaturised display devices make mobile maps more personal than their predecessors. Although the same mobile map can be shared by virtually networked and spatially separated users like a usual web map, it does not primarily act as a collaborative thinking instrument, rather a common memory to back up the group mobility. The contents and presentation styles of a mobile map need to be adapted to the actual requirements and cognitive abilities of individual mobile users (or collaborating mobile user groups). Not only the technical factors such as limited display size, energy supply and bandwidth of wireless network, but also non-technical factors ranging from time-critical user tasks, constantly altering environments to volatile user emotions force the designer to accommodate in the mobile map only the information that is instantly needed and effortlessly comprehensible with little or no interactivity (*Reichenbacher* 2004). The general postulate in conventional cartography: “Map use is an effortful process that needs training” is obviously no longer valid for mobile applications. A mobile map is somewhat like a snapshot of an environment around a certain location and time, but with highly selective information and integrated intelligence. Often a few points of interest (POI) floating on a skeletonised background graphic would suit the short-term memory of a mobile user better than a more detailed presentation. Likewise, a quick-and-dirty design solution, e.g. a sketch, would more likely arouse the association with the non-persistent information affordance than a complete-looking visualisation (*Halper et al.* 2003). Due to its temporal nature, a mobile map is mainly intended for one-time or first-time use. Apart from technical issues such as network accessibility, positioning quality and transmission speed (*Sayda*, *Reinhardt* and *Wittmann* 2002, *Schult* and *Kretschmer* 2003), the designer has the essential task to match a “meager” map with the “meager” user requirements filtrated through a very narrow space-time slot. The matching must take place in real time or pseudo real time, which means that a mobile map will not be accepted by its user unless it is immediately usable.

## 1.3 Affordances of maps

The technology-driven evolution from view-only maps to mobile web maps as described in the preceding section has not only extended the typology of cartographic products, but also progressively enriched the map functions. In relationship to its intended usage and required learning effort, a map which is understood in its broadest sense can have one or many of the following affordances:

- As a visual stimulus to be seen. The overall layout is perceived as an advertising and eye-catching unit.
- As a work of art to be admired. The aesthetic aspects of design elements are perceived and evaluated.
- As a valuable document to be carried with. Due to its general usage a map is able to emotionally safeguard the user for his spatial tasks.
- As a regenerative knowledge pool to be shared. Networked users can exchange their spatial ideas synchronously or asynchronously through a map and depict the results in the map.
- As a symbolised presentation to be decoded. Descriptive information answering the questions such as "what is it?", "where is it?", "how much is it?", "how far is it from one place to another", "why is it so?" is embedded in map symbols and their relations. It can be interpreted by virtue of map legend, interactive tools and user association.
- As an intelligent agent to be relied upon. Procedural knowledge on "how to do what and in which order" is encoded as self-explaining instructions or self-evident gestures. It can directly guide user activities such as travel planning, fleet management, traffic monitoring etc.

Map-based mobile services are a special type of value-added LBS. They afford both the descriptive information and procedural knowledge through mobile maps.

## 1.4 Research challenges of designing map-based mobile services

Human-centred design, or put it more precisely, user-centred design, has been a topic since years with the goal to create usable design solutions that allow users to do the things they want to, not the things they have to (*Nielsen* 1993, *Cato* 2001). This is exactly what a mobile user desires to experience with map-based mobile services. According to ISO 13407, user-centred design is an iterative process composed of the stages: (1) identify the need for user-centred design; (2) specify the user and organisational requirements; (3) produce design solutions; and (4) evaluate designs against requirements. One of the key issues in such a process deals with user modelling by tracking dynamic user behaviour and constructing user profiles. Theoretically, a user model is composed of numerous facets, with each representing a particular user. For mobile applications that require real-time design solutions, it obviously makes little sense to investigate all possible demographic attributes and personality variables that make up a unique user. Although every human decision is essentially triggered by an interplay of a variety of user features such as gender, age, learning history, experiences, domain knowledge, preferences, intelligence, social-cultural background and physical environment, what matters most in the mobile context are the actual task, the actual information need, and the actual cognitive ability of the mobile user.

Activity theory based on the belief "you are what you do" proves an efficient approach to build up a functional user model that focuses on task-relevant user behaviours (*Engeström* 1987). Being driven by a certain task or goal, user behaviours such as interactions with the map and mobile trajectories in physical environments (*Mountain* 2004) give valuable clues on the time pressure, the information need and the way this need gets satisfied. For instance, a tourist and a business man travelling through a strange city with different time pressures typically select different objects as landmarks to get oriented. However, activity theory has its limitations as soon as the actual cognitive ability of the users is concerned. It is generally known that the actual cognitive ability of a user is correlated with his actual emotion state which tends to fluctuate more in mobile than in stationary environments, and more with time pressure than without. Indeed many users do not consult a map at all unless they are disoriented or seized with a panic (*Muehrcke* 1992). Situations that cause troubles are often demanding situations involving many error-prone spatial decisions. Unfortunately, emotionally unstable users may behave entirely differently from what they would likely do in normal situations. Some may experience a memory black-out, while others may on the contrary show an increased performance of information processing. Even the same user may react differently in similar panic situations that occur on different occasions. The unpredictability of emotion-conditioned behaviour makes it a more or less blind action to trigger an adaptation of the map information that would help the chaotic user get out of the trouble. Bearing this fact in mind, it would be a better choice to embed personalised solutions (e.g. instructions or gestures as mentioned in section 1.3) in the mobile map than to screw up or down the mapped contents. By providing ready-to-work services instead of ready-to-get information in troublesome situations, the mobile map takes over an essential part of mental effort for information processing from the user, thus makes the non-deterministic influence of the user's actual cognition ability less critical.

In the realisation of user-centred mobile maps on small display devices then, the designer typically has to find trade-offs

- between the frequency of adaptation (e.g. alignment of map orientation with the moving direction, determination of map scale in accordance with the moving speed) and the necessary consistency a mobile user would like to rely on,
- between the degree of adaptation and the degree of interaction,
- between the maximally allowed visual load on a mobile display device and the minimum amount of information required by the user for a certain moment,
- between the maximum number of visual signs a user can recognise within a certain time limit and the minimum number of information units he can efficiently remember,
- between reusable and one-time design patterns, and
- between conventional design solutions (e.g. topographic map, 2D city plan) and egocentric presentation styles (e.g. fish eye view, 3D perspective from the current user location and time).

This list is not intended to cover all the research questions involved in the design process. Rather, it tries to highlight some essential problems that are frequently encountered in the design practice.

## 1.5 About the book

Mobile environments provide an exciting playground for the development of map-based services. A great number of constraints in relation with location, time, user, technical possibilities and available intelligence in physical environments need to be balanced in real time in order to reach the immediately usable solutions. This book is dedicated to design and usability issues of map-based mobile services. With works by authors from universities, research institutions and software industry around the world, it is meant to illustrate the state of the art of researches and applications in mobile cartography – a field where many disciplines work together. The chapters are divided into three parts that respectively address theoretical, methodological and practical considerations. In the first series of chapters, a number of new and reusable design elements of mobile maps are introduced along with a conceptual framework of user modelling. The second part describes adaptive design methods and empirical rules suited for typical user tasks and movement modalities as well as experiences gained from field studies. The last chapters demonstrate prototypical mobile mapping systems and their performance in supporting mobility for different applications. Human factors are emphasised throughout the book as the essential element guiding the design.

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# 2 Portrayal and Generalisation of Point Maps for Mobile Information Services

Alistair EDWARDES, Dirk BURGHARDT, Robert WEIBEL

Department of Geography, University of Zurich

**Abstract.** One of the most frequent operations in mapping for mobile information services is the conflation and portrayal of geo-coded thematic information with a topographic base map in response to *ad hoc* queries on a geographic database. Usually this operation is performed by a simple overlay of the symbolised features with no consideration for maintaining the impression of spatial relationships both between the foreground features and the base map and amongst the foreground features. This chapter discusses the problems of this approach in relation to the dynamic between communicating symbolic and communicating spatial information cartographically. It describes ways in which this balance might be managed through better models of space. Further it places the problem within the broader remit of cartographic generalisation and discusses how these techniques can be combined with spatial modeling to better support mapping activities.

## 2.1 Introduction

Mobile mapping makes extreme demands on cartographic and geographic information systems. It desires to provide highly flexible views of geographic databases rapidly and in almost any situation but carries the crippling constraints of small, low resolution screens, limited processing power and intermittent network connections. Whilst arguably some of these constraints will smooth out with the maturation of technologies there remain deeper considerations for cartographic theory at a more fundamental level. As (*Meng* 2003) notes:

*"Instead of following the motto "Today's theory is the key of tomorrow's practice", cartographers have been spending the majority of their effort in learning the latest and often very volatile technologies as if keeping pace with technical developments were the only choice that could protect them from becoming a loser in the super-competitive society. Although new technologies help to make the cartographic practice work better, they do not necessarily yield better products and more usable systems. In the long run, the lack of theories and methods that should guide cartographic processes may cause the degradation of the scientific value of cartography."* (*Meng* 2003, p. 1888).

An area where such concerns can be highlighted is in one of the most common activities performed in mobile mapping. This is the conflation and portrayal of geocoded location data, serviced by some third-party information provider, within a topographic base map. Reichenbacher (*Reichenbacher* 2003), for instance, describes the use and *adaptation* of such information (landmarks, points of interest (POI), geolocation of people, objects and events) in 'geovisualisation' services. There are three core problems related to this issue that require the development of a more complete theory:

- Methods are needed to conserve the spatial and topological relationships between the thematic (foreground) data and the topographic base map (background) data after each data source has been symbolized.
- Methods are needed to preserve the spatial relationships amongst the foreground features after these have been symbolized.
- The types of spatial relationships that are relevant to the feature types at different scales need to be understood and modeled so that they can be preserved.

This last point is particularly important for considering the geographical aspects that the map should communicate. Different types of data have different structural relationships both to the space in which they are located and to the other features around them.

## 2.2 Context of research

The context of the research reported here is the EU project *WebPark* (2004) which is developing a mobile information system for the delivery of contextual information services to visitors of national parks. Within this project the emphasis of the research described is the mapping of point based information about points of interest and wildlife observations (*Edwardes et al.* 2003). Here the thematic foreground data is delivered by 'third-party' information service providers (in general the geographic information departments of a national park) which will generalized and then overlaid on a topographic background map. Such a process figures prominently in a variety of mobile information services, where a user wishes to make *ad hoc* queries on a database of geo-coded point information. This situation has particular challenges that differentiate it from more typical topographic map generalisation.

- The foreground data, potentially from several different providers, must be conflated with a base map that is static with respect to the generalisation process. Relationships, such as topology, between the foreground and base map should be preserved.
- There is no cartographically consistent source dataset which triggers the generalisation process or that can be referred to in evaluating a situation.

- In general, the information service provider is ignorant of the types of spatial relationships inherent amongst features in their database, and of the factors that govern these relationships.
- The foreground data often has many different dimensions (attributes) of which only a few can be portrayed. Having different dimensions also usually means that the data can be classified hierarchically in many different ways (*Timpf* 1999).

## 2.3 Maps as a representational medium

Maps are analogue representational media (*Palmer* 1978) that communicate information in two ways: symbolically and spatially (*Berendt et al.* 1998). Symbolic information is represented explicitly by presenting selected attributes of the features illustrated by icons. Spatial information is represented implicitly by using the spatial characteristics that constrain the map medium as analogous to those constraining geographic space (*Sloman* 1985). Hence spatial relationships in geographic space can be said to be represented more or less "faithfully" in the map space. These two dichotomous forms of information description do not generally sit happily together. Symbolising features on a map, beyond their real world footprint, necessarily impacts on the ability of the map to represent spatial relationships. Two inter-related mapping activities affecting this relationship activities can be distinguished: portrayal and scale selection.

- Portrayal relates to the selection and application of a set of graphical styles that will be used to communicate selected attributes of the information symbolically. Different schemes of portrayal will have different effects on the ability to describe spatial relations.
- The scale selection further affects the way in which the extensional dimensions of the symbol will scale relative to the scaling of the properties of space. Figure 2.1 illustrates this.

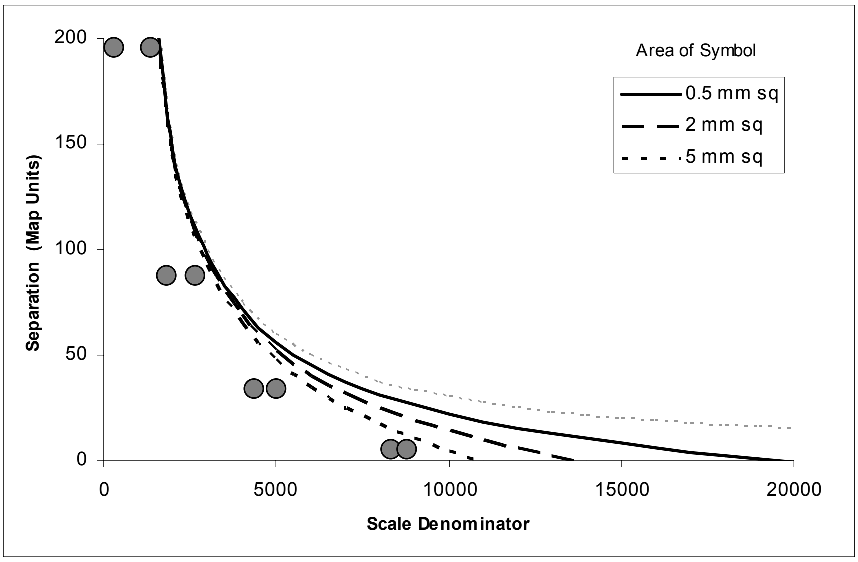


**Fig. 2.1.** Scaling, representation and spatial relationships

Figure 2.1 shows how the (minimal) separation distance in map units between two point circle symbols of areas 0.5, 2 and 5 $mm^2$ changes with scale. It can be seen that the scaling rates are dependent on the property of the symbol, here varied by size (area). Hence the larger the symbol the faster the degradation of spatial relationships as scale is decreased. Maps are always portrayed at some scale so these effects are always evident. However they are particularly marked in mobile information services where the relatively coarse resolution of the device screen requires larger symbols than would be required for other display media.

The operation of cartographic generalisation can serve as a mediator in the relationship between these two forms of information representation. On the one hand, generalisation can omit and reconfigure the information in order to preserve the communication of spatial relationships. On the other hand, generalisation can change the form of portrayal to describe phenomena at a different 'level of organisation'[1].

## 2.4 Map types and multiple views

Since the objective of mapmaking is to describe some of the spatial characteristics of information, maps will always present a certain degree of spatial and a certain

[1] See *O'Neill and King* (1998) for a useful discussion on the difference between scale and levels of organisation taken from the perspective of landscape ecology.

degree of symbolic information. Conceptually, we can think of a map as striking a balance between these two types of abstraction processes. On one hand is the ontological abstraction of phenomena that exist in the world and their properties. This is the selection of salient features and their important attributes, the classification of these into feature types, their ordering and the definition of semantic inter-relationships existing amongst types. On the other hand is the abstraction of spatial relationships. This is the process of defining the types of spatial characteristics that are important for the description of a geographic phenomenon at a given scale. For example, Piaget and Inhelder (1971) describe a model of different levels of abstraction of spatial relations which they suggest explains the development of spatial understanding of children. This sees peoples' thinking about space as developing through stages from topological understanding, projective understanding and finally to comprehension of fully Euclidean spaces. DeLucia and Black (1987) also present a system of abstraction for spatial relations and spatial patterns. They use gestalt rules for perception to describe different abstractions in the context of cartography.

One reason for having different types of maps, or forms of portrayal, for representing the same data is to place more or less emphasis on one or other consideration. Berendt et al. (1998) term these factors *aspects*, which they define as "properties of and relations between geographic entities". For example, "Point of Interest" maps emphasise the symbolic aspects of a dataset, whereas continuous density surfaces highlight the spatial aspects of a dataset.

An ordering of portrayal types based on how they balance this relationship is useful but problematic to create. Ideally we would present an ordering from low to high "abstraction". However the different dimensions of abstraction make it unclear how they are combined intuitively in an ordering relation. Alternatively we could adopt the term used in spatialisation research of "fidelity" (Fabrikant, *pers comm.*) which describes map-types in terms of how faithful they are to reality. Finally, we could just consider the level of abstraction of spatial relationships that are preserved in a map view. Following the arguments of *Piaget and Inhelder* (1971), this perhaps provides a more user-centered, "simple" to "complex", ordering of map views. Figure 2.2 shows an ordering for a selection of map views used in the WebPark project.

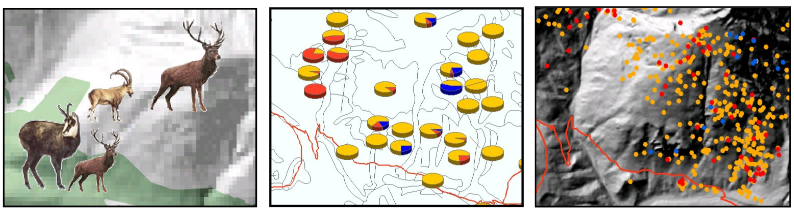

**Fig. 2.2.** Portrayal schemes showing differing degrees of spatial relationships

The first example in Figure 2.2 attempts to describe data on animal observations by emphasizing symbolically the attributes of each individual observation. It uses large heterogeneously shaped icons which allow rapid identification of the principal type and relative number of animals observed at each location but because of this is limited in its ability to describe spatial relationships between observations. The second example describes information about the diversity in types of animal observed at the same location. It takes a more balanced approach between the symbolic and spatial aspects of the information by using smaller, more homogenous looking icons with diversity shown as a pie chart graphic. More information about spatial arrangement amongst locations is provided but at the cost of less readily understandable attribute information for any one observation. The third example uses simple coloured dots to describe locations and number of animals observed. It emphasizes the spatial aspects of the information such the pattern of density and distribution but is limited in what it can further describe about the attributes of the information or about the characteristic of any one site.

## 2.5 Symbolisation and spatial relations

As has been shown, whenever we adopt a form of portrayal to communicate information through a map, we must accept that this selection will have a direct knock-on effect on the ability to communicate spatial relations. As choices about what is to be communicated must be made. A question that arises is: What are effects that symbolisation has on the ability of a map to represent space and spatial relations? Whilst there has been a great deal of research on the semiotics of individual symbols themselves (e.g. *Bertin* 1974) as well as on how symbolisation affects the perception and cognition of spatial information (e.g. *Board et al.* 1977, *Dent* 1972 and *Muller* 1979), defining the limits to spatial representation posed by symbolisation more directly has received far less attention.

The impact of symbolisation on space can be considered according to whether we view space as relative or absolute. Viewing space as absolute, the symbol is thought of as occupying a region of space, or consuming “white space”. Viewing space relatively, the impact of symbology is to distort space around a feature. Figure 2.3 illustrates these perspectives for a set of point features viewed in terms of absolute and relative space.

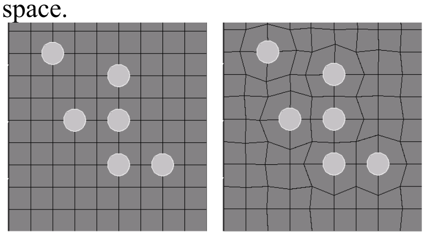

**Fig. 2.3.** Distortions of space and spatial relations caused by symbology, in absolute (left) and relative (right) terms.

In Figure 2.3 the grid in the background is used to represent the underlying space as a coordinate system in which points can be located. If we consider only those points of space where the grid lines cross, we can see that for the absolute view there are points that are covered by the symbol. For the relative view these same points are preserved because they have been pushed away from the symbol. The only point that is covered by the symbol is the location of the symbol itself. We can still locate all other points within the grid. For example, if we took a GPS position for a person and located this within the distorted grid reference system of Figure 2.3, the person would always remain next to the feature rather than underneath it. Formally this means that the relative view preserves the point-set topology (c.f. *Galton* 2000) of the underlying space. This property of the relative view makes it useful for considering the impact of symbolisation on the spatial characteristics of the map.

This distortion can be modeled as an extension of the type of variable scale projection described by Harrie et al. (2002) and Rappo et al. (2004). These authors present projections where the map scale varies locally within the map space from an user-centered, circular region at a constant, larger, scale decreasing to a constant, smaller scale, in the rest of the map space. Figure 2.4 shows this projection including the symbolized point and without. The extension here is to think of the operation of symbolizing a point as magnifying the *neighbourhood* of that point to the size of its symbol. Here neighbourhood can be defined in terms of the data resolution. This scale deformation is then gradually absorbed to bring the space back to its original scale.

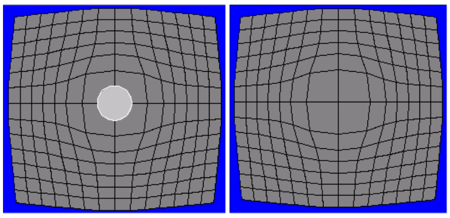

**Fig. 2.4.** The use of a variable scale projection to distort space around a map symbol, following the method of Harrie et al. (2002). Left: space with symbol. Right: space without symbol.

### 2.5.1 Space distortion from symbolisation in data conflation

Modelling the distortions of space caused by symbolisation can be used in one of two ways. As a *measure* for cartometric analysis, distortions of the map space can be used to consider which spatial relations can still be described in different regions of the map following symbolisation. As an *operator* it can be used to reconfigure symbolized features so they meet cartographic requirements. For example by displacing features to avoid symbolisation conflict whilst preserving their spatial arrangements or by assisting in the conflation of data so as to maintain the relationships between the foreground and symbolized base map features. Here distortions to the grid are computed based on the portrayal scheme of the map features. Smoothing out these distortions results and reprojecting the data results in features being moved apart. Figure 2.5 illustrates this process. Figure 2.5a shows the undisplaced points. Figure 2.5b shows the distortion to the space caused by the portrayal scheme. Figure 2.5c shows the points displaced under the transformation create by the distortion.

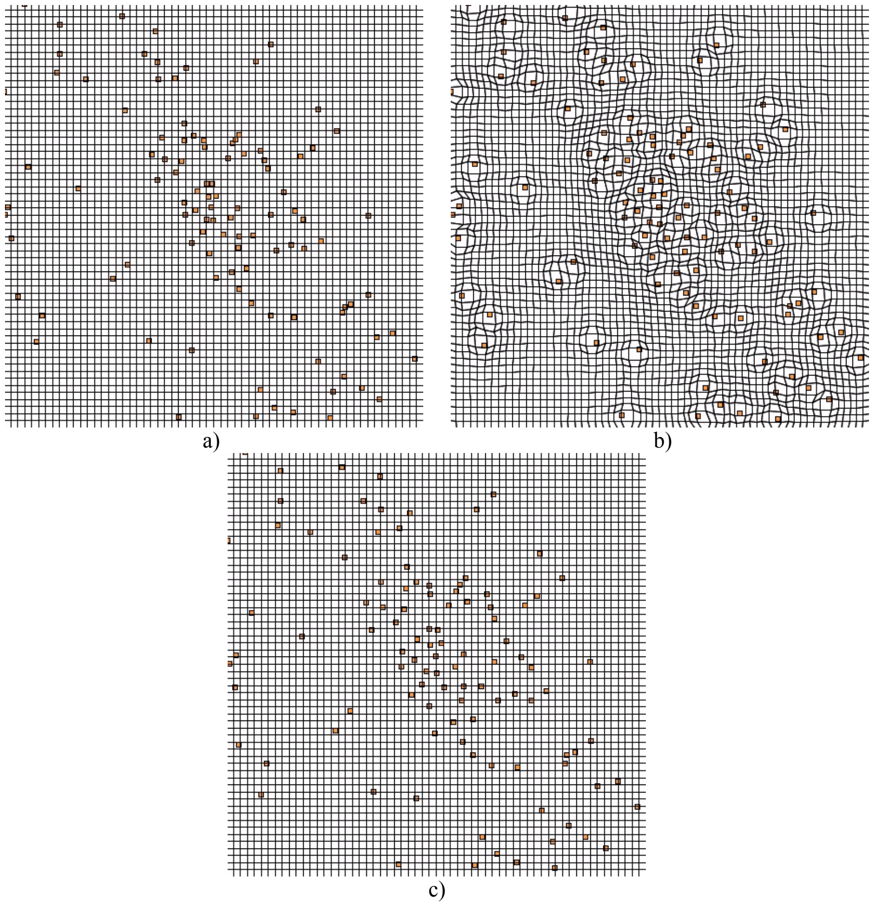


**Fig. 2.5.** The use of a model of symbolized map space as an operator

By creating hierarchies within the process, such that base map features can distort the space but are not displaced by it, the transformation can be also be used effectively to aid the data conflation process.

### 2.5.2 Abstractions of spatial relations

Treating space as absolute is the usual perspective taken in cartometric analysis for map generalisation, in the sense that it is common to view "white space" as having been consumed by symbolisation. Relative spatial relations existing amongst features are also considered. These are abstracted (*DeLucia and Black* 1987) and modeled explicitly through the construction of auxiliary data structures that integrate symbolisation effects within a spatial context (*Mustière and Moulin* 2002). Such structures include Delaunay Triangulations (*Ruas* 1998), (*Ware and Jones* 1998), Voronoi diagrams (*Hangouët* 2000), Minimal Spanning Trees (*Regnauld* 2001) and Energy Minimising Splines (*Burghardt and Meier* 1997). It is suggested here that, as a complementary approach, it can also be helpful to construct a model of relative space that considers all points in space and not only those that are symbolised as features.

According to the relative view, local distortions of space mean that not all the relationships that can be determined in a completely Euclidean space can be supported. Instead a less constrained space should be considered that preserves fewer properties.

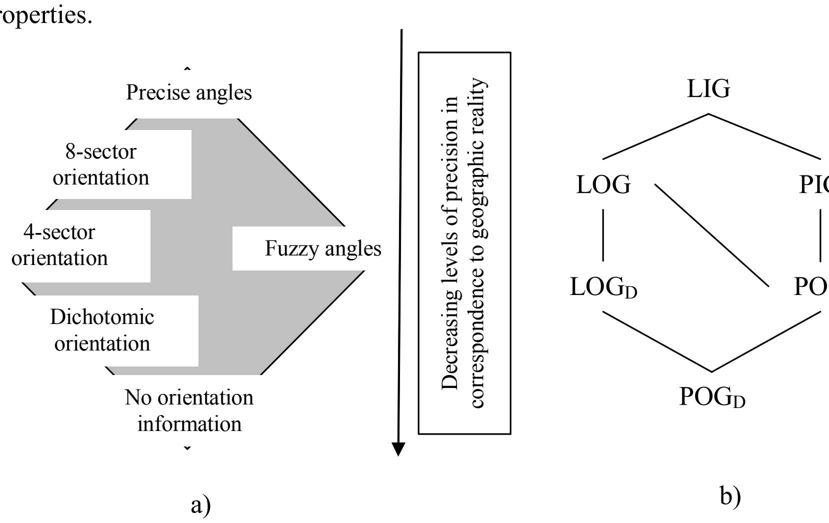


**Fig. 2.6. a)** An example of a hierarchical structure for representation correspondence from Barkowsky and Freska (1997, p.358) **b)** Containment structure of geometries from Habel (2003, p.88); LIG – linear incidence geometry, LOG - linear ordering geometry, PIG – planar incidence geometry, $LOG_D$ – LOG with direction, POG – planar ordering geometry, $POG_D$ – POG with direction.

Habel (2003) terms this *representational commitment*, where the map maker commits to a specific level of abstraction within an axiomatic system of geometries. Habel's description of representational commitment relates mainly to global aspects of map design, such as choosing whether to represent data in a geometrically accurate or in highly schematic form. Barkowsky and Freska (1997) similarly propose an ordered system for representational commitment, which they term *representational correspondence*. They suggest this might be used to guide more local generalisation processing. Examples of geometry structures from these two groups of authors are shown Figure 2.6.

These examples for abstracting spatial properties can be followed in considering the effects of distortion in a relative space modeled with a deformable grid. Assuming a model of linear interpolation across a cell, distortion can be considered as representing different types of transformation (e.g. conformal, affine, projective). These transformations affect the metric properties of the space to preserve aspects such as angles, lengths and parallelism of lines (and other properties e.g. ratios and cross-ratios). Examples of transformations on the grid cells are shown in Figure 2.7.

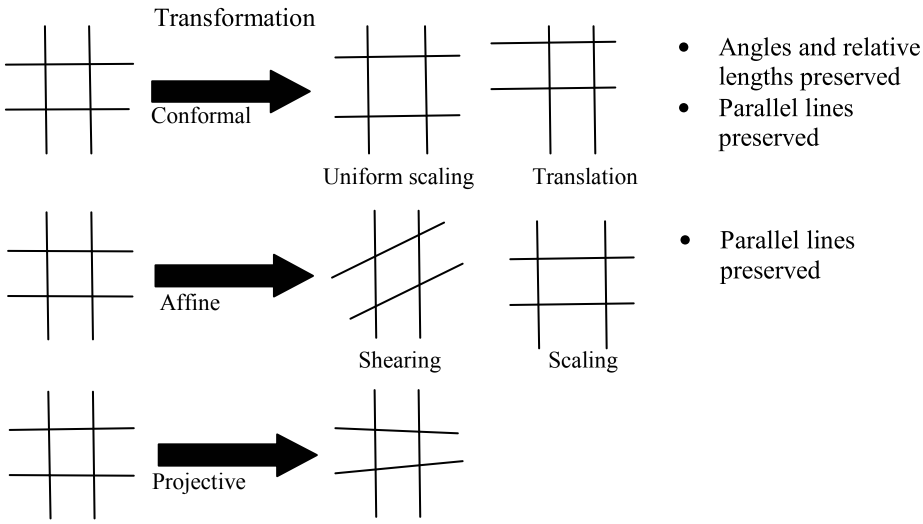


**Fig. 2.7.** Distortions of the grid expressed as transformations.

Within this context the example hierarchy of *Barkowsky and Freska* (1997) in Figure 2.6a) can essentially be seen as a partitioning of the space of possible transformations according to the severity with which different transformations degrade the preservation of angles.

The interesting point, for the generalistion process, gained from these observations is that they present a view of generalisation from the perspective of generalizing the properties of the space itself rather than generalizing the spatial arrangements of feature within the space.

## 2.6 Geographic space

Modeling the map space can help determine *how* to preserve spatial relations during portrayal and generalisation, but to consider *what* spatial relationships should be preserved the geographical properties of the map need to be considered more explicitly. Since the motivation for this work is in developing theory to support the portrayal and generalisation of information stored as points, it is useful to consider the statistical techniques used to model densities, distributions and arrangements of point patterns in geography. The model used in spatial analysis to describe the spatial autocorrelation structure of geographic information is defined in terms of first and second order spatial variation (*O'Sullivan and Unwin* 2003), (*Atkinson and Tate* 2000). First order spatial variation relates to the degree to which the distribution of data points is influenced by some underlying property of the geographic space. For example, the density of observations of deer is likely to vary partly because of the influence of underlying biotic and abiotic factors, such as vegetation and thus what the deer may forage on. Second order spatial variation relates to the degree to which local interactions amongst features will effect the resultant distribution. Using the previous example, the arrangement of deer observations is also likely to be partly dependent on social and behavioural aspects of the animals, such as herding.

The relative strength of first and second order properties of variation is related to the scales over which different underlying causal processes operate. Decreasing scale changes the resolution of the map because it increases the smallest distance over which spatial relationships can be considered. Following the deer example, at detailed (larger) scales processes based on interactions amongst animals will be realised as patterns that show strong second order variation, whereas at more general (smaller) scales these processes will be far less significant and patterns will tend to be influenced more by processes showing first order variation. In the main, however, both factors are likely to contribute. For example, there may be clusters of observations based on herds of animals in niche locations that show largely first order variation but the separation of these clusters may be determined by territorial interactions such as competition.

Most statistical analysis is premised by the fact that we can compare a pattern to one that is random in order to describe spatial variation. In many situations it may not be possible to demonstrate any spatial variation. In this case it can only be concluded that a pattern is random. Randomness is itself also an important spatial relationship to represent. Many generalisation operators assume that there are spatial relationships that must be preserved but to apply such techniques to a random distribution would produce maps that are misleading. In these situations only the locations of points themselves rather than their distributions can be generalized.

Whilst these different types of variation can be described, in practice it is difficult to separate out their individual contributing effects without expert interpretation of the data and hypothesis testing. Particularly in the context of an information service provider this experience is generally not available. This is not to say such factors should be ignored but rather a map author should try to actively limit the degradation that occurs in the presentation of spatial variation, for example by comparing the characteristics of Ripley's K function before and after generalisation (*O'Sullivan and Unwin* 2003).

## 2.7 Generalisation

McMaster and Shea (1992) present a model of the generalisation process decomposed into three operational areas. These consider the why, when and how to generalise.

Why generalisation is conducted relates to the cartographic principles of map design for maintaining the clarity and fidelity of spatial information in a communication. In automated generalisation theory these are captured through the definition of cartographic constraints (*Beard* 1991), (*Weibel* 1996). Many of these constraints can also be thought of as relating to the distortion of space. If symbols touch or overlap we can think of the underlying space as having been torn, since we can no longer consider a point in space between two symbols as having a neighbourhood. If the density of symbols is too high the distortions of space mean we are limited in the spatial relationships that can be communicated and therefore what can be said about spatial variation.

When to generalise relates to the identification of points at which the map has broken down in terms of its ability to describe aspects of the spatial variation of geographic space at a given scale. Ratajski (1967) termed this breakdown the *generalisation point*.

How to generalise relates to the application of generalisation operators to remedy this breakdown and return the map to a meaningful state. In this state aspects of the spatial variation that are relevant to the geographic phenomena and processes operating at the scale of the map are communicated in a way that respects the cartographic constraints. In terms of the distorted space we can think of generalisation operators as relaxing areas of high distortion or finding existing solutions within a distorted region by reconfiguring features to commit to a more abstract, less constraining, level of spatial relations.

### 2.7.1 Generalisation operators for point maps

Five operators that are most meaningful for the generalisation of point maps for mobile information services are: selection, simplification, aggregation, typification and displacement. These operators are guided by measures that provide information about spatial relationships and spatial variation that should be preserved and that define the domain of features over which the generalisation operator should act. Tools for the statistical analysis of geographic space and for modeling the distortions of relative space are two groups of measures. In addition clustering tools are required that identify feature domains spatially, that is, the groups of features where variation occurs.

### *Selection*

Selection is the identification of features and their attributes to be portrayed at a given map scale. Selection is concerned with the semantics of the features rather than their location attributes and as such represents the abstraction of the symbolic aspects of the map. Selection can be applied globally or locally. Globally, selection is a filtering of features (*Timpf* 1999). One the one hand, the impact of global selection is usually to create the conflicts in the map space which must be solved by other operators. On the other hand, global selection within a set of already selected features creates a smaller set and thus reduces the potential for conflicts. Figure 2.8 (left) illustrates the global selection operation. Locally, selection is more appropriately thought of in terms of its inverse, omission. Local selection is triggered by conflicts amongst map symbols. It seeks to omit features within a conflicting set based on their relative semantic importance. Local selection is important where the primary concern is with maintaining the positional accuracy of features or relative positional accuracy between symbols of the foreground and base map, since the operator does not change the position of features. This is particularly the case when a point set shows a random distribution. Figure 2.8 (right) illustrates a local selection operation.

**Fig. 2.8.** Selection: left - global selection, right - local selection

### *Simplification*

Simplification can be thought of as a form of selection that filters features based on spatial properties. It is often presented using an optimisation technique with an objective function of finding a subset which best approximates the set of all features with respect to some defined characteristics (Cromley and Campbell 1991). The size of the subset may be dictated in advance or may be dependent on some error bound. Simplification is usually applied globally to a map, though it is possible to apply it more locally to clusters. The purpose of the operator is usually to relax the solution space for the conflicts rather than solve them entirely, though this requirement may also be integrated as constraints on candidate approximations. In general simplification acts to reduce the density, or level of detail, of data. As such it can be thought of as an operator that primarily considers the first order aspects of spatial variation. Figure 2.9 illustrates the simplification operator applied to a set of points. De Berg et al. (2004) describe an algorithm for simplifying point patterns using ε-approximations that aim to preserve first order variation across the map space.

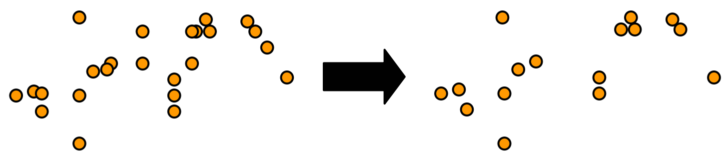

**Fig. 2.9.** Simplification operator for a point set

### *Aggregation*

Aggregation is the replacement of two or more features with a new feature or phenomenon. Its main purpose is to reduce the level of detail in the map by decreasing the number of features and the level of abstraction in the semantics of the feature types. Aggregation is used where semantically similar features are spatially too close together to be considered as existing at unique locations and hence their individual identities are no longer meaningful. This may occur because a change in the map scale reduces the resolution which distances can be described at, or because a change in the feature type abstraction means that two features are no longer distinct. Aggregation therefore involves the application of two types of rules which define the spatial and semantic conditions that must exist prior to a joining (Molenaar 1998). Points can be aggregated only if there is a feature type whose semantics incorporates their individual identities. Hence, the features will either have a common classification or there needs to exist a more abstract feature type that integrates the individual classes which is often expressed through 'part-of' relations in the feature type schema. Points can be aggregated only in certain geometric or topological situations, termed linkage rules. For example, as well as being close enough the features may also need to be on the same side of another feature in the base map, e.g. a river. Linkage rules get more complex as the number of points that can be combined into a single point increases. Aggregation is applied globally to a map and only resolves graphical conflicts amongst the limited set of features satisfying the linkage rules. Even then the resultant compound feature may be in conflict with others. Figure 2.10 illustrates the operator.

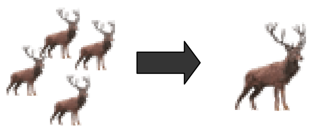

**Fig. 2.10.** Aggregation operator for a point set

### *Typification*

Typification can be seen as a type of aggregation. However it differs in that it uses the pattern of spatial relationships amongst a group of features to imply the existence of a new phenomenon. Because of the primacy of spatial relations, typification presents the new phenomena using an arrangement of a reduced set of the features rather than a single one. These are positioned in a way that enhances aspects of their configuration, for example alignment. Because typification presents a group of features as a new phenomenon, it may be possible to relax some cartographic constraints amongst the individual features of the group. For example, it is possible to present a typified pattern comprised of overlapping symbols in order to give an impression of density. Here the phenomenon itself will have its own constraints such as: that enough of each symbol is visible to uniquely identify it within the group, that smaller symbols always lie above larger ones and that the shape of the group reflects the shape of the underlying distribution. This example is shown in Figure 2.11. Here two sets of points are typified differently in order to highlight different aspects of the configuration. Both typifications highlight the density of point set but in addition on the left the homogeneity of the symbols is also highlighted and on the right the heterogeneity. Typification should always remove graphical conflicts amongst the group of features concerned. However conflicts may still remain between this group and other features. Burghardt and Cecconi (2003) and Regnauld (2001) present algorithms for typifying the arrangements of buildings which also offer possibilities for the typification of sets of point symbols.

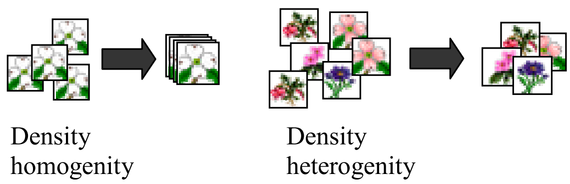


**Fig. 2.11.** Typifications of a point set on the left density and homogeneity is highlighted on the right density and heterogeneity is highlighted.

### *Displacement*

Displacement operates locally. It reconfigures symbols in order to resolve conflicts by moving them apart. Displacement is also often presented as an optimisation problem where the aim is to find the best approximation of a set of locations that satisfies a body of constraints. These constraints always involve resolving conflicts but may also include considerations for preserving spatial relationships. Unlike other operators that generally result in a set of features with a smaller overall footprint, displacement usually results in the features covering a larger overall area. For this reason displacements need to be propagated through the map space and guided by some notion of where space is available to move into. Mackaness and Purves (2001) describe a displacement algorithm that respects aspects of first order spatial variation whilst satisfying graphical constraints. Figure 2.5 illustrated a method using a transformation derived from a distorted grid. Figure 2.12 illustrates a displacement operator on a set of points. Here as well as satisfying minimal distance constraints the approximate shape (relative positions) of the group is also preserved.

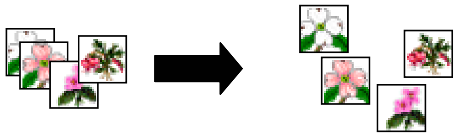

**Fig. 2.12.** Displacement operator on a point set

### *Summary of generalisation operators.*

Table 2.1 summarises the different generalisation operators according to their abilities for reducing the level of detail in the map and explicitly resolving graphical conflicts.

**Tab. 2.1.** Summary of generalisation operators

| **Operator** | **Reduces level of detail** | **Resolves graphical conflicts** |
|---|---|---|
| Global Selection | Yes | No |
| Local Selection | Yes | Yes |
| Simplification | Yes | No |
| Aggregation | Yes | No |
| Typification | Yes | Yes |
| Displacement | No | Yes |

### *Strategies for generalisation*

Generalisation is usually decomposed into two sequential stages of processing: model generalisation and (carto)graphical generalisation. Model generalisation is concerned with preparing a data set to be generalized to an appropriate resolution, or level of detail, for the target map scale. Graphical generalisation is concerned with ensuring the legibility of information with respect to defined graphical constraints (e.g. minimal separation distance between symbols). Global selection, aggregation and simplification are examples of model operators. They act globally on the data to set the level of symbolic abstraction (selection, aggregation) and the level of density of information (simplification, aggregation). Local selection, typification and displacement are graphical generalisation operators. They act locally to resolve graphical conflicts. If possible, graphical generalisation operators should also integrate some of the global information identified in the model stage of the generalisation process; otherwise they can result in locally satisfactory solutions that distract from the global patterns of the map, violating its *consistency*.

Ratajski (1967) uses the term *map capacity* to describe the number of symbolized features, or the amount of detail that a map can support. One of the greatest unsolved problems in cartographic generalisation is effectively estimating the map capacity for a map to be created by a generalisation process. One of the commonly used solutions is the empirically determined "radical law" of Töpfer and

Pillewizer (1966). In the absence of this knowledge it becomes very difficult to parameterize globally acting model generalisation operators without either over generalising the map, e.g. by removing more points than necessary, or over-emphasising the local alterations to the map that are required because of symbolisation conflicts, e.g. by trying to squeeze more features into the map than it ideally has capacity for.

A model of geographic space can help to mediate between these two situations. Model generalisation should realize patterns that preserve the underlying spatial variation of the geography of the map, in particular the first-order spatial variation, i.e. the density of information. Carto(graphical) generalisation will make modifications to the overall structure of spatial variation on account of symbolisation conflicts, however it needs to be particularly concerned with the second order structure of spatial variation or spatial arrangement. Understanding the structures of variation that exist at different resolution, for example by identifying clusters at different scales, allows the need for preserving some spatial relations at more detailed scales to be relaxed in favour of preserving others at more general scales. A model of the symbolised space is particularly useful in this regard. It provides an overview of the level of abstraction of spatial relations that it is possible to preserve in different regions of the map. This helps to identify a set of appropriate local operators and parameterize these to reduce the domain in which they need to search for solutions.

A model of symbolized space also aids local processing for other reasons. It identifies conflicts in the map space and can describe the severity of those conflicts relative to the surroundings. This can assist in deciding which conflict to deal with first and the order in which to apply operators. For example, local selection and typification will relax the distortion of space whilst displacement will smooth it.

## 2.8 Conclusions

The research reported here is motivated by the needs of geographical information service providers to produce clear visualisations of thematic databases at different scales and for differing portrayal schemes. Whilst this issue is particularly pertinent in geographic services for mobile devices, the problem of what can be described by a map using different systems of portrayal is equally important in many other areas of cartography and geographic information science. Diverse fields such as thematic cartography, Internet mapping and geovisualisation all need to consider the dichotomy between representing information spatially and representing information symbolically and the limits that balancing these aspects place on the construction of a view of information.

The work reported here sets out a theoretical basis on which further research is being undertaken. In particular, it identifies the need for better models of the effects of symbolisation on the map space and makes suggestions as to how these might be constructed. Such models are important because they help unify the processes of finding an appropriate level of feature abstraction with the process of finding a suitable level of abstraction of spatial relations. Since the main task of cartographic generalisation is to represent and communicate abstractions of geographic phenomena and their inter-relationships at different scales cartographically, it is within the theoretical framework of this research domain that such models can be most usefully applied.

## Acknowledgements

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# 3 Activity and Context - A Conceptual Framework for Mobile Geoservices

Doris DRANSCH

Institute of Geography, Humboldt-University at Berlin

**Abstract.** This chapter unfolds a theoretical-based conceptual framework to describe and model activity and context as essential parameters for mobile geoservices. It gives an introduction in the general ideas of activity theory and shows how these ideas can be transferred to mobile geoservices. The proposed concept points out how activities supported by geoservices can be defined and structured, it gives an idea how to model users of mobile geoservices and shows what social and spatial context parameters have to be considered.

## 3.1 Mobile Geoservices

Digital services provided via the internet present a fast growing trend. The services support specific tasks as well as everyday tasks. According to their functionality high-level and low-level services as well as smart web services are to differentiate. Smart web services are aware of user attributes like identity, role, or preferences; they form the basis for more personalized services like mobile geoservices.

Geoservices as a subgroup of internet services support spatial tasks, for example way finding or navigating from one place to another. A comprehensive description of geoservices is given by Meng and Reichenbacher (2003), they characterise them as "web services which provide, manipulate, analyse, communicate and visualise any kind of geographic information". Different geoservices already exist, e.g. catalogue service, feature access service, map service or geocoding service.

Mobile geoservices are a special type of geoservices. They operate with mobile devices and mobile networks; they can be used during mobility and be applied at any place and time. Because of their mobile and ubiquitous use mobile geoservices bring about an application situation which is quite different to that of stationary services: A user's position, as well as his or her surroundings change during the application, and also the activities of a user alter. Mobile geoservices have to take into account these alterations and adapt the presented information to the different context and activity.

The most well-known mobile geoservices are location-based services (LBS) which are aware of user's current spatial position and provide specific, relevant information according to this position. Examples are city- and tourist guides (*Gartner and Uhlirz* 2001, *Zipf* 2002) or weather information services (*Meissen and Pfennigschmidt* 2002) that give information related to a specific place. Also in the field of professional work LBS support indoor and outdoor activities (*Heidmann and Hermann* 2003).

LBS use „location“ as context parameter to which the presented information is referred. However, context is much more than location; it is the complete situation in which a user acts and requires spatial information. Mobile geoservices have to adapt their information to this entire situation. This challenge is pointed out by Reichenbacher (2004): “The vision of a mobile cartography is to present the user always the right spatially related information at the right moment at the right place. Whoever the user is, he/she will always get the information related to his or her current context and interests, knowledge and skill level, presented in a way he/she is used to.” Accordingly, the core-idea of mobile geoservices “is not only to make information available to people at any time, any place, and in any form, but to reduce information overload by making information relevant to task-at-hand and to assumed background knowledge of the users.” (Fischer 2001, in *Reichenbacher* 2004).

Offering information with the greatest relevance to users requires a comprehensive understanding of users’ situations: what do mobile persons do, how do they act, what context parameters influence their decisions or actions, and what user characteristics are to consider. Activity and context are the key elements for presenting the most relevant spatial information. For that reason, it is necessary to take a closer look at these components.

## 3.2 Concepts of activity and context

In order to use activity and context effectively, we must understand what they are and how they can be used. As Dey and Abwod (1999) pointed out in their paper most people have a general idea about what context is. However, “a vague notation is not sufficient; in order to effectively use context, we must attain a better understanding of what context is.” Some different approaches are developed to describe and formalise the parameters that characterise a certain situation of application (*Dey and Abwod* 1999). They differ in description of context (e.g. description by example, by synonyms) as well as in parameters they use. Some approaches are restricted to measurable, automatically detectable physical parameters as context elements, others include “activity” as a further context element. Activity and context are in strong relationship; they cannot be separated and have to be regarded in the whole. The following paragraphs unfold a concept about activity, context and their relations.

### 3.2.1 Activity

In common sense, activity means all what we do; for example driving a car, planning a route to a selected destination, looking for a place in a map, or detecting a map symbol on a mobile device. On a more precise look the given examples show that activities are different not only in their doing but also on a formal level. They can be differentiated in manual and cognitive actions and they can be described at different hierarchical levels. "Planning a route to a destination" is more complex than "detecting a map symbol". Also, activities are influenced by several constraints like legal or social rules, for example the one-way rule of a road, or choosing particular social meeting points. Activities are directed by a person's attitude and they are guided by other persons.

Regarding activities in more detail makes apparent, that they are not a trivial thing; on the contrary, they are a complex component we have to handle. Dealing with activity arises following questions: How can activities be described and how are they executed? What parameters influence an activity? How can an acting person be modelled?

A good framework to answer these questions is provided by the activity theory. This theory was developed to explain human activities and related processes. It has been applied in many disciplines which deal with activities, for example, psychology, sociology, work organisation, geography, and computer science, especially in human computer interaction. Recently it was applied as well to cartography (*Dransch* 2002).

Activity theory broadens the behaviouristic approach on action, which explains activities as a sequence of stimulus and reaction. It postulates that an activity is more than a reaction; it is a conscious and directed act that is executed to reach a defined goal. According to this concept the goal a person pursues determines his or her activity. Activity in this sense can be described as a process of planning (according to cognitive action plans), executing and evaluating. The cognitive action plans which consist of goals, sub-goals, and actions organize the structure of an activity. Goals and sub-goals are in a hierarchical order, actions, which are executed to attain the goal or sub-goal, are sequentially organized. For example an employee of a power authority has the goal "to plan a gas service pipe". Sub-goals are "to locate the pipe's route" and "to define all technical and cost parameters". "Locating the route" can be divided further in "to get an overview about the situation of the intended route" and "to decide where the pipe's route should exactly run". To achieve the sub-goal "to get an overview about the situation of the intended route", different indoor and outdoor actions are necessary like "identifying and recording barriers for example trees or technical devices, making out the quality of the ground, locating other service pipes, and identifying the ownership of properties which are crossed by the route". Figure 3.1 shows the hierarchic-sequential structure of goals, sub-goals and actions.

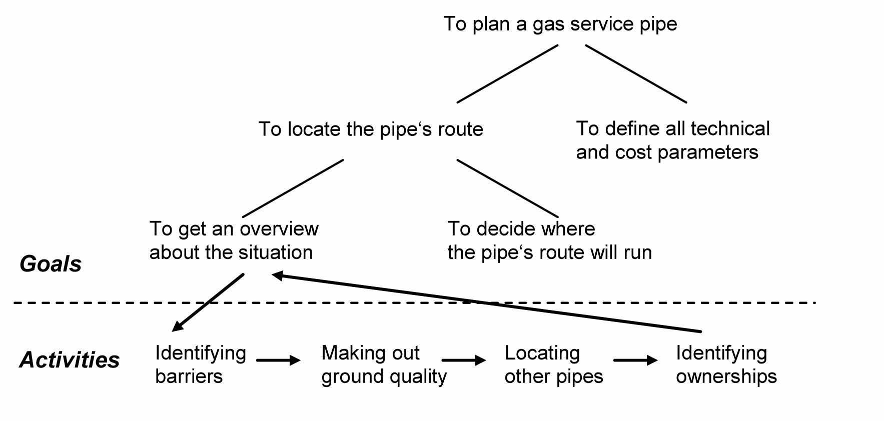


**Fig. 3.1**. Hierarchic-sequential structure of an activity

A further relevant aspect in activity theory are artefacts. Artefacts are used as tools to execute an activity. In the mentioned example of planning a gas service pipe the artefacts can be traditional paper maps, interactive geoinformation systems or mobile geoservices for outdoor work that help the employee to get all information he needs. Artefacts are created to support persons achieving their goal; as "functional organs" (*Kaptelinin* 1996) they improve the execution of an activity. Artefacts and activities are in a mutual relation: On the one side, the properties of an artefact are determined by an activity, thus, the artefact keeps implicitly an activity's structure. On the other hand, the artefact's properties influence the way in which an activity is executed. For that reason, a modification of the artefact causes a modification of goals and activities and, vice versa, a change of goals and activities changes the artefact. The strong relationship between artefacts and activities is also described by Norman (1986). He points out the problem to execute a person's action plan by an artefact. The action plan has to be transferred to an artefact; the so called "gulf of execution" has to be bridged. Only artefacts which are well related to an action plan allow crossing this gulf without any problem. In the case of planning a gas service pipe, all actions the employee has to fulfil have to be supported by the maps, information systems or mobile geoservices. The artefacts' mediating role is emphasised in following remark: "If we want to study artefacts, we cannot study them as things, we need to look how they mediate use. Artefacts are not just means for individuals, they also carry with them certain ways of sharing and dividing work. Furthermore, the artefacts have no meaning in isolation; they are given meaning only through their incorporation into social practice." (*Bannon and Bodker* 1991).

Activities always take place in a certain situation with a specific context. This context influences an activity as an exterior frame. Engeström (1987) formulated activity context as a network of different parameters that influence each other. This network is structured as following: An *acting person* who wants to achieve a specific *activity goal* belongs to a *community* with *rules*. The activity goal and the social position in the community define a person's *role*. The community to which an acting person belongs to, creates, offers and uses *artefacts* which also influence how a person acts. In our example the employee who has to plan a gas service pipe is enclosed in the power authority's community which has certain rules, e.g. to locate services pipes to specific principles. He has a certain role in the community, e.g. planner, technician or information specialist that guides his work and his knowledge. To perform his work, he can use the artefacts the power authority company makes available; this can be a paper map, an interactive geoinformation system or also a mobile geoservice for outdoor activities. The framework shown in Figure 3.2 describes the social context of an activity and makes apparent social parameters that influence an acting person and his/her activity.

In activity theory acting persons are described in the way: "You are what you do". This statement bases on activity theory's postulation that consciousness is shaped by activities and, vice versa, activities are directed by consciousness, by mental action plans. Accordingly, there are two components in a person's activity enclosed: the action plans, which are the internal (mental) component of an activity, and the actions themselves which are the exterior component.

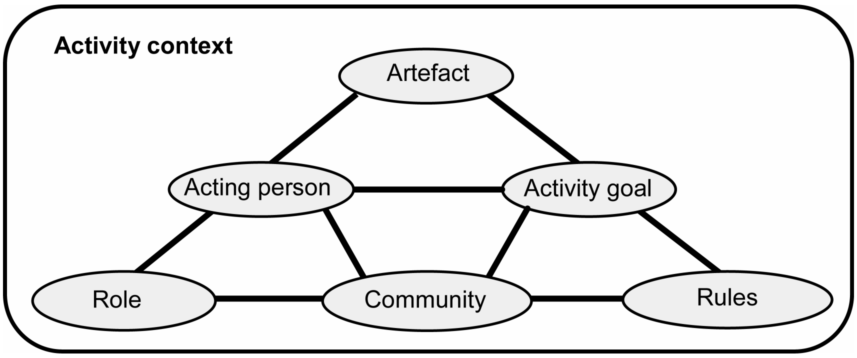


**Fig. 3.2.** Activity context (after *Engeström* 1987)

Action plans are always determined by a specific activity goal, for that reason, action plans of different people may differ in detail but they correspond in their main structure. This relationship makes apparent that we do not have to deal with individual people but with types of people or "roles" that can be characterised by their activities e.g. "planner", "technician", or "car driver". The consciousness or mental action plans related to a role can be defined as role-specific knowledge. "You are what you do" intends that first of all an acting person can be characterised according to his or her activity; individual attributes are less important when we regard people in action.

### 3.2.2 Activity and Mobile Geoservices

Activity theory identifies the items which are essential when dealing with activities. The concept clarifies the framework we need to handle mobile activities and geoservices. The most relevant ideas of the framework are: Activities which are supported by mobile geoservices are directed to specific goals. The goal guides how a mobile user acts and it also determines the structure of an activity. The structure is organized in a hierarchic-sequential way with goal, sub-goals and actions. It reflects a mobile user's mental action plan. Mobile geoservices as artefacts have to meet all the goals and sub-goals and they have to mediate all related actions. Mobile activities are not isolated, they are integrated in a social context, for example the related activity community and its rules. Users of a mobile geoservice are characterized predominately in respect to their activity goals, and their role, not accordingly to their individual characteristics.

The mentioned framework forms a suitable basis to design mobile geoservices. It helps to answer following questions which are important for the design of appropriate mobile geoservices.

- What activities, goals and sub-goals have to be supported by the service?
- What social context parameters have to be considered?
- How can users of mobile geoservices be modelled?

*What activities, goals and sub-goals have to be supported by the service?*
According to activity theory mobile geoservices are regarded as artefacts that mediate activities which are related to or executed during movement. They can either be used continuously throughout a mobile activity, like a service that supports navigation and presents information continuously related to changing spatial context. Or they can be applied discretely during a mobile activity at a special place or/and time to get information about nearby spatial objects. The leading idea of mobile geoservices is presenting information with relevance to a user in a specific mobile activity and context. This goes far beyond the possibilities of a traditional analogue or digital map. Mobile geoservices are a new type of artefact.

Activity theory postulates that artefacts and activities are in a mutual relation. Therefore, new artefacts cause new or changed goals and activities. Current application situations are not adequate to formulate all activities that could be supported by mobile geoservices. For this reason, it is necessary to describe new situations to acquire the full variety of possible applications and to get the range of activities and contexts that have to be assisted. A suitable method for this is scenario description. A scenario is "a possible set of events that might reasonably take place. … The main purpose of developing scenarios is to *stimulate thinking* about possible occurrences, assumptions relating these occurrences, possible opportunities and risks, and courses of action." (*Jarke et al.* 1999). The strong point of the scenario method is its focus on a changed application situation: What is the current-state scenario and what will the future-state scenario be? "With a wide range of possible user situations, we need to have a way for the services to adapt appropriately." (*Dey and Abowed* 1999). Scenarios for mobile geoservices have been defined by Reichenbacher (2004), Zipf (2002), Heidmann and Hermann (2003). They indicate how mobile geoservices can assist users in private, tourist or work situations.

However, it is not sufficient to know all activities on a general level. Activities consist of goals, sub-goals and actions which have all to be supported by mobile geoservices. Therefore, it is necessary to know the detailed structure of an activity. Scenarios are also good means to this structure. The textual scenario can be transferred into a more abstract description by the hierarchic-sequentially organized activity goals and actions. This abstract model can form a good basis to derive activity typologies or ontologies. Some approaches have been conducted for specific application fields like that of McCullough (2001) who proposed a typology related to everyday situations.

The hierarchic-sequentially structured activity model derived from a scenario can also be used as a description of a mobile user's spatially-related action plan. Action plans are essential because they guide how a person acts. They have to be transferred to the mobile geoservice as mediating artefact during activity. For that reason, they are a good basis to make clear what spatial related information, functionality, interaction, and adaptation are necessary in a mobile geoservice for a specific activity. The action plans derived from scenarios as well as the properties of a designed geoservice artefact have to be verified in practice with prototypes of mobile geoservices. This is essential because artefacts always have to be studied in use; they can be evaluated only according to the criteria how they mediate use.

Regarding mobile geoservices as artefact requires a differentiation between activities performed in real world space (e.g. way-finding) and activities accomplished in map space (orientating in a map, extracting map symbols). To reach an intended activity goal in real world with the help of a map-based mobile geoservice, e.g. to navigate from a place A to a place B, or to find a location, a person has to act in different "spaces". He or she has to orientate, to find specific objects and to move in real world. The person has also to do these activities on the map; he or she has to orientate, to find objects, to discriminate map symbols and to move on the map. Mobile geoservices have to support both types of activity. This is especially important in the mobile application situation with its specific characteristics: the user is mobile, often he or she is in a hurry, the surroundings are very dynamic, and the user has to treat a lot of changing information simultaneously.

Figure 3.3 shows a map that supports a mobile person to localize where he/she has to go, how to navigate to the place and to identify a specific location. The map is an example from "Berlin-Adlershof", an area where university departments, research institutes and business companies are established. The area is a very new one, it is still in expansion and not finished yet. Because of this, traditional city maps do not show it correctly, street names cannot be find completely in the map. Orientation as well as navigation is difficult for that reason. The map in our example, a potential map of a mobile geoservice, may support a person in the following way: At first it helps to localise the chosen place by highlighting the object. Next it informs about the way a person has to take from the urban railway station "Adlershof". It gives the direction where to go outside the station, and depicts the route. Lastly, when the person is close to the final destination it shows the building realistically to identify the correct object.

*What social context parameters have to be considered?*

Engeströms' concept of social activity context (1987) mentioned above gives a framework of different social parameters that influence an activity. Some of these parameters are discussed separately in this section like activity and acting person. The parameter “community”, which is strongly related to all the others, will be investigated now.

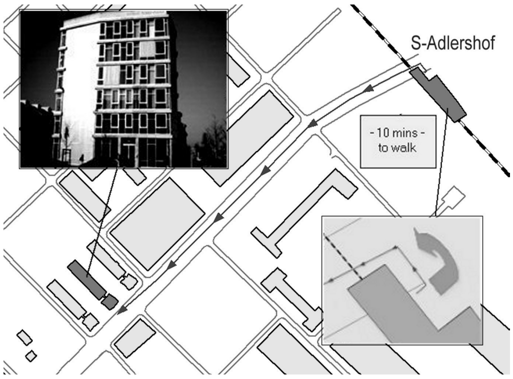


**Fig. 3.3.** Example of a mobile map for orientation and way finding

Activities which are to be supported by mobile geoservices cannot be regarded in isolation, they are integrated in a social context. Even users of mobile geoservices are mostly single persons they belong to a social community on behalf of the activity they carry out. For example a service pipe planner belongs to the power authority’s community, a car driver is part of the community of people involved in traffic like other car drivers, pedestrians or bicycle drivers, and a visitor of a museum belongs to the group of people visiting or running museums. In these communities rules are established that influence a person’s activity, e.g. planning principles determine the planning process and decision, traffic rules direct how we drive, a museum’s opening hours guide when we can visit the museum. Mobile geoservices that intended to give the most relevant information at any place and time to a user have to consider these rules when presenting information.

Acting persons are also part of a particular community because of their attitude. These communities have a sort of social rules, too. They guide the interest, the places a person goes to, or the events he or she prefers. Social guidelines effect our activities, therefore, they are also relevant for mobile geoservices.

*How can users of mobile geoservices be modelled?*

One characteristic of mobile geoservices is their ubiquitous use. Because of this, the application field as well as the amount of potential users is huge. Mobile geoservices should support users with relevant information, i.e., with personalized or egocentric information. However, individuals are so different that it is almost impossible to do this individually for each single person. A more reasonable way would be defining user groups. User groups can be described by social parameters like age, sex, culture and interest. Groups can also be formed by users’ behaviour like highflier, trendsetter, poser, or social contact seeker. Certainly, these characteristics are of relevance; however, they are not the most important criteria which define user groups. Users of mobile geoservices are first of all acting persons. Activity theory postulates: You are what you do. Thus, the activity and the related objective are the essential criteria when defining user groups. Bearing this in mind, geoservices should be designed e.g. for "mobile spatial information seekers" or for "spatial navigators". A user attains a particular role because of his or her activity, like "car driver". Roles are related to a role-specific knowledge. This type of knowledge can be regarded as a user's pre-knowledge which has to be considered when designing mobile geoservices. In the field of mobile geoservices activities change over time and therefore, a user's role and role-specific knowledge modifies, too. Geoservices have to regard this and adapt to these changing user parameters.

### 3.2.3 Context

Context in common sense means surroundings. What "context " or "surroundings" exactly covers, is difficult to describe. "While most people tacitly understand what context is, they find it hard to elucidate" (*Dey and Abowd* 1999). Many papers in the area of mobile and ubiquitous computing gave descriptions and definitions of context: "Context [is] a collection of relevant conditions and surrounding influences that make a situation unique and comprehensible" (*Brezillon* 2003). "Context is generally defined as physical parameters (location, temperature, time, etc.) obtained from sensors. However, the user is not considered in this approach. … Conversely, there is another approach, in which the user (through his knowledge and reasoning) is central in the modelling of context." (*Kouardi et al.* 2003). "Our consideration of context moves from the nature of underlying infrastructure context to consider the overall system context, the broader application domains context, and finally the actual physical context. " (*Dix et al.* 2000). "The principle of context tells us to go to the customer's workplace and see the work as it unfolds." (*Beyer and Holtzblatt,* 1998). "Important aspects of context are: where you are, who you are with, and what resources are nearby." (*Shillit et al.* 1994, in *Dey and Abowd* 1999) "Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves." (*Dey and Abowd,* 1999).

All these definitions and explanations characterise "context" in different ways; they alter in description as well as in parameters they consider. The most comprehensive approach to define context comes from Dey and Abowd, they describe context as any information that can be used to characterize the situation of an entity and that is relevant to the interaction between a user and an application. This description is a good basis to formulate and model context; however, "*any information*" is a very broad and hazy term that has to be made more concrete. A suitable completion to Dey and Abowd's description is the concept of Dix et al. (2000). It differentiates between several types of context and makes clear what sort of information is necessary to give a complete description of context. They distinguish a more technical context (infrastructure and system context), a domain context, and a physical context. The technical context includes all technical parameters of the infrastructure and the computer system. The domain context can be described by all components and relations that are outlined in the previous section about activity. This includes the activity that has to be supported by the computer system with its goal, structure, action plans and strong relationship to artefacts; the social community in which the activity is performed and its rules; and the users, the acting persons with their specific role and role-related knowledge. The physical context finally, covers all parameters derived from physical environment.

### 3.2.4 Context and Mobile Geoservices

The context categories mentioned above can be a suitable basis for the design of mobile geoservices. Technical, domain and physical context consider all parameter which are important for mobile geoservices.

The technical context of geoservices has to deal with hard- and software parameters like mobile devices, mobile networks, positioning techniques, OGC-services, standards etc. It will not be regarded here in more detail because it goes beyond the focus of this paper.

The domain context of geoservices is pointed out in the previous section about activity and mobile geoservices. It gives insight in those parameters which describe and influence domain context of mobile geoservices.

The physical context of mobile geoservices involves parameters like location, time, temperature, light etc. As Dey and Abowd (1999) pointed out some parameters are more important than others. In the field of mobile geoservices location and time are the most important physical context parameters. Because of its eminence for mobile geoservices location will be examined more precisely.

Location is always defined in a particular system that describes space. The most common are geographical and geodetical coordinate systems that give the absolute location of an object. Another idea of space is a more topological description of space where location is not considered in an absolute sense but in relation to other objects. Both concepts treat space and location from a mathematical point of view. Despite their widespread use, they are not the only possible schemes to express space and location. Other concepts define space in a more human-related way. They regard space as spatial structure that is arranged by persons and their activities. According to this concept space is only determined by activities; they form specific spatial areas, the physical objects in these areas get importance and meaning only through an acting person and his or her action (*Werlen* 1997).

Geoservices should support the mathematical as well as the human-related concepts of space. Mathematical concepts are necessary to fix a person's absolute or relative spatial position, e.g. to support place finding or navigation. A more human-related idea of space can help to determine personalized, egocentric activity areas, e.g. "activity zones" or "social zones" (*Reichenbacher* 2004, *von Hunolstein and Zipf* 2003). Egocentric structures of space can be a good basis to select and present the most relevant spatial information to an acting person. In a recent paper about space and location in mobile systems Dix et al (2000) claim to combine "the real with the virtual". Geoservices should do this, too. They should combine real mathematical space with the virtual person- and activity-related space.

## 3.3 Conclusion

Mobile geoservices differ from traditional maps or stationary geo-information services. Their mobile and ubiquitous use produces an application situation that is characterized by changing user positions, changing surroundings and changing activities. A suitable mobile geoservices should take into account these alterations and adapt the presented information to the different context and activity. These requirements make it necessary to take a closer look to activity and context, and to develop a framework to describe and model both. Activity theory as well as some recent descriptions of context form a good basis for such a framework which is outlined in this paper.

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# 4 Effectiveness and efficiency of tourism maps in the World Wide Web and their potential for mobile map services

Frank DICKMANN

Institute for Geography, University of Göttingen

**Abstract.** Today many different forms of cartographic representations are available on the World Wide Web. Modern maps are no longer used for mere presentation but for interactive and individual exploration of temporal and non-temporal spatial data. The capacities, and the ability to suit a wide range of tastes and preferences, are particularly significant in the context of tourism. Tourists are making increasing use of the web for obtaining information prior to departure, including organisational information such as route planning, traffic news or accommodation, as well as information on the destination, e.g. topography, landscape and land use. The following presents the results of an empirical study on the effectiveness and efficiency of web-based maps in transferring spatial information. Such research is all the more timely since the encroachment of new transmission techniques (UMTS) and mobile terminals (PDAs) is likely to further encourage the use of web-based maps, for instance in the context of location based services. In many respects the results of this empirical study could equally apply to mobile map services. In that context however, well-known problems surrounding screen-based perception and the difficulties in using interactive web maps might take on even greater significance.

## 4.1 Introduction

Since the mid-1990s the number of maps designed and distributed on the World Wide Web has increased dramatically. From an original scientific niche, this new technology has grown to almost universal application in many practical contexts. The many different forms of cartographic representations available on the World Wide Web today seem to meet growing demands for fast access to information and transfer of spatial data.

An important area of application is that of tourism and leisure, where traditional cartographic means offer a wide range of city maps, leisure maps, road maps, trail maps etc. Vacation planning itself is mostly based on map-based information, with most people consulting maps before beginning their journey. Not surprisingly, countries with a significant tourism economy have quickly developed tourist-oriented websites, where easy access to up-to-date information can help in making vacation planning more effective (Brown 2001). Once more however, trends seem to be changing. Due to technological developments, people are making increasing use of mobile map-based services, preferring targeted information on specific locations to broad and general information on a region. Interactive maps are perfectly placed to meet this need.

In most cases, tourists using conventional printed maps or interactive web maps are hardly professional map users. Most only use maps during their holidays. In order to develop suitable concepts for visualising geographical spatial information, new and developing media need to be critically assessed, not only in terms of their technological potential, but also with respect to their ability to represent spatial information in a readily accessible format. Here, comparisons are required to conventional techniques, particularly in the context of the target group's ability to read and assimilate the information presented.

The following sections present the results of an empirical study on the effectiveness of web-based maps. The main aim was to determine how effective these new techniques actually are at transferring information. This research is all the more timely since the encroachment of new transmission techniques (UMTS) and mobile terminals (PDAs) is likely to further encourage the use of web-based maps, for instance in the context of location-based services (LBS). Design guidelines derived from empirical research are therefore urgently needed.

## 4.2 Web maps and tourism

The advent of internet and intranet techniques has lead to profound changes in how spatial information is distributed. Compared to static printed maps, screen-based spatial maps can easily be processed, updated and analysed interactively by most users. Modern maps are no longer used for mere presentation but for interactive and individual exploration of temporal and non-temporal spatial data, very much reflecting individual tastes and preferences *(Fuhrmann/Kraak 2001)*.

These capacities are particularly significant in the context of tourism. On the consumer side, tourists are making increasing use of the web prior to departure, both for organisational information such as route planning, traffic news and accommodation, and for information on the destination such as topography, landscape and land use. For this latter some websites have begun to provide so-called "virtual tours" or VRML-based landscapes with 3D impressions. On the provider side, regional tourist organisations have recognized that official websites can play an important role in generating tourism. Host regions can highlight specific regional features, provide a calendar of events and target their presentation to specific groups of holiday makers. The use of location-based mobile services increases the potential for accessing information during travel and throughout the holiday period.

Of the growing number of integrated visualisation systems already used in the World Wide Web, interactive maps play a key role. Some of the key restrictions of printed maps vis-a-vis tourism can now be overcome, including insufficient up-to-dateness, lack of interactivity or limited information content. Advantages of web maps are:

– direct access to spatial data
– interactivity
– advanced cartographic components (3D; animation, sound)
– short refresh period (up-to-dateness); high transmission rate
– unlimited access independent of time and place
– simultaneous processing of dispersed data
– tailored information for specific target groups (scaling of information)

## 4.3 Empirical analysis

In practice, both types of maps are now equally well used. To estimate the potential added value of the new technology, the effectiveness of web maps needs to be compared to that of printed maps. This was done by using two groups of test persons, whose patterns of use were analysed for conventional printed maps and interactive web maps. The primary objective was to determine the effectiveness of spatial information transfer. Results are considered relevant to the current debate on modern "function-oriented map design" (*Herzog* 1992) and can assist with the definition of guidelines for web map design. They can also contribute to assessing the possibilities of map-based online systems and finding ways for their optimisation.

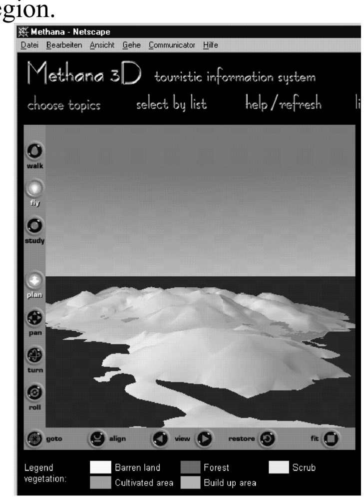
An important methodological aspect is the time required to absorb and understand the information contained in an online map. Effective transmission of information requires two features. First of all, the information must be transmitted completely and correctly (effectiveness), but secondly, the result must be seen in relation to the amount of time required to achieve full and correct information (efficiency). This aspect also meets the requirements of the ISO-Norm CD 9214 on software ergonomics, which is one of the baselines for using the World Wide Web. For *Bollmann* (1981), speed and accuracy of interpretation are essential criteria for determining the success of a map from a perception-oriented point of view. *Schumann/Müller* (2000) define the quality of screen-based graphics as the ratio of information perceived in a specific period of time to the information that should be transmitted in that period of time. Recent research findings have revealed the existence of a third aspect linked to overall usability and quality, which is the degree of satisfaction or pleasure experienced by map users (outlined in other chapters of this book).

The following describes a first attempt at contrasting the effectiveness of information transfer of a web map and a conventional printed map. The "Topographical Map of Methana Peninsula“ was used as a conventional map, which is a detailed and comparatively new topographical map at a scale of 1:25 000 (produced by the Institute of Cartography, ETH Zürich, 1991-1994). The corresponding formed part of a wider online tourist information system on the Methana Peninsula.

A total of 84 first-term geography students of Göttingen University were divided into two equally sized groups and asked to respond to a list of questions. In order to be comparable, the questions asked (primarily targeting spatial patterns and correlations) were identical for the conventional map and the online version. This also enabled an estimate of the time required for assimilating and processing information.

The main point of interest in this comparison was the transfer of cartographic information on relief and land use, a topic often encountered in the field of tourism. To evaluate topographic and land use details from a web map, a VRML-based 3D-graphic was used which was retrieved online during the experiment (Figure 4.1, http://www.karto.ethz.ch/~hm/methana/). The selected area covers the Greek peninsula of Methana, which forms part of the Peleponnes and projects into the Saronian Gulf. With a maximum diameter of 10 kilometres and a total of 55 square kilometres, the area is suitable for online transmission on account of its manageable amount of data. An online tourist information system has been developed for potential visitors, using a digital elevation model and providing added topographical information on this Greek holiday region.


Topographical Map of Methana Peninsula,
1:25 000, 1994, Institut for Cartography, ETH Zürich




VRML-based 3D-graphic of Methana
(www.kartog.ethz.ch/~hm/methana)

*Courtesy: Lorenz Hurni, Institute for Cartography, ETH Zürich*

**Fig. 4.1**. Printed map an we map of Methana (Greece)

The aim of the questionnaire was to find out how well topographical and land use information could be extracted from such a cartographic online representation. Questions focused on the location of specific areas and spatial phenomena on the whole peninsula, e.g. the search for special topographic characteristics, identifying the visibility of special points and the visual analysis of the relationship between topography and land use. The following are some sample questions of the questionnaire on relief and land use:

- How can the landscape shown be characterized?
- Where are the highest areas of the peninsula?
- Are there any particularly steep and rugged areas?
- Are there any plains on the peninsula?
- Is it possible to see the settlement of Methana from the highest point of the peninsula?
- What would you describe as the dominant form of land use on the peninsula?
- Where are the largest areas without vegetation (scree) on the peninsula?
- Where are the largest expanses of forest?
- What seems to be the main factor determining the distribution of forest on the peninsula?

## 4.4 First results

Results indicate a general difference in the perceptive behaviour of both sample groups, although the differences between the two forms of visualisation are not always very much articulated. Of particular interest for evaluating the success of map-based online information transfer was the proportion of correct answers, where the greater effectiveness of 3D-graphics is immediately apparent (Figure 4.2). For six out of nine questions, answers given on the basis of interactive web tended to be more correct than those based on conventional maps. The average proportion of correct answers is about 76 % with web maps, whereas printed maps only achieved 61 %.

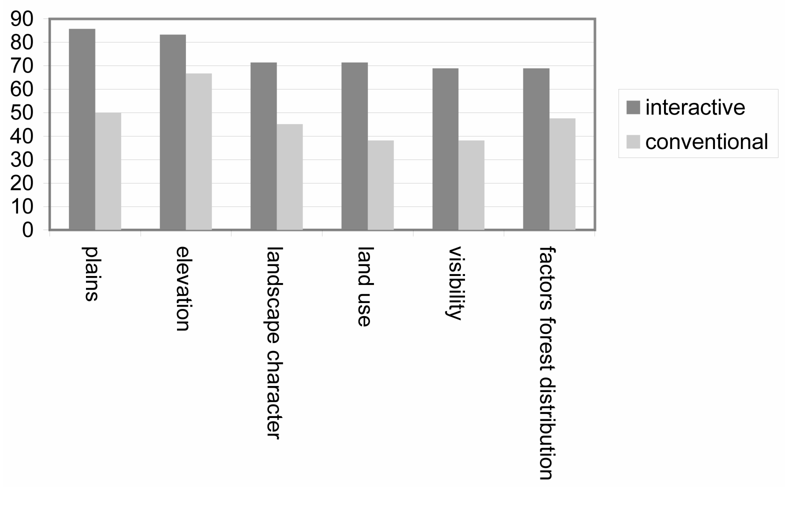


**Fig. 4.2**. Proportions of correct answers of test persons using web maps and printed maps (in %) - I

### 4.4.1 Comprehension of overall topographic structures

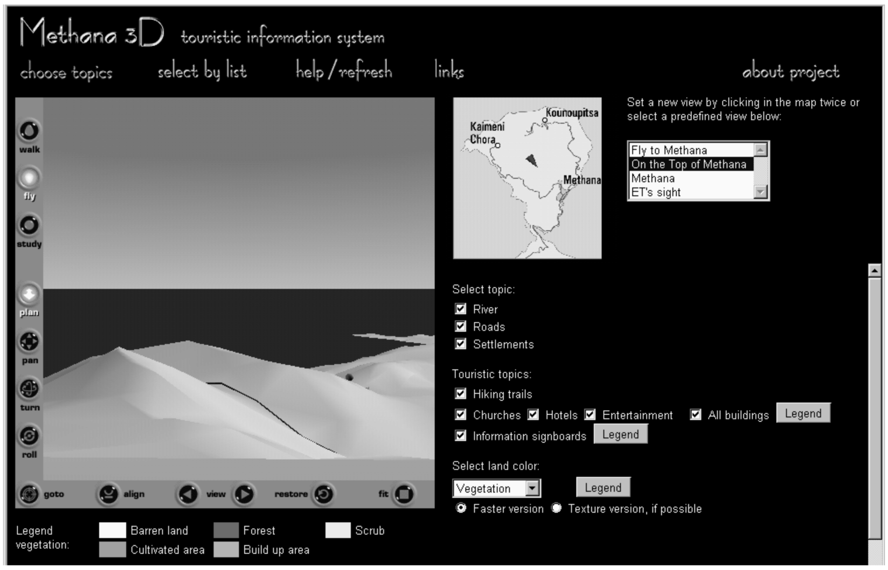
The superiority of 3D-graphics becomes apparent when demanding a rapid assessment of the main topographic features of the sample area. Asked to characterise the overall landscape as either mountainous, hilly or flat, 54% of answers given in the printed map group were incorrect, compared to 70% of correct answers given in the web map group. Similar to classic 3D cast models, VRML-based elevation models do not need to encode relief information in visual variables such as contour lines. Relief information is therefore much more readily communicated.

This hypothesis is confirmed by the results of other questions. The task of pinpointing plain areas on the peninsula again reveals significant differences between the test groups. Only 50% of the printed map users gave correct answers compared to more than 85% of the web map users. Although the colours representing the absolute elevation of the relief were not very distinctive (Figure 4.2) the three-dimensional impression of the landscape allowed very fast assimilation of relief information. The other group had to contend with the usual problems encountered by less experienced map readers. Many had problems translating contour lines into visual images of the landscape and often failed to correctly identify topographical features using this instrument alone. Here too, conventional topographic maps are clearly inferior to 3D web-based maps.

### 4.4.2 Assimilation of complex spatial information

Questions requiring more complex assimilation of spatial information also give web-based maps a clear edge. This is evident in two questions concerning the visibility of objects and the factors governing forest distribution. As expected, being able to interact with the 3D-systems was crucial for the correct transfer of information. Test persons were first asked whether the village of Methana could be seen from the highest point of the peninsula, a question which might be relevant for tourists when selecting hiking trails.

More than two-thirds (69%) of the web map users were able to give a correct answer. Test persons were relatively easily able to “visit” the highest point of the peninsula and look for Methana using the web map as a navigation instrument (Figure 4.3). Viewers had a realistic all-around-view upon the surrounding heights and were able to determine that Methana is not directly visible from the top on account of some mountain ranges between the top of the peninsula and the coastline.




(www.kartog.ethz.ch/~hm/methana)

**Fig. 4.3**. VRML-based view from the highest point of the peninsula of Methana

Answering the same question using the topographical map, only 38% of that test group achieved correct results. This significant difference is hardly surprising, for an unequivocal response to this question would have necessitated the use of additional tools (e.g. drawing an elevation profile). Uncertainty is also expressed in the longer time required to give an answer at all (Figure 4.4). Whilst in most cases, the response time was shorter with the printed map users, this question was the opposite, with answers not coming as quickly as in the web-based group. Despite some limits of technology and the limited skill of the users, the digital map proved to be far superior to conventional maps in answering this question.

The question on factors governing the distribution of forest on the peninsula yielded similar results. Test persons were asked whether altitude, exposure or inclination of the area were the determining factors for the spatial distribution of forest. Around 70% of the digital map users interpreted the map correctly, compared to only 47% of the printed map users. The realistic impression resulting from the 3D-representation of an interactive DEM obviously contributes to a better understanding of the terrain, which leads to significantly better results.

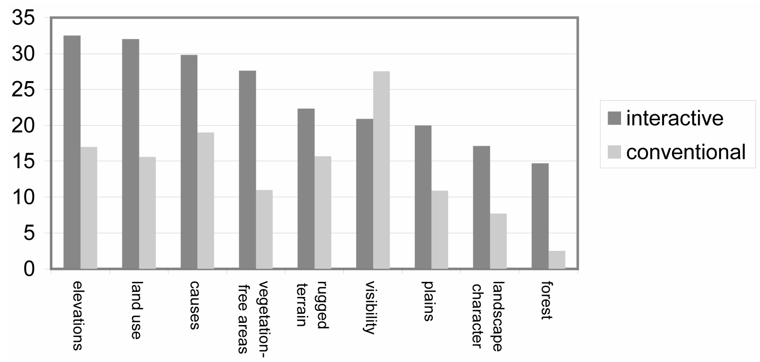



**Fig. 4.4**. Average time required for answering questions using conventional and interactive maps (in seconds)

### 4.4.3 Assimilation of detailed geographic information

Despite their obvious advantages, the study was also able to pinpoint some limitations of web-based maps. These particularly concern the retrieval of more detailed spatial information, such as the spatial relationship between objects or scale-based differences of topography. Rugged terrain, forested areas or areas without any vegetation were more readily identified using conventional topographical maps (Figure 4.5).

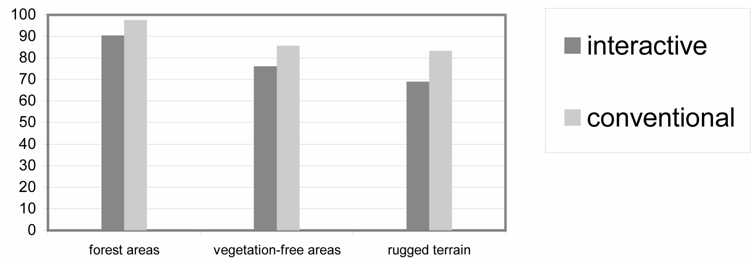



**Fig. 4.5**. Proportion of correct answers using conventional and interactive maps (in %) - II

The ability to depict small-scale features is a clear advantage of printed maps. Compared to the detail represented in printed maps, the resolution of web maps is still low, the result of a compromise between an acceptable transmission rate and the amount of data that can be accommodated. Large sections of internet-based maps therefore show little topographic differentiation, especially where representations of land use are concerned. Also, small morphological features or variations such as small valleys or gorges cannot be adequately captured and represented, quite in contrast to the considerable detail available in printed maps of a 1: 25.000 scale.

It is expected that future online applications will contain a considerably greater level of topographic detail. The implementation of new web technologies (vector based formats, Java 3D) and respective online systems are likely to revise some of these results.

## 4.5 Conclusion

Although the study was unable to include all forms of cartographic presentations present in the World Wide Web, results indicate that spatial information is more effectively transmitted by internet-based maps as part of an integrated visualisation system than classic printed maps. A few provisos remain: Printed maps are still quicker to use, and detailed spatial information can be assimilated at a glance. It should be noted that on average, the proportion of correct answers based on interactive web maps is about 15% greater than that of printed maps, indicating a higher effectiveness of map-based online systems. Both in research and in practice, the use of these technologies is likely to increase since options for interactive manipulation and variability in data visualisation appear to meet the different perceptive and analytical needs of individual map users. Map-based mobile services are particularly likely to benefit from improvements in facilitating the assimilation of spatial information.

In many respects the results of this empirical study on web map efficiency could equally apply to mobile map services. Most of the basic advantages of web maps also apply to mobile map services, e.g. unlimited access to information independent of time and place, up-to-dateness or retrieval of information tailored to specific target groups. Restrictions imposed by the transmission rate are likely to be solved in the near future (UMTS). Using similar techniques to web maps, mobile map services could make it easier for consumers to retrieve higher rates of correct spatial information.

However, the results of this study also indicate that the well-known challenges of screen based perception and problems of use may be of much greater significance in the context of mobile map services. Detailed geographic information is unlikely to be represented as well as on topographic maps since the display size of mobile map services only measures 80x60 mm2. This, then, must be counted as one of the basic restrictions of such systems, which is all the more important since a change of display size is not expected due to recently established technical standards (Brunner 2002). Disadvantages in displaying overall topographic structures, presenting complex spatial information (spatial correlations) and - last but not least - the speed of map reading will remain. Display quality and the practical instruments available for research remain limited compared to a standard PC, and just like the tools for specifying information searches (definition of criteria), they require considerable intuition on the part of the end user. What is required thus are simpler, but not overly simplified cartographic concepts and intuitive user interfaces on a par with web maps. After all, the target group of web maps and mobile maps services is very heterogeneous and only few users are skilled even in traditional map reading.

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# 5 The Cognitive Reality of Schematic Maps[2]

Alexander KLIPPEL, Kai-Florian RICHTER, Thomas BARKOWSKY, Christian FREKSA

Transregional Collaborative Research Center SFB/TR 8 Spatial Cognition
Universität Bremen, Bibliothekstr. 1, 28359 Bremen

**Abstract.** In graphics and language, schematisation is an important method to emphasize certain aspects and to deemphasize others. Different disciplines use schematisation for different reasons. In cartography, graphic schematisation is one aspect of map generalisation. In contrast, cognitive science addresses schematisation as a method to intentionally emphasize certain aspects of knowledge beyond technical necessity; therefore, the notion of *schematic map* is proposed to denote maps that employ schematisation for cognitive representational reasons. This chapter discusses different views of schematisation from cartography, linguistics, and artificial intelligence. Connections to qualitative reasoning in artificial intelligence are drawn. We address human spatial cognition and present examples of task-oriented representations. Finally, multimodality for conveying spatial knowledge and its application in schematic maps are discussed.

## 5.1 Introduction

Long before it was possible to create spatially veridical representations of geographic space, people created geographic maps based on their mental conceptualisations of their surroundings (e.g., *Harley & Woodward* 1987). Although these maps were topographically inaccurate in terms of Euclidean metrics, they conveyed many details concerning aspects of the spatial environment that were important for the mapmakers. When cartography developed as a scientific discipline, one goal was to create spatially veridical maps. As this problem seems to be well understood and solvable for any specific requirements, the focus of interest in mapmaking has turned back towards cognitive issues that may have been the driving force for creating maps in the first place (e.g., *Montello* 2002).

In many situations, we are no longer interested in conveying the details of an environment to human map users with high precision such that the users can derive the in-

[2] This chapter summarizes work done in the project *Spatial Structures in Aspect Maps* of the German Spatial Cognition Priority Program and the *MapSpace* project of SFB/TR 8 Spatial Cognition: Reasoning, Action, Interaction. References to literature therefore focus on publications from these projects. For more detailed references, please refer to these publications. Funding by the Deutsche Forschungsgemeinschaft (DFG) is gratefully acknowledged. We want to thank two anonymous reviewers for their thoughtful comments that helped clarify the ideas presented.

formation they need; instead, we now look for more abstract, cognitive ways to directly convey to the map user the information for solving certain tasks. This goal requires a formal characterisation of kinds of spatial knowledge and an understanding of human spatial concepts and how they are used in spatial problem solving.

Cartographic developments, for example the invention of mathematical projections, have placed a set of formal rules between the conception of space and its representation. Map production is guided by technical and formal models (e.g., object ontologies) and a set of rules established within the cartographic community (e.g., *Bertin* 1974; *Dent* 1996). Some of the methods used for making spatially accurate maps and for making 'cognitively adequate' maps are rather similar. In particular, both targets require simplification of some sort. In this chapter, we look at *schematisation*. We work towards an answer to the question whether schematisation required for technical / graphical reasons are of the same type as schematisations introduced for cognitive reasons. We work out a more precise underpinning of the notion of schematisation and we motivate the use of the term *schematic map* for a certain type of intentionally distorted maps.

## 5.2 Schematisation and Generalisation

Cartographic maps depict aspects of a geographic environment on a spatial scale much smaller than 1:1. To maintain good legibility of small geographic features, certain characteristics (e.g. the width of a road) must be exaggerated. As a consequence, the representation must be simplified to fit all important features onto the representational medium. Simplifications of this kind can be considered as *schematisations*, as certain aspects are summarized in these maps. For example, on a hiking map the width of the trails is not depicted to scale; their width is exaggerated. Therefore, not all curves of a serpentine might fit on the map. However, curviness of a trail is a very important feature that should not be eliminated by smoothing the curve; thus, on some hiking maps serpentines are depicted with fewer turns, falsifying the number of turns but maintaining the general character of the trail. The shape of the trail has been schematized due to spatial constraints on the map. As simplifications of this kind are generally applied to cartographic maps, cartographers rarely speak of *schematic maps*.

In areas outside cartography, the terms *schematisation* and *schematic map* are used in the context of qualitative knowledge representation, qualitative spatial reasoning, design computing, and in cognitive science (e.g., *Tversky & Lee* 1998). Lately, the term *schematic map* has been used in the context of spatial cognition to denote diagrammatic artefacts in order to bridge the gap between physical and conceptual structures (cf. *Freksa* 1999). In the context of AI / cognitive robotics, the term is used to denote maps that are intentionally distorted beyond representational requirements to simplify shapes and structures or to make maps more readable (*Freksa et al.* 2000). Examples of *schematisation* procedures and algorithms to convert topographic maps into *schematic maps* have been presented by Barkowsky et al. (2000).

So far, there has been no definition of *schematisation* and *schematic map* in cartographic terms and some cartographers reject the notion of a special class of maps that is called schematic[3]. Although cartographic maps are highly schematic, it is not clear, (1) whether cartography considers 'schematic maps' as regular instances of one of the classical cartographic maps (and if so: what 'schematisation' by cognitive principles means in cartographic terms) and (2) to what extent cognitive considerations and notions can be expressed in terms of classical cartographic language. We argue for using the term *schematic map* for a certain type of maps—those that are intentionally schematized beyond the requirements of the representational medium.

In the following, we will argue for the significance and relevance of schematisation and schematic maps from a cognitive perspective of knowledge representation and reasoning. We will analyze the usage of the term *schematisation* in the context of the cognitive science literature, especially in linguistics, cognitive psychology, and artificial intelligence. Stating the meaning of 'schematisation' more precisely, particularly by juxtaposing it to generalisation, we will be able to clarify the term *schematic map* and to work out its importance for cognitively adequate representations.

There are at least two meanings of the term *cognitively adequate* (*Strube* 1992): (1) representations that resemble mental knowledge representation, and (2) representations that support cognitive processes. The argumentation for the importance of schematic maps draws on both meanings: the qualitative character of schematic maps makes them a unique tool for modelling cognitive knowledge representation. Additionally, a correspondence between internal and external representations can be assumed to support cognitive processes.

Authors often use 'schematisation' when they refer to a reduction of information content. The term is restricted neither to a cognitive domain nor to a technical domain. In contrast to the term *generalisation*, schematisation does not correspond to a research area (e.g., *Müller, Lagrange and Weibel* 1995). On the level of natural language, it is difficult to demarcate schematisation from related terms like idealisation, abstraction, generalisation, and conceptualisation. The distinction we make is that schematisation aims at cognitive adequacy in the first sense defined above and, therefore, intentionally distorts (aspectualises) a representation beyond technical constraints. This perspective will be explained in the course of this section.

Cognitive science, especially linguistics, looks at schematisation from an information processing point of view, focusing on the relation between language and space, i.e. concepts—their corresponding spatial objects and/or spatial relations or even actions (events)—and their matching spatial expressions. Herskovits (1986) states: "[T]here is a fundamental or canonical view of the world, which in everyday life is taken as the world as it is. But language does not directly reflect that view. Idealisations, approximations, conceptualisations mediate between this canonical view and language" (p. 2). On this proposition, she proceeds defining schematisation in two ways: "Systematic selection, idealisation, approximation, and conceptualisation are facets of schematisation, a process that reduces a real physical scene, with all its richness of detail, to a very sparse and sketchy semantic content. For expressions such as 'The village is on the road to London,' this reduction is often said to involve applying some abstract spatial relation to simple geometric objects: points, lines, surfaces, or blobs" (Herskovits, 1998, p. 149; emphasis by the authors). In other words: "Schema-

[3] D. R. Montello and S. Fabrikant pointed out that especially thematic maps are (highly) schematic. In fact, naming a map schematic is regarded as a pleonasm (pers. comm. Dec 2003).

tization involves three distinguishable processes: abstraction, idealization, and selection" (p. 150).

Herskovits' work is grounded on ideas proposed by Talmy (1983) who defines schematisation as "... a process that involves the systematic selection of certain aspects of a referent scene to represent the whole, while disregarding the remaining aspects" (p. 225). Yet, this definition does not capture schematisation completely as it only focuses on the aspect of *pars pro toto*, i.e. a part standing for the whole.

One problem remains: The processes used to define schematisation are not well-defined concepts themselves and, hence, cannot easily be operationalized. Selection, idealisation, approximation, abstraction, and conceptualisation give just an idea what schematisation is but do not really define its contents or processes.

Another question that arises is whether and how these ideas can be transferred to the domain of graphic representations of our spatial environment or whether they are restricted to the relation between language and space. When we speak of *space* we refer to what Herskovits has termed the canonical view on space, i.e. the world as it is or as we perceived and described it if we employed gauges for precise measurement. If we look at some approaches in cognitive science taken in this area we find especially work by Tversky (1999), Tversky and Lee (1998; 1999), Freksa (1999), and Berendt et al. (1998).[4]

Tversky and Lee are concerned with prototypical graphical representations of space. Tversky (1999), for example, mentions the fact that drawings of human participants do reflect the results of a schematisation and conceptualisation process for a specific domain, and states in congruence with the view found in Herskovits' work: "[...] drawings reveal people's conceptions of things, not their perceptions of things" (p. 94). Tversky and Lee's (1998) understanding of drawings and their claim that both, sketch maps and language expressions, reveal something about people's conceptions about the world result in the term *'ceptions* they introduce. 'ceptions mirror human conceptions about the world no matter in what form of representation they are expressed.

Berendt et al. (1998) present a computational approach to schematisation. They provide a framework for constructing schematic maps. The resulting maps represent the specific knowledge needed for a given task. The knowledge, called aspects, is extracted from existing knowledge prior to map construction. Accordingly, the resulting maps are *task-specific maps* (*Freksa* 1999). Three different types of knowledge are distinguished in this approach: knowledge that needs to be represented unaltered, knowledge that can be distorted but needs to be represented, and knowledge that can be omitted. This distinction guides the map construction process (see Section 3).

Otherwise, in computer science, especially in artificial intelligence, the modelling of schematisation processes is not a great research topic (or at least not an explicit one). Herskovits mentions this fact: "Work in artificial intelligence sometimes mentions schematization, but I know of no computational model of the use of spatial expressions in which it plays a significant role. Yet, schematization cannot be overlooked in modeling human abilities; it is most certainly a key to understanding both the strengths and limitations of spatial language" (*Herskovits* 1998, p. 149). Whereas

[4] A discussion on the influence of maps on spatial cognition and on maps as reflecting cognitive principles can be found in Uttal (2000a; 2000b) and Tversky (2000).

she refers to the domain of spatial language, the like can be stated for modelling in the graphical spatial domain. There is no consistent approach to model schematisation. On the other hand, there are several approaches that could serve as building blocks for defining schematisation for graphical representations (e.g., *Berendt et al.,* 1998; *Wahlster et al.,* 2001).

According to Bryant, Lanca, and Tversky (1995), the study of diagrams is one of these approaches: “Another way of dealing with space is by use of diagrams. This is an interesting case because diagrams are intermediate to language and physical environments. A diagram is representational, intended to convey spatial information about a place that is not physically present, just as in language. A diagram, however, is also a physical object having its own spatial properties, just as do real environments. The study of diagrams also has ecological justification because maps, sketches, pictures, and so on are commonly used to provide spatial information” (p. 536). Freksa (1999) supports and emphasizes this view: “Space can be realistically explored by operating on its representation” (p. 26). Note though, that this works for schematic maps only if we assume that the map-reader applies a conceptual level in the interpretation (see next section).

Schematisation is also an important aspect in the area of wayfinding even if it is not named this way all the time: “[...] whereas full guidance instructions can have a negative impact upon wayfinding performance, less complex instructions that link landmarks to directions have the capacity to enhance wayfinding performance” (Jackson 1998, p. 1000).

Some of the remaining questions not answered yet include the following: Is schematisation a process or the result of a process? Are concepts or conceptualisations the result of a schematisation process? For the map domain this may be easier as we could claim that the result of a schematisation process is a schematic map, which is a non-deniable fact, but what is the schematic map composed of? Another question that should be answered is: do we schematize spatial relations or do we schematize spatial objects? Do we schematize intersections or do we schematize angles between streets? The former corresponds to the toolkit approach by Tversky & Lee (1998, 1999), the latter is closer to ‘classical’ generalisation in cartography. To pinpoint the distinction between map design that gradually adapts representations through simplification and map design that starts with identifying cognitive concepts and integrates them in depicting spatial knowledge rather than spatial information, we contrast the *data driven approach* with the *cognitive conceptual approach* (cf. *Klippel*, 2003a).

## 5.3 Maintaining Qualitative Information

Maps are regarded to be spatially veridical (*Mark & Egenhofer* 1995). Additionally, the representational medium does not support underspecificity, i.e. it requires the instantiation of exactly one representation. As a consequence, maps are suited for representing spatial objects and relations schematically only to a limited extent (cf. *Berendt, Rauh, Barkowsky* 1998; *Habel* 2003). Hence, to avoid misinterpretation one has to make sure that people using the map recognize the type of map, i.e. that they can distinguish veridical and schematized content and interpret them correctly. This is a bigger problem in the graphic domain than in the linguistic domain as gra-phic representations are obliged to choose one possible interpretation, i.e. one graphical realisation, and have to make sure that this interpretation is not regarded as a veridical representation of a canonical view of the world but as the result of a schematisation process. MacEachren mentions that “Early railroad cartographers routinely straightened routes in an effort to convey an impression that their own route was the most direct” (*MacEachren* 1986, p. 18). To overcome this drawback of schematized representations, Agrawalla and Stolte (2001) used a rendering algorithm to give their 'map' the appearance of sketch maps to suggest spatial inaccuracy. Yet, there has been no systematic behavioural research on this question.

In the project *Spatial Structures in Aspect Maps* (*Berendt et al.,* 1998), we took another approach. Following the distinction of knowledge into three different types as presented in the last section, the aspects to be depicted are ordered in a depictional precedence (cf. *Barkowsky & Freksa* 1997). This precedence denotes the rank order of the knowledge to be represented, i.e. its importance for the task. Knowledge that needs to be represented unaltered is at the top of the order, followed by knowledge whose representation can be altered; at the end of the order is knowledge that can be represented highly distorted or even missing. This depictional precedence is used in the map construction process, for example, to decide on which knowledge can be distorted to solve (local) conflicts that result from space limitation in the depictional medium, i.e. the map. When reading a schematic map, the user's assumption about this depictional precedence, i.e. whether some information is depicted veridically or not, needs to match the actual depictional precedence used. Otherwise, map reading may lead to mis- or over-interpretation (*Berendt, Rauh, et al.,* 1998), i.e. some information in the map is assumed to be represented veridically while it is not and, thus, invalid conclusions can be drawn.

Subway maps are a good example for the approach of depictional precedence. While the direction and distance relations between stations along a line can be distorted, for example, to fit a qualitative eight-sector direction model, and therefore cannot be read off the map literally, the ordering information between different subway lines needs to be preserved in order to keep the maps usable. This latter aspect can be seen to be veridical.

This is also a good example that certain spatial knowledge needs to be maintained while other knowledge can be altered or omitted. Altering or omitting objects is easier since these changes are more obvious to the map-reader than modifications in the depiction of spatial relations. Omitting a specific type of object in a map is easily understood; it is simply not present. On the other hand, ignoring distance relations in the construction of a map, for example, is much more problematic. Due to the characteristics of the representational medium, one can always read off the map distances between objects that, in this case, are purely accidental. Thus, spatial relations conveyed in a map need to be characterized in a way that allows for different levels of granularity. That is, the map should communicate which deviations from the precise relation can be considered qualitatively equal to the original one and at which point deviations actually start changing the relation in a way that leads to different inferences. In contrast to cartographic approaches, successfully applying this approach requires an explicit specification of the spatial knowledge needed: the kind of knowledge and its intended qualitative level needs to be given prior to actual map design in order to create the depictional precedence and to resolve design conflicts. For the characterisation of spatial relations in schematic maps qualitative approaches can be taken into account (*Schlieder* 1993; *Barkowsky et al*., 2000).

These considerations, for example schematizing local features of the knowledge while preserving its global ordering, led to the development of a schematisation algorithm (*Barkowsky et al.,* 2000). The algorithm is based on the method of discrete curve evolution (DCE) by Latecki and Lakämper (2000). Latecki and Lakämper use this method to simplify the shapes of objects as a preprocessing step for measuring shape similarity in image comparison. The process of discrete curve evolution runs on closed polygonal curves. It simplifies these curves in a stepwise manner by eliminating kinks; its main accomplishment is that it preserves the overall perceptual appearance of an object while ignoring features of minor importance. The main idea of DCE is to remove in each step the kink of an object that is least relevant to its overall shape. The effect of this algorithm is comparable to simplification of detail due to scale reduction in cartographic generalisation.

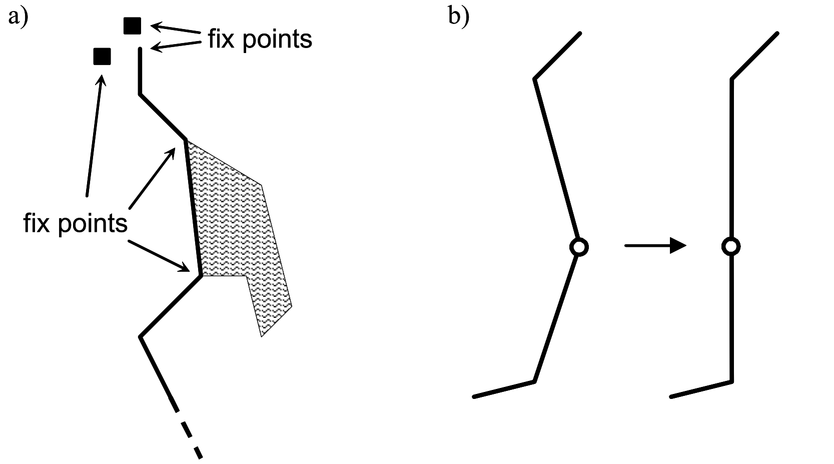


**Fig. 5.1.** a) Examples of fix points: Single-point objects, endpoints of lines, and points shared by two or more objects are treated as fix points in the simplification process; b) Example of a simplification step: movable points on linear entities are projected back onto the entity after the simplification step

We adapted DCE to meet with the requirements of map schematisation; in addition, we enhanced its functionality to account for design goals in map-making. DCE runs on closed polygonal curves, but entities in a map can be point-like, linear, or two-dimensional. While shape simplification as performed by DCE can be applied to linear and two-dimensional entities, their special properties and constraints and their relations need to be taken into account. As the relevance measure in DCE depends on pairs of line segments, no such measure can be computed for entities represented by single points or for the endpoints of linear entities. These points are excluded from the evolution process and are no longer considered. The points that belong to more than one entity, for example points on a shared boundary, need to be retained unchanged as well, as eliminating or displacing them violates topological information that needs to be preserved. These points are marked as fix points. Point-like entities that are located on linear entities are another special case; these distinguished entities need to be projected back to the linear entity when it is changed by the process of DCE. They are thus marked as movable points. All these cases are shown in Figure 5.1. Just like in the original DCE process, a given threshold determines the degree of schematisation.

The basic algorithm can be extended easily in different respects, one being the relevance measure. Other extensions include an additional factor that depends on the object at hand, for example, streets or rivers. The factor increases or decreases the relevance measure of an object's points. Therefore, this object will appear more or less simplified compared to others. In addition, a different cost function can be used that captures different aspects. The algorithm ensures that topological and various ordering relations are maintained. For example, a point-like object that is located left of a linear object will stay in this relation. On the other hand, panoramic ordering information as defined by Schlieder (1993) for point-like objects in the plane will not be kept on a general basis. Current lines of research elaborate the integration of qualitative distance concepts.

It is then possible to restrict the schematisation such that certain minimal (or maximal) distances between objects remain preserved. By eliminating a kink from an entity, the distance of this entity to other entities is changed. This change in distance is not restricted as long as it does not violate any topological relation. Thus, the distance may get arbitrarily small and be no longer perceivable but the schematized map will still be a valid result of the algorithm's application. This can be avoided by introducing a minimal distance between objects and testing it before applying the changes. If the new distance is smaller than this threshold, the change is not performed. Likewise, this can be used to push entities away from each other if their distance is smaller than the threshold in the original map.

## 5.4 Aspects of Human Spatial Cognition

In this section we present two approaches to map design that reflect principles of human spatial cognition (wayfinding choremes and focus maps) and how these approaches can be combined (chorematic focus maps). Additionally, we discuss multimodality as a key feature of human communication about space and how it can be related to map design.

### 5.4.1 Wayfinding Choremes

Klippel (2003a) defines wayfinding choremes as mental conceptualisations of primitive functional wayfinding and route direction elements. Given their focus on functional aspects, i.e. the action that takes place in environmental structures, they reflect procedural knowledge, i.e. knowledge about how to interact with the world. In this sense wayfinding choremes are schemata and do not as such concern categorical knowledge about physical spatial objects (e.g., *Neisser* 1976). Here the approach differs from toolkits (e.g., *Tversky & Lee* 1998, 1999) and computational approaches (e.g., aspect maps). Wayfinding choremes can be externalized, for example, graphically or verbally. They are key elements of a formal grammar, which models route information on a conceptual level (*Klippel* 2003a).

The wayfinding choreme theory got inspired by the idea of chorematic modelling, invented by the French geographer Brunet (e.g., 1987). Most pertinent for following a route is direction information at decision points on which the research efforts are placed. In Klippel (2003b) the empirical basis for wayfinding choremes is detailed. One major achievement is a clearer distinction between structural and functional elements of route information and how this distinction contributes to a better understanding of conceptualisation processes. Most approaches concerned with the visualisation of route information focus on *structural* aspects, i.e. they are concerned with the conceptualisation or depiction of objects. In contrast, the wayfinding choreme theory aims at a *functional* characterisation of route information, i.e. it focuses on actions that demarcate only parts of a physical spatial structure. The distinction is reflected in the following definitions (see also Figure 5.2):

Structure – denotes the layout of elements physically present in the spatial environment that are relevant for route directions and wayfinding. This comprises, for example, the number of branches at an intersection and the angles between those branches.

Function – denotes the conceptualisation of actions that take place in spatial environments. The functional conceptualisations demarcate parts of the environment, i.e. those parts of the structure necessary for the specification of the action.

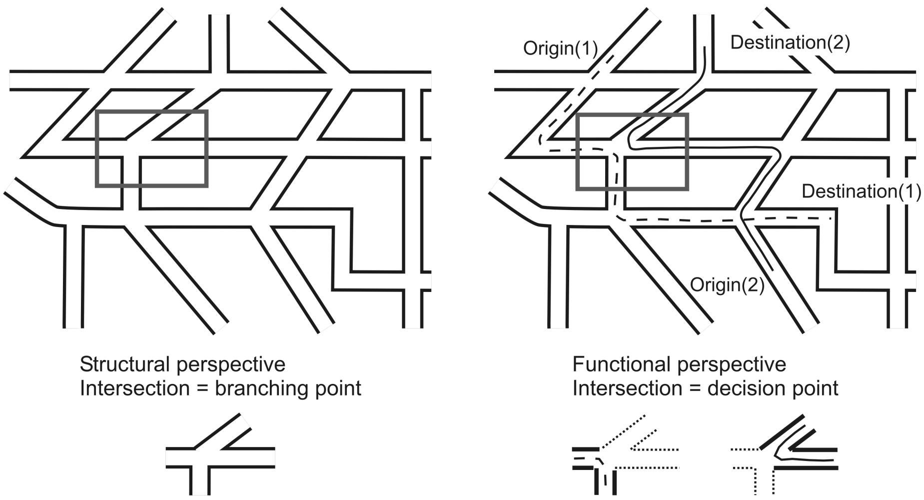


**Fig. 5.2.** Distinguishing structural and functional aspects of route information

An important goal of the wayfinding choreme theory is the combination of prototypical functional and veridical information. Prototypical graphical instantiations communicate the action required at a decision point. This prototypical action representation is then embedded in a veridical spatial situation (see Herskovits' definition of schematisation, Section 2).

Figure 5.3 shows the results for prototypical turning directions at decision points explicated in Klippel (2003b). Participants adhere to the prototypicality of the turning actions, i.e. the functional aspects of decision points. It is important to note that they do not adhere to the prototypicality of the structure of the intersections. The experiments confirmed a seven direction model for turning actions which is taken as a basis for the graphical representation of turning actions at decision points. The seven resulting wayfinding choremes are employed to schematically depict route information.

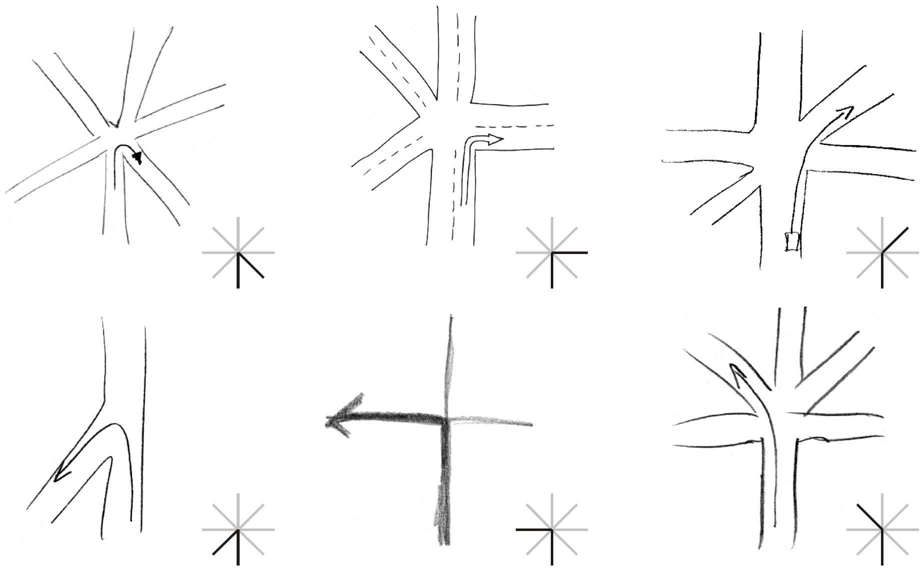

**Fig. 5.3.** The behavioural basis of wayfinding choremes (Klippel, 2003b)

### 5.4.2 Focus maps

Zipf and Richter (2002) present the approach of focus maps. These maps are designed such that a user's attention is drawn towards the map part of interest. Clearly, this map part, the region of interest, depends on the task at hand. In the case of wayfinding, it is the area along the route to be taken. By focusing on this region, the user's mental processing of the map information is guided to the area of relevant information. The map shows the remaining parts of the depicted environment, as well, but they are recognizable as less relevant. This way, they can still be used, for example, to orient oneself with respect to an area well known but not in focus. Hence, with focus maps, a user's interpretation process is inadvertently focused on the region of interest. This eases the map reading process as the amount of information to be processed is reduced.

Zipf and Richter (2002) achieve the focusing effect by employing two techniques: a generalisation to different degrees and fading colours. In the region of interest, map features are displayed veridically; generalisation of these features is kept to a minimum. With increasing distance to this region, map features' degree of generalisation increases, i.e. map features that are far off from the region of interest are simplified to a high degree. This is the first step in order to create a funnel towards the region of interest. The second step lies in the use of colours. Since in map making colour is often used to denote a feature's class membership, it is not feasible to use completely different colours inside and outside the region of interest. However, it is possible to use different shades of the same colour category; bright and shiny colours for features inside the region of interest, dimmed and greyish ones for features outside. As with generalisation, colours fade out with increasing distance. The combination of increasing degree of generalisation and fading out of colours results in a kind of funnel that focuses the user's attention on the region of interest.

### 5.4.3 Chorematic focus maps

In Klippel and Richter (2004) wayfinding choremes and focus maps are combined, resulting in *chorematic focus maps*. From a representation-theoretic point of view, these maps should be well suited for wayfinding assistance. Their design process comprises four steps: first, calculating the route, i.e. connecting origin and destination; the route determines the area on the map to be depicted. Second, relevant aspects for the given task are selected. In the third step, these aspects are used to construct a focus map. In the last step, functionally relevant parts of the selected route, i.e. the branches of a decision point that will be used by a wayfinder, are replaced by the corresponding graphical wayfinding choreme (see Figure 5.3).

Wayfinding choremes and focus maps complement each other ideally. Both approaches draw their motivation from cognitive principles of information processing. One approach, wayfinding choremes, is cognitive-conceptual and highlights the relevant information by employing conceptual prototypes. The other, focus maps, is data driven and keeps the relevant information veridical but deemphasizes other information. Their combination eases information processing significantly. With focus maps a user's attention is drawn towards the map's region of interest. This focuses the mental process, map reading, on the location of the relevant information, its *where part* so to speak. Graphical wayfinding choremes emphasize the functionally relevant parts of decision points. Additionally, further information remains veridical. By this procedure, the route and the corresponding actions to take stick out in the map and are easy to process. Wayfinding choremes emphasize, so to speak, the *what part* of the information. In combination, the resulting map allows a user to concentrate *on* the relevant information *in* the relevant part of the map; thus, the cognitive effort to process the information is drastically reduced, and map reading should become easier.

### 5.4.4 Multimodality

Paper maps and their digital counterparts are monomodally focused on the visual sense (disregarding, e.g., tactile maps). Yet, they can mimic various modalities. This is possible through the representation-theoretic characteristics of signs and symbols (e.g., *Palmer* 1978). Following the idea to reflect cognitive principles of knowledge representation in maps (see Section 2), we generally can distinguish between abstract mental conceptualisation on the one hand and various output modalities by which these abstract mental concepts can be externalized on the other hand. In the case of wayfinding choremes (*Klippel* 2003a), this fact is terminologically reflected by adopting a Chomskian (1986) distinction. Chomsky differentiates between I-language and E-language. 'I' stands for internal and denotes an abstract part that underlies the observable behavioural aspects of language. 'E' stands for external and means these observable behaviours. Correspondingly, the wayfinding choreme theory refers to mental conceptual primitives, i.e. abstract mental concepts of basic route direction elements, as I-wayfinding choremes. In contrast, the (graphic) externalisations of I-wayfinding choremes are termed E-wayfinding choremes:

I-wayfinding choreme – the mental conceptualisation of primitive functional wayfinding and route direction elements.

E-wayfinding choreme – the externalisation of mental conceptualisations of primitive functional wayfinding and route direction elements, i.e. the externalisation of an I-wayfinding choreme.

Whereas the wayfinding choreme theory primarily deals with graphical and verbal externalisation, other forms are possible for maps. One prominent example is the use of symbols for gestures that Hirtle (2000) terms *map gestures.* Map gestures can be compared to gestures used together with (verbal) route directions, for example, 'the hotel is over there' plus gesture. The gesture can subsume a variety of necessary actions without specifying them in detail (see also *Tufte* 1997).

The wayfinding choreme theory discusses the possibility of chunking primitive route direction elements into secondary or higher order elements, termed HORDE (cf. *Klippel*, *Tappe and Habel* 2003). Whereas the current theoretical state of HORDE allows for identifying the route direction primitives involved, this is not necessarily the case for map gestures. Figure 5.4 depicts an example. The map is used as part of a route direction. The map gesture subsumes all actions necessary to get from the S-Bahn station 'Landungsbrücken' to the nearby docks. Like most interurban train stations, the station 'Landungsbrücken' has more than one exit. Moreover, from each of these exits various options exist to reach the docks. On the one hand, this makes the situation complicated as different sequences of route directions elements have to be arranged. On the other hand, the situation is comparatively easy. Even though there are several possibilities, the destination is rather obvious—a classical you-can't-miss-it situation. The environment constrains the movement in the most important direction by the river, which conceptually functions as a giant T-intersection; in the terminology of Lynch (1960), an 'edge', terminating the general possibility of moving in one direction.


**Fig. 5.4.** A map gesture (cf. Hirtle, 2000) describing a generic route from the train station to the dock. It subsumes all possible routes to reach dock '4' from station 'Landungsbrücken'

In this sense, the wayfinding choreme theory combined with map gestures reflects a fundamental aspect of knowledge representation: granularity. Or, to quote Hobbs (1985): "It is that our knowledge consists of a global theory together with a large number of relatively simple, idealized, grain-dependent, local theories, interrelated by articulation axioms. In a complex situation, we abstract the crucial features from the environment, determining a granularity, and select the corresponding local theory" (p. 435).

## 5.5 Applications

The ideas and approaches detailed so far are important elements in several applications. The schematisation algorithm explained in Section 3, for example, is used in a system that computes the placement of You-Are-Here maps for a given environment (*Richter & Klippel* 2002). The system's underlying model is based on spatial cognition research; its basic representation is a graph that consists of routes calculated in advance. Locations along these routes that are relevant for the placement of You-Are-Here maps are determined locally before being reduced to those actually needed in a global judgment of all locations. We employ the schematisation algorithm to simplify the graph; this reduces computational complexity. The algorithm ensures that the structure of the simplified graph stays similar to the environment's system of paths, which is a prerequisite for the system's success.

Another application area is the field of robotics. We use schematic maps as means of communicating with mobile robots (*Freksa, Barkowsk, and Moratz* 2000). The approach is based on the presumption outlined earlier in this chapter that meaningful interaction requires an appropriate level of abstraction for intelligently solving tasks in a given domain. In the domain of wayfinding in a structured environment, a representation of space on the abstraction and granularity levels of decision-relevant entities is considered appropriate. The approach especially makes use of qualitative ordering information of environments' features for localisation and navigation of the robot and for communication with a human user. The robot employs qualitative spatial reasoning on the information provided by the schematic maps and its sensor readings both for planning and for plan execution. This way, it tries to match the given information, i.e. the map, with the perceived information, i.e. the real world.

## 5.6 Conclusions

In this contribution, we set out to give an overview of several approaches that evolved within cognitive science and that aim at making graphic representations cognitively adequate. A central concept for cognitively adequate representations of environmental knowledge is that of a schematic map. Even though all maps are schematic for reasons of graphic constraints, our intention was to show that schematisation may be usefully applied as a cognitively relevant concept that has a special significance beyond graphic and spatial requirements and should not be applied to every map. Thus, although from a cartographer's perspective every map is schematic, not every map is a *schematic map*. It is important to note that we refer to cognitive adequacy here in both meanings of Strube (1992): the external representation resembles a mental internal representation; additionally it supports cognitive processes. The latter statement is supported by the assumption that correspondence between an internal and an external representation facilitates map reading.

Within this general framework, the project *Spatial Structures in Aspect Maps* has approached several facets of representing spatial knowledge in a cognitively adequate way and has explored major fields of research in cognitive science drawing on results from artificial intelligence, cognitive psychology, and linguistics. Formal methods relying on different kinds of spatial knowledge (e.g. topological or ordering information) and qualitative calculi have been specified for schematizing information, providing a different perspective for cartographic research on this topic. Psychological results on prototypical representations and the focus of attention have been extended by behavioural experiments providing the necessary results for map design. Linguistic and psychological approaches on conceptualisation and the importance of an action-oriented characterisation of spatial information have been employed to shape a theory of cognitive-conceptual map design and to specify a grammatical approach to (graphic) route directions on a conceptual level. Action-oriented approaches have gained high visibility under various hotly discussed topics in cognitive science; amongst others, the embodiment of cognition, situatedness, and the central role of events in current research efforts (e.g., *Worboys & Hornsby* 2004). Work in the aspect map project has been extended to incorporate findings of research on multimodality to the design of maps and map symbols. Finally, these finding have been shown to be applicable not only in map design but also in fields such as the interaction with robots by schematic maps.

Finally, to sum up, we discussed the following types of maps in this chapter: Schematic maps: intentionally simplified representations aiming at cognitive adequacy; aspect maps: a class of maps that adopts a hierarchy of aspects to decide whether or not certain aspects have to be depicted in a map; wayfinding choreme maps: map design based on identifying conceptual primitives, for example, prototypes for turning actions at intersections; and focus maps: application of various graphic means to centre the attention of a map user on spots of highest interest.

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# 6 Adaptive Visualisation of Landmarks using an MRDB

Birgit ELIAS, Mark HAMPE, Monika SESTER

Institute of Cartography and Geoinformatics, University of Hannover, Germany

**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.

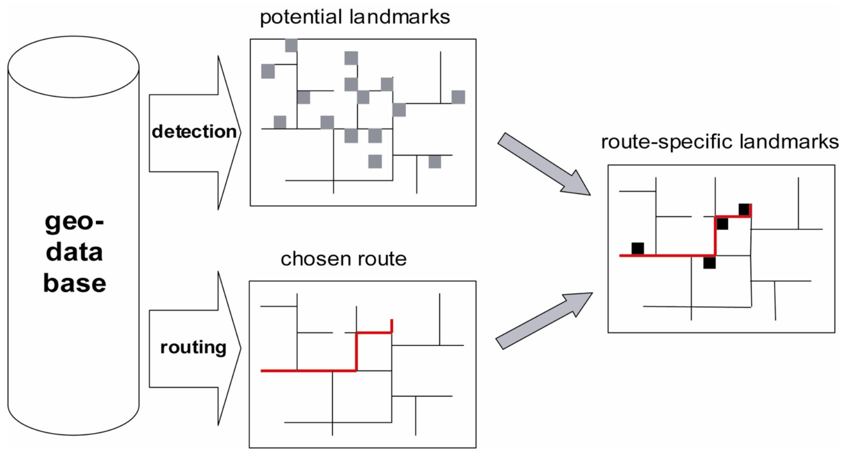


**Fig. 6.2.** Generation of route-specific landmarks

### 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.

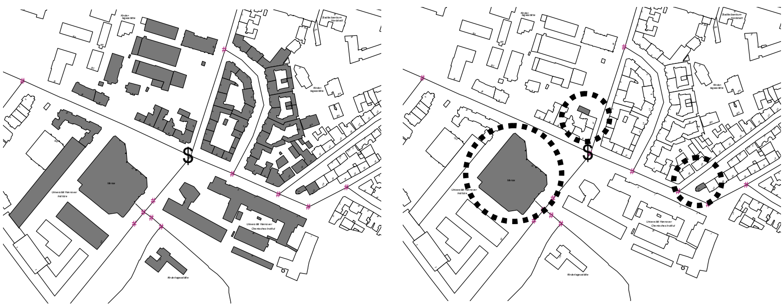

**Fig. 6.3.** Scene of Hanover (road network with decision points, buildings) – left: "local environment" around chosen decision point (created by a buffer), right: potential landmarks after processing (filled objects, inside circles).

### 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.

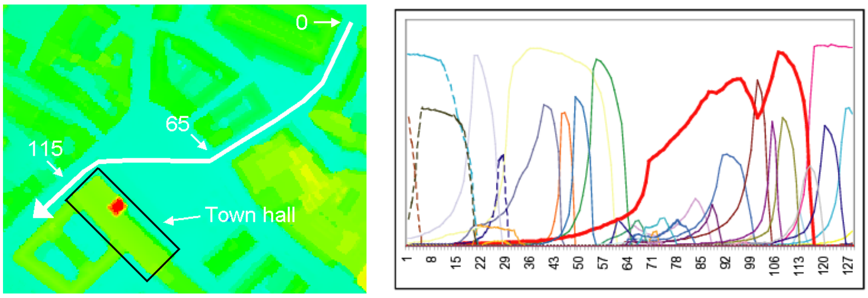


**Fig. 6.4.** Visibility tracking – left: trajectory approaching town hall, right: visibility plot of different objects, wide line: town hall (from (*Brenner & Elias* 2003)).

## 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.

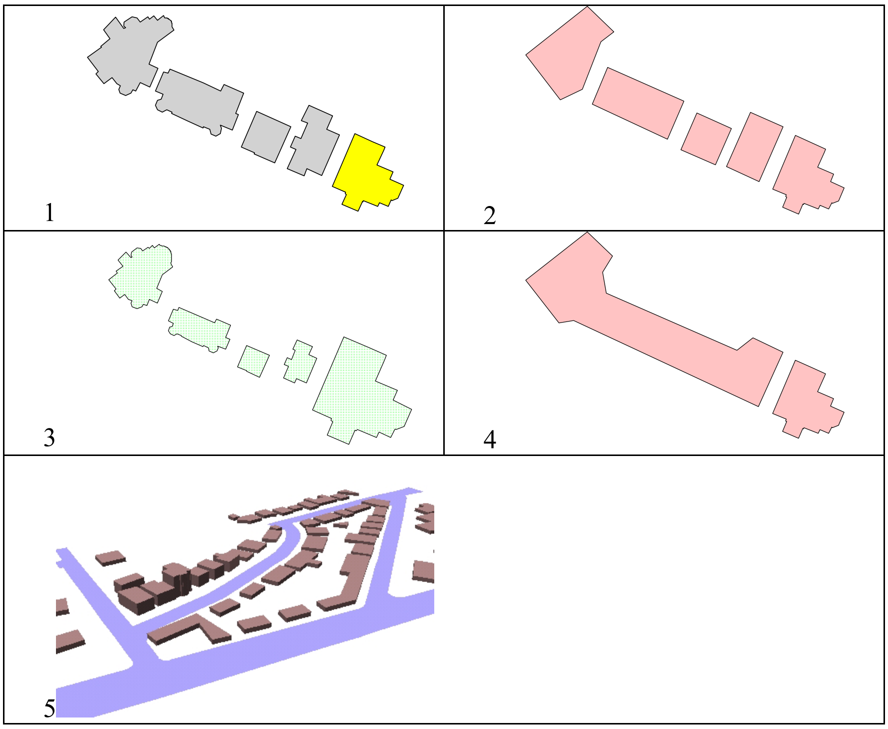


**Fig. 6.5.** Visualisation of different possibilities for enhancing individual objects: use colour, simplify background objects, enlarge landmark object, aggregate background objects, use height as indication for importance (from (*Sester* 2002)).

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).

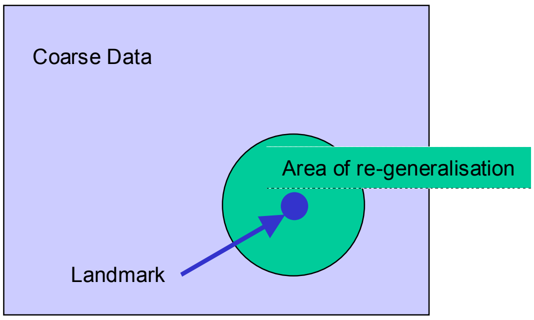


**Fig. 6.6.** Schema of re-generalisation in vicinity of landmark.

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.

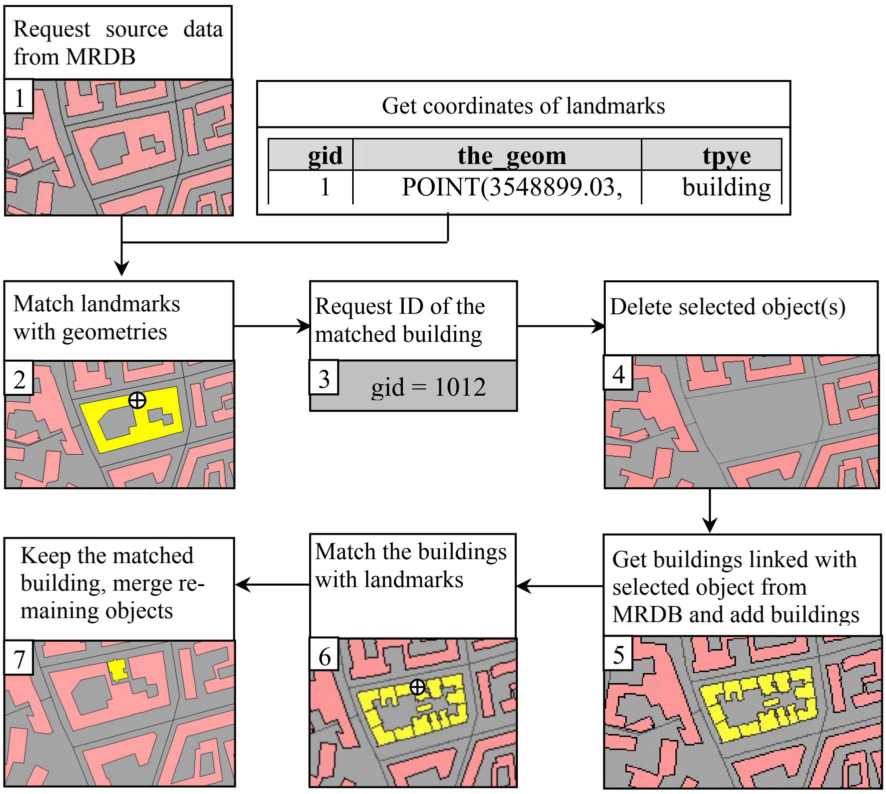


**Fig. 6.7.** Workflow for visualising landmarks using original shape of buildings.

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.

## Acknowledgement

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# 7 Ego centres of mobile users and egocentric map design

Liqiu MENG

Department of Cartography, Technical University of Munich

**Abstract** In contrast to the traditional allocentric mapmaking that strives for the communication of geoinformation in an unbiased way to diverse users, there is a growing trend of designing the so-called egocentric map, a phenomenon resulted from the rapid technical progresses and the increasing personalisation of geoservices. Some tools of egocentric map design are already available in current cartographic systems and there is an increasing awareness of their impacts on usability issues. However, personal user requirements are far from being sufficiently understood. A systematic study of methods for the detection of ego centre is missing. This chapter stresses the importance and necessity of egocentric design for mobile applications. Based on a general description of the aspects influencing the usability of an egocentric map, the author discusses different forms an ego centre may take. A number of approaches for the detection of ego centres and the subsequent design patterns of egocentric mobile maps are introduced and compared to each other. What remain open for the further development are the verification of hypotheses on ego centres and the formalisation of verified ego centres in computer languages.

## 7.1 Introduction

As a result of the dazzling technical progresses in cartography during last decades, maps have been constantly reshaped and their functions redefined. Although topographic maps will continue to serve a large public for general purposes in diverse use occasions, their traditional mass production tends to go over to the production on demand. Meanwhile there is an increasing need for digital landscape databases consisting of topographic base information and a large number of georeferenced thematic attributes as well as relationships. Each of these digital landscape databases, no matter how they are constructed and maintained, can be treated as a unbiased scaled-down model of the reality with a consistent geometric, semantic and temporal precision, thus acts as the data source for the design of map-based services. While the design of topographic maps still follows the internationally well-established conventions, thematic information may be expressed in different ways, e.g. as one or many visually highlighted theme layers superimposed upon a topographic base, as graphic variables merged with the existing topographic symbols, or as retrievable alphanumeric tables connected to the spatial reference. In spite of their diversity, the different design solutions share a common constraint, namely the limited display surface which allows only a small facet of a digital landscape database to be made visible. To identify the right facet and render it in the right way that is expected and preferred by its target user are two principle challenges for the designer.

Traditionally cartographers consider it a “holy” responsibility to strive for an unbiased allocentric visualisation of our living environment. Even when a generalisation procedure conditioned by map scale or display resolution has become inevitable, still, they make attempts to find repeatable and consistent solutions by applying objective criteria for the detection of graphic conflicts and the evaluation of generalisation results. As a matter of fact, allocentric maps have been always used as both presentation and storage medium in pre-digital era. Being characterized by their portability, geometric measurability, well-balanced semantic density and symbolic abstraction, allocentric maps usually remain up-to-date for a longer time than their corresponding reality. For this reason, their predominant position in cartography was never threatened by the occasionally published non-allocentric products. With the introduction of digital technologies, however, this situation has undergone a number of dramatic changes.

In digital cartography the function of a map as presentation medium has evolved into a visual “window” of an underlying geodatabase which has essentially taken over the function of storage medium. The contents within the window can be interactively layered or peeled off. Their corresponding symbols can be designed either so elaborately as to fasten user’s eyes on the visual surface or so modestly that user will feel forced to see through the plain look of every symbol by diving deep into the geodatabase. In other words, the communication process of digital maps takes place either directly between the user and maps or between the user and a geodatabase with maps as the mediator.

The popularisation of Internet has further refined the window metaphor. Instead of converting the contents within the window into an eye-catching but shallow surface or a simple plot of all individually accessible objects, the designer of web maps can choose a graceful compromise by making the window so attractive that even the impatient or casual users become irresistibly curious, at the same time, embedding hyperlinks in a few symbols which are highlighted so that users feel tempted to click on them. It is such a combination of overview and selective access to open-ended data sources that makes the design and use of internet maps so exciting and challenging. Yet, web maps suffer the inherent immobility of stationary computing systems.

The marriage of Internet with wireless telecommunication technology has won back the portability for digital maps along with the new possibility of ubiquitous computing and communication. The display surface of a mobile map, however, must reduced to the size of a palm. Also, the dynamic usage environment does not allow extensive interaction. For all these reasons, mobile maps suit as a communication vehicle for well-defined user tasks rather than a thinking instrument for exploration purposes. With regard to the limited memory load in mobile situations, what a user needs for a particular moment at a particular place may be not more than one single piece of message. The more time-critical the task, the “sharper” the information need of the user and the higher his requirement for the immediate legibility of the map service. A taxi driver, for instance, attends probably only the actual route towards his destination including one or two landmarks within his vision field during driving, while a tourist in a strange city may attend simultaneously to many scenic spots scattered all over the map and possibly also the navigation routes connecting them. Bearing this fact in mind, a mobile map does not even have to accommodate so much detail as maximally allowed by the miniature screen. Map symbols for mobile usage could adopt much larger graphic sizes than the empirically determined minimal dimensions for screen design. In short, the usability issue stands out as a more critical factor than technical issues.

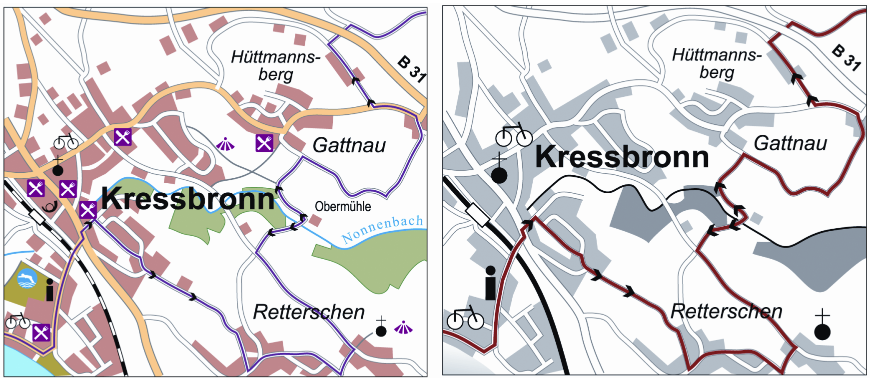


**Fig. 7.1.** Presentation based on empirically determined minimal dimensions for mobile display (left), presentation with intentionally increased legibility for biker (right) (see the colour figure on CD)

Finally the integration of the multiple tend-to-be omnipresent positioning technologies with mobile devices has led to the generation of location-sensitive maps with their two-fold mobility: (1) they are movable along with the mobile devices, (2) their spatial reference is constantly refreshed in order to accommodate the actual user location and its associated meanings, i.e. semantic location according to (*Ibach and Horbank* 2004). Nevertheless, the synchronised communication with the virtual space displayed on maps and the physical space is an effortful process that requires collaboration of multiple sense and motor organs of the user. Often a mobile user will not feel like to consult a location-sensitive map unless the latter is able to relax his mind and extend his physical capability. This hard constraint makes the visual emphasis of the actual user location and its relevant vicinity an indispensable design strategy. In other words, a location-sensitive map does not have to obey allocentric design rules. Rather, it should be generated as an egocentric and self-explaining gesture guiding individual user actions in the mobile environment.

## 7.1.1 Usability of the egocentric mobile map

The egocentric design can be regarded as a typical personalisation approach, with the individual user profile being embodied as the ego centre in the corresponding map. The usability of an egocentric map can be judged by the degree to which both pragmatic and hedonistic requirements of its target user are satisfied. The pragmatic requirements are objective, easily measurable and purpose-oriented. They concern the effectiveness and efficiency of map use. While the effectiveness has to do with the questions such as whether the map contains information wanted by the user, whether the user really understands the meanings of map symbols as explained in the legend and whether the interactive functions achieve the expected performance, the efficiency can be measured by the times spent on successfully finished actions such as searching, comparing, navigating etc., the number of successfully finished actions within a limited time slot, the price of the service compared with its performance and so on. Hedonistic requirements are subjective, diffuse and independent of map purpose. They concern the user's emotion such as joyfulness or irritation during the interaction with the map (*Burmester et al.* 2002, *Hassenzahl / Hofvenschiold* 2003, *Fuhrmann / Heidmann* 2003, *Hermann / Peissner* 2003). In a mobile usage context, the user emotion tends to be very sensitive to environmental factors. An available mobile map possesses already some intrinsic hedonistic quality because it makes its user feel safe, especially in panic occasions. A well-designed egocentric map should be able to further release its user from stress and make him happy. Often the hedonistic quality is somewhat positively correlated with the pragmatic quality. On the one hand, effective map contents tend to enhance the feeling of trust and safety. On the other hand, in a relaxed mood the user tends to be more efficient in map use. As reported in (*Latzina* 2003), users who feel "at home" with a design product are far more productive than those who have trouble getting to grips with one. Here the feeling of "at home" implies a high degree of familiarity which in turn is a factor that raises the degree of self-confidence.

### 7.1.2 Necessity of designing egocentric mobile maps

From designer's perspective the production of an allocentric map intended for an average user might be cost-effective because every user can get something useful from the map. In mobile usage context, however, an allocentric map can hardly remain cost-effective due to the following reasons: What an average user needs is often much more than what is necessary for an individual user. The unnecessarily large amount of information claims not only more network capacity to get transmitted from server to client, but also longer time to get rendered. The rendered graphics is likely cluttered on the small display, which makes the recognition of particular symbols difficult, thus impedes the reading efficiency. Also, an unpleasant look of the graphic could irritate the user. Due to its typically limited display size, a mobile device, being held in hand or mounted in a moving vehicle, is a more suitable platform than a stationary PC for personalised services including egocentric maps. The generation of an egocentric mobile map begins with the retrieval of information required by its user for a spatial task at hand, which is usually composed of a series of concrete actions. The retrieved information, then, has to be symbolised in a way the user prefers. For each of the user actions conducted at different moments, only a subset of map symbols is particularly relevant, therefore, needs to be highlighted. In other words, what the user immediately catches on the small screen is a further selection of the available information focused on his current location or interest. Such a map is also termed as Focus Map (*Zipf and Richter* 2002). Likewise, the interaction mode needs to be constantly adjusted so that the user will get access to his wanted information with minimal mental effort and at his most convenience. Fig.7.2 shows an egocentric presentation of *TomTom GO* (www.tomtom.com) for a driver by daytime and by night respectively. The driver simply needs to follow the gestures intuitively embedded in the map. The visual emphasis of the dynamic ego centre has brought the map mentally closer to its user, thus made it immediately usable. However, the timely detection and visualisation of the ego centre are by no means trivial tasks because they require an insight into the actual user profile in addition to general ergonomic concerns and physical influences of the transient usage context.

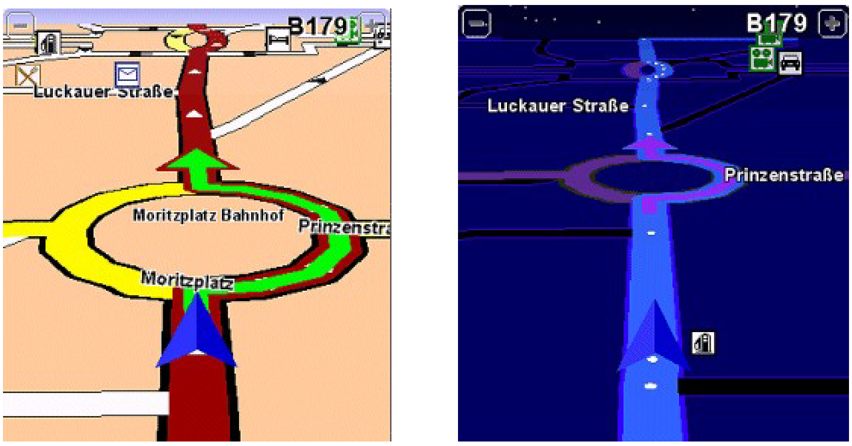


**Fig. 7.2.** Screenshot of an egocentric presentation of *TomTom GO* (www.tomtom.com) for a driver by daytime (left) and by night (right) (see the colour figure on CD

## 7.2 Detecting the ego centre of a mobile map user

The profile of a mobile user from which the ego centre will be derived is generally composed of a location-independent part and a location-sensitive part. Characteristics such as user goal, demographic data, personal preferences, habits, visual literacy, ability of spatial cognition, domain knowledge and computer experiences are relatively location-independent. Their values tend to remain stable throughout a map use session. Other characteristics such as information need, action and emotion are apparently location-dependent and volatile. Often the user himself is able to provide certain information about his location-independent characteristics, though not always precise and unambiguous. The location-dependent part, however, can only be reasonably constructed during the map use.

It is obviously impossible and unnecessary to bring all the facets of a user profile into view on a miniature screen. Often an ego centre can be already sufficiently detected on the basis of a small fraction of the user profile. Depending on the mobile usage context, the ego centre is reflected in various aspects, such as (1) the current user location in form of a point, a route or a region of varying size, (2) one or many locations that are currently of interest to the user, (3) data items that are currently of interest to the user, (4) actions or operations that are frequently performed by the user, (5) symbolisation styles preferred by the user, and (6) interaction modalities preferred by the user. In its most general form the ego centre can be expressed as a function of all these aspects. Detecting such an ego centre requires a continuous contact with the user in his mobile usage context. Some available approaches for this purpose are described in the subsequent sections.

### *7.2.1 Behaviour tracking*

User behaviour can be tracked with a head-mounted device that is able to register user's eye movements or brain waves during map use (*Brodersen et al.* 2002, *Heidmann & Ziegler* 2002, *Gelgon and Tilhou* 2002). The eye-tracking measurements typically reveal the parameters of visual perception and cognition such as how the user's attention is distributed among the symbols, how the user's actual location is related to his attention, how often and in which order the eye fixations occur, how many fixations follow each other within each information unit, how long each fixation lasts, how long each saccade between two successive fixations lasts, what is the average saccade duration of each symbol, how many saccades are necessary to process each symbol. The brain waves that are usually recorded as electroencephalogram (EEG) or magnetencephalogram (MEG 2003) reflect the relative intensity of the user's mental efforts in searching for map contents or understanding them, thus give important clues on the visual salience, the relative importance or difficulty of individual map symbols.

User behaviour can also be tracked without sensor. (*Egner and Scheier* 2002) reported a software-supported approach of attention measurement similar to the sensor-based eye movement registration. (*Hölldobler* 2001) described a system that can infer the personal interest of a user from his traceable interactions with multimedia presentation elements. (*Wilhelm et al*. 2003) presented a site-covering method according to which a webpage was divided into a number of areas of interest AOI, each being covered by a grey transparent card. Each subject was asked to remove one card at each time, perceive the underlying information and cover it again before the next card is removed. The duration and frequency of his attention to each AOI can thus be registered. (*Schwab and Kobsa* 2002) put forward another approach for learning interest profiles from positive user observations only. The perceived information is considered as relevant and useful only when it leads to a successful solution to a task. This approach eliminates the need to prompt users for ratings or other artificial evidences. Due to their inexpensive and flexible nature, non-sensory methods can be very well applied to trace the individual mobile map users.

As a whole, tracking methods serve a two-fold purpose: (1) to ensure the usability of egocentric information. A mobile map is considered as sufficiently personalised if the attention of its target user can be immediately drawn to the most relevant map contents and if the user can efficiently decode the map symbols; (2) to detect the mismatch between the decision of map designer and the actual behaviour of map user. Attention concentrated on map contents that are not visually emphasised by the designer may very well reveal user's personal interests, hence, ego centric information.

### 7.2.2 Mobility-conditioned user profile

Since many years it has been a dream to track all the characteristics that differentiate the users from each other. In spite of numerous investigations, no breakthrough is yet in sight. The experiments either ended up with an enumeration of general rules that can hardly be converted into a machine language or created a plethora of atomised facets that cannot be traversed by a single system. In a stationary usage context the usability of a map may be influenced by a great number of user characteristics. In addition to support the user to perform his intrinsic tasks, i.e. tasks that he has already planned, a stationary map can also further motivate the user to accomplish some extrinsic tasks, i.e. tasks that come up during the map use. In other words, the user enjoys the richness and depth of the map information, at the same time runs the risk of getting distracted from what he initially plans to do. In a mobile environment, however, the user behaviour is very much constrained by his intrinsic task and the time pressure. If a map is needed, it must be immediately usable by rendering shallow-structured and focused information. Obviously the mobile environments have made the majority of user characteristics irrelevant. Interviews or on-line questionnaires focused on a few characteristics such as location, task, intuition, visual literacy, computer skills and habit may be already sufficient to capture some straightforward and essential aspects about the ego centre.

### 7.2.3 Acquisition of scenarios

A desktop cartographic system intended for a wide user spectrum usually consists of extensive geodata and interactive tools of for visualisation and analysis. By virtue of horizontal prototyping (customisation of geodata) and vertical prototyping (customisation of interactive tools), different subsets of the system can be selected for different target groups and applications. However, even if a system has shrunk its size to a prototypical subset, still, the majority of its available resources may be superfluous for mobile contexts. Equally unrealistic is the attempt to automatically identify what an individual mobile user would urgently needs at a particular moment and location because the mobile environment is too transient. A reasonable compromise would be the extraction of use scenarios, with each corresponding to a further reduced subset at the joint of horizontal and vertical prototyping in Fig.7.3. A scenario is somewhat like a personal story or diary that documents the experiences on what the user wanted to do with the system, which data and interactive operations he selected for a certain task, in which order he activated the operations, which errors he made and how he corrected them etc. Unlike the behaviour information tracked by a sensor or a computer program, a scenario is more or less structured and mentally processed by the user in terms of thinking-loud method. Not only user tasks and interactions, but also the reasoning conducted by the user is recorded in a scenario. From a sufficiently large sample of various scenarios documented by a sufficiently large number of various users recurring user tasks of different granularity levels and user clusters can be derived. Accordingly, reusable design patterns could be identified. The idea of patterns was originated from the work of the architect Christopher Alexander (*Alexander, et al.* 1977). Each pattern consists of a number of attributes describing a recurring task and the representative strategy, e.g. a sequence of interactive operations, adopted by a user or a user cluster to accomplish the task (*Borchers* 2000). As suggested in (*Erickson* 2000), patterns are “ways of representing knowledge about the workplace so that it is accessible to the increasingly diverse set of people involved in design”. When a user begins to perform one of the recurring tasks (e.g. orientation), the system will try to identify at first the cluster he belongs to based on his current and/or past behaviour (*Cotter and Smyth* 2001), and then recommend him the geodata and interactions his cluster will most probably select (e.g. finding and highlighting certain type of landmarks). What his cluster typically likes and does is not exactly identical but most similar to his egocentric behaviour.

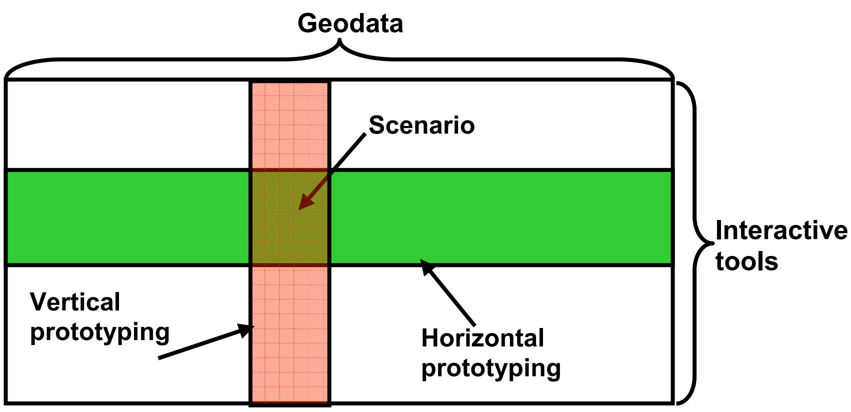


**Fig. 7.3.** User scenario containing information about the ego centre

### 7.2.4 Generation of repertory grids

In practice, not many users will get along with a mobile map so intensively that statistically significant recurring tasks and user clusters may be extracted. Yet, every mobile user is at least able to judge the usability of a map. A cognitive process such as map design often ends up in a number of equivalent solutions to a certain user task. This equivalence is viewed from the designer's, not the user's perspective. Very often the alternative design solutions are not equally usable for a user. As reported in (*Lee, Tappe and Klippel* 2002), for example, different route presentation methods have different impacts on route memory. In evaluating the usability of each design alternative the user does not have to obey any formal rules, rather he can apply his own empirical criteria and articulate his thoughts and feelings best representing his personality. The personal constructs of each user are then stored as a repertory grid in which the pragmatic quality (e.g. fitness for the intended purpose) and the hedonistic quality of the concerned design (e.g. pleasant look for the eye) are unconsciously brought together (*Stringer* 1974). Indeed, each repertory grid contains at least two aspects of the ego centre - the personal preferences of a user and his personally perceived characteristics of the design solution. From the repertory grids new evaluation dimensions and requirements can be identified (*Burmester et al.* 2002). Meanwhile, user clusters can be found based on the semantic similarities in their constructs, e.g. some users are rather insensitive to visualisation differences, while others tend to be fastidious. Repertory grids reflect more authentically and spontaneously the user profiles than the information that could be acquired by interviews or questionnaires because interviews are often guided or moderated by the interviewer and questionnaires tend to trim the user opinions to a limited number of standard answers or ratings.

### 7.2.5 Participatory map design

Although egocentric information can be derived from repertory grids and guide subsequently the improvement of design, it is often too late or too expensive for the developer to make substantial modifications or redesign the whole system if the egocentric requirements deviate too much from the existing solution. Such undesired situation may be avoided to a certain extent if mobile users could be involved in the design process. The earlier the users participate in the design, the earlier the potential problems will be revealed. The more extensively the users are involved in the design, the more impact their ego centres will have on the final design solutions. According to the principle of participatory design, mobile users will be allowed to change design parameters, add symbols, define new visualisation styles and document their reasons for their personal solutions in which their ego centres are embedded. Participatory design is also an excellent way to detect the missing data and/or tools in a system because the user knows his personal behaviour and emotional state for his mobile task in an envisaged context (such as wayfinding in urgent situations, field work under volatile weather conditions) better than the designer.

## 7.3 Designing egocentric map

The aforementioned approaches help to gather the implicit and explicit evidences about ego centres of individual mobile map users. They can be implemented either separately or in a combined way. Their usual outcome consists of both objectively recorded user behaviour and subjectively expressed user opinions from which unambiguous statements or hypotheses will be derived in a post processing stage. It is a challenging work to interpret the user information. Concretely, the following tasks are involved:

- Categorisation of user goals based on their tasks in scenarios, e.g. travelling, fleet management, group appointment, field work.
- Categorisation of user tasks of various granularity levels based on their recurring frequency, e.g. outdoor navigating, positioning, orienting, searching for land marks, routing, measuring distances, estimating travel time etc.
- Categorisation of users based on their interactions and personal constructs, e.g. users who prefer pictograms to abstract symbols; users who use finger instead of touch pen to transcribe input command; users who dislike dynamic rotation of map contents.
- Transformation of contradictory statements into fuzzy rules, e.g. "The contrast of the display is too small at 10 am and too large at 7 pm" can be transformed into a fuzzy set of contrast with the membership value $\mu(t,w)$ between 0 and 1, depending on time and weather.
- Conversion of diffuse descriptions into values or value ranges of the individual design parameters, e.g. "The route is a bit too dark" will be converted into "Raise the brightness of the colour for the route symbol by 20%".
- Enrichment of the user location with semantic attributes or events, e.g. a GPS coordinate pair can be complemented with expressions such as "near the National Theatre", "on the top of *Olympiaberg*", "inside *Deutsches Museum*", "moving along the river bank of *Isar* from *Wittelsbacherbrücke* to *Eisenbahnbrücke*" etc.
- Classification of user requirements according to their relative stiffness into "must", "should" "could" and "may", e.g. the size of a point symbol must be at least 5p; the current location should be marked with a dot of 10p; the orientation of the map could be aligned with the walking direction of the user; the background information may be eliminated.

With regard to the transient nature of mobile environments, however, it is often neither possible nor necessary to begin with the egocentric map design after the ego centre is precisely determined. In fact, the design process can take place (1) at the same time as the process of user tracking, or (2) as soon as some evidences of the ego centre have been determined. While the efforts to detect the ego centre aim at finding out what the user exactly needs and which way he prefers to get his need satisfied, the egocentric map design has to serve the user with his wanted information in real time and express it in a cartographic language the user will immediately understand. An ideal egocentric mobile map should be able to

- Support the user non-intrusively. The mobile environment badly needs the so-called “subdued computing” (*Ibach and Horbank* 2004). The interaction with the map should take place intuitively and make the user feel like effortlessly fetching information from the ambient environment into which map has discreetly melted.
- Draw user’s attention immediately to his wanted information. The ego centre should be located at the most conspicuous place within the vision field.
- Present a striking contrast between the ego centre and its context. The ego centre should be respectively recognised as floating figure on a receding background.

The following design patterns that have been partly practised in conventional cartography and human-computer interface design are worthy to be (re)considered in the mobile usage context:

1. Centring
If the ego centre is a spatially concentrated or continuous location such as a post address, a street segment or a region within the walking distance, its associated semantic contents will be placed around the optical or geometrical centre of the map field. Such an intuitive graphic transform can be easily realised as soon as the location of the ego centre is explicitly defined by user himself or automatically determined by means of positioning techniques. A mobile map that is dynamically centred on the location of user’s actual interest possesses, in addition to its functionality, certain hedonistic quality because it renders a reliable impression, thus makes the user feel relaxed.

2. Nested levels of details
If the ego centre is a region such as a downtown area the user is going to explore, approaching from his current location lying outside, an overview of the region along with its detailed connection to the current location will be rendered. In this sense, a higher level of details is nested in a lower one. Fig. 7.4 illustrates a detailed route from the Munich airport to a destination *Putzbrunn* nested in the overview of Munich city.

3. Location-dependent levels of details
If the ego centre embraces one or many focused locations within a region of certain extension, the region will be visualised at varying levels of details. The objects in close vicinity of a focused location are displayed in larger map scales containing more details than those farther away. The scale transition, smooth or abrupt, is usually realised by applying various distortion techniques such as anamorphosis, multi-focal projection, fisheye view, interactive local magnifier or databases of multiple resolutions (*Rase* 1992, *Harrie, Sarjakoski and Lehto* 2002, *Singer* 2002, *Alistair Edwardes, Dirk Burghardt and Robert Weibel* 2004). An overview about the fisheye view for small display devices was given in (*Rappo, Cecconi and Burghardt* 2004). In a fisheye view, each focused location is dis-

played as a blown-up circular or rectangular area containing fine but legible details while the peripheral area is progressively displaced, compressed and generalised. Since the enlarged ego centre is balanced by the reduced peripheral area, the overall display space remains constant. What the user sees is a detailed ego centre in continuously connection to an overview of its context.

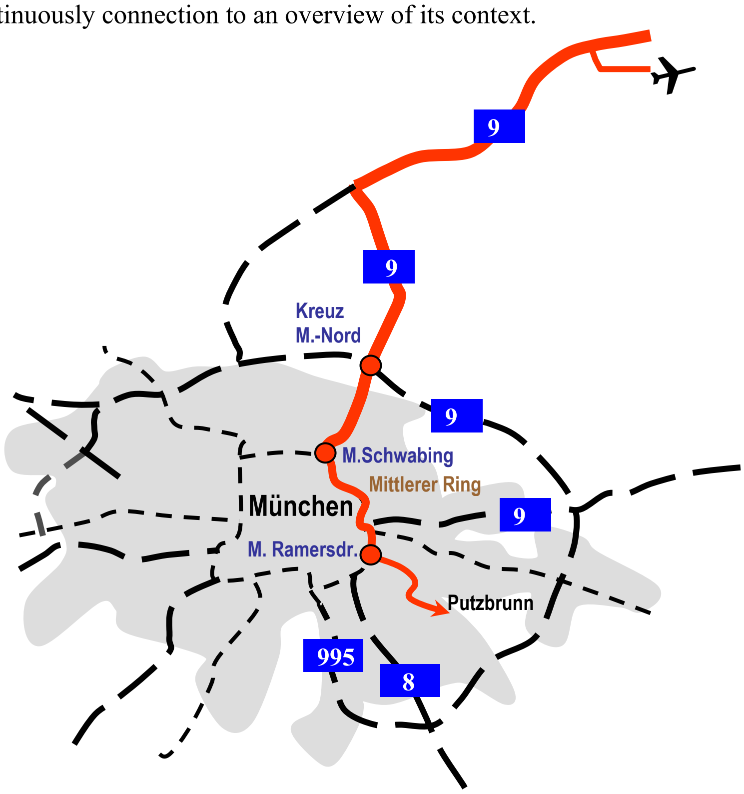


**Fig. 7.4.** A detailed route from Munich airport to Putzbrunn nested in the overview of Munich city (see the colour figure on CD)

4. Movable piece

Though a map showing varying location-dependent levels of details makes good use of screen space and at the same time maintains the topological relation to the context, its user may have difficulties to estimate the distorted spatial distance. Some users have even a general aversion to distorted presentations. Moreover, what a mobile user such as a city tourist most frequently requires are only two levels of details – street level as the ego centre and the overview of the city as the reference. A possible way to keep the ego centre and an overview simultaneously visible without distortion is provided by movable piece, a design pattern introduced by (*Tidwell* 1999) for user interaction. Here the contents of the ego centre (e.g. the nearby surroundings of a street) are displayed with fine details at a uniform map scale while a small-sized overview that synchronously indicating the location of the ego centre (e.g. the highly generalised city plan) is treated as a floating element that does not need to be laid out precisely. The user can freely drag the overview to an adjacent place that will neither cause eye shift nor interfere with the actual ego centre. Moreover, the synchronised overview and detailed view allows the user to jump to a new ego centre whenever he wants.

5. Space contraction
In case that the ego centre is composed of spatially widely separated locations, its overall extension will be intentionally contracted to make the associated contents simultaneously visible within the same window. The levels of details and the topological relations remain unchanged during the contraction. An example of spatial contraction is illustrated in Fig.7.5 where a number of locations that are of user's current interest have been brought together despite of their large distances from each other. This design pattern eliminates the need to use interactions such as scrolling and panning.

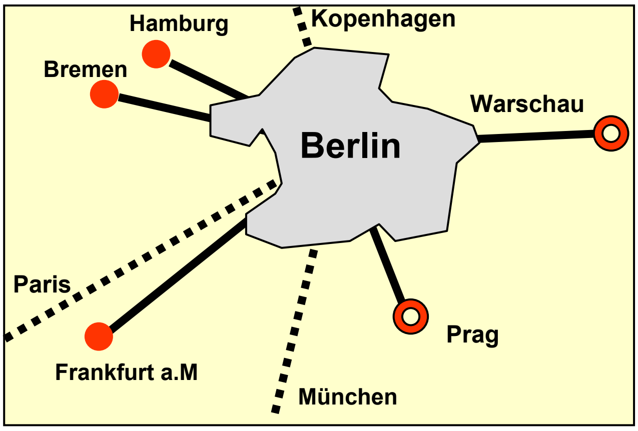


**Figure 7.5.** Space contraction of spatially discrete components of an ego centre

6. Single window with details on demand
The screen space of a mobile device is obviously not able to accommodate the ego centre in multiple windows adjacent to each other. Drilling through the tiled windows, on the other hand, may cause the abrupt change of the presentation or loss of context, hence disorientation. For all these reasons, a single window with details on demand is a more suitable design pattern than multiple windows. Within one single window essential parts of a complex ego centre will be presented to the mobile user, while the supporting information such as legend, live picture and online help instructions keeps hidden behind the whole display or the individual map features. When user interactively requires, the hidden information will be made temporarily visible (or audible) at a selectable granularity level. For instance, if the user tries to click on a certain point of interest, its associated details will be broadcasted by an anthropomorphic agent or pop up in a blown-up window which has, in case of plain text, a manual or automatic scrolling function adapted to the

average reading speed. Such a simple interaction helps to overcome the limitation of the screen space and at the same time confirm and strengthen user's egocentric model.

7. Redundant encoding
The contents of ego centre can be visually differentiated from the peripheral information by using a graphic variable such as colour hue. For instance, the ego centre displayed in red visually stands out on a grey background. Adding one more graphic variable such as size, the ego centre (e.g. with increased symbol size or line width) can be made even more salient (*Wilkins* 2003). Though this redundant encoding method does not bring additional information, it helps to reinforce the visual acuity of the ego centre and at the same time it still allows users who miss one graphic variable (e.g. colour-blind users) to attend to the ego centre.

8. Augmented focusing
If the ego centre contains many salient but sparsely distributed map features, the mobile user with his limited memory load may still have difficulties to attend to all of them. Moreover, large jumps from one salient feature to another may cause the user to become confused or disoriented. Therefore, a fine-tuning of the distinctions among these salient features based on their relevance to the actual user action is necessary. The one or two most relevant map features for the actual user action will be visually further enhanced with extra design elements such as a bounding box, 3D symbols, blinking, voice, large label, animated magnifier. Being termed as augmented focusing, this design pattern proves desirable for time-sensitive tasks such as driving or walking along a complex route. Although the mobile user needs an overview of the entire route containing the starting point, the destination, a number of intermediate stations as well as landmarks. At each particular moment, however, he may be just attentive to the most recently passed station and the on-coming station with its one or two landmarks. An example is illustrated in Fig.7.6.

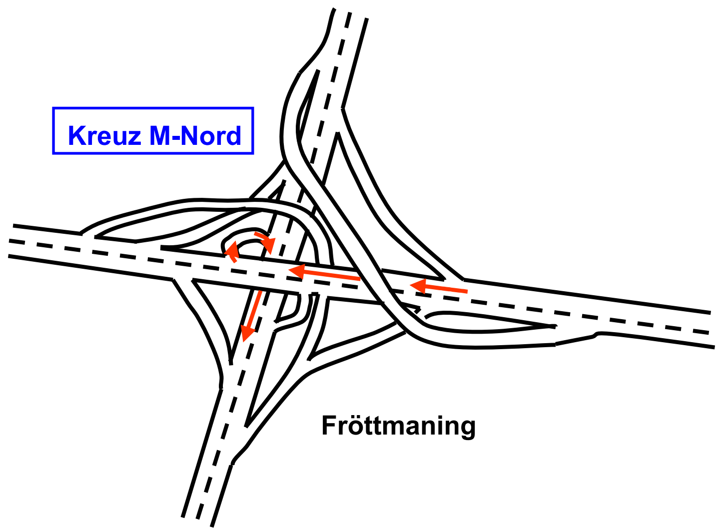


**Fig. 7.6.** Augmented focusing on the current action of passing through a highway crossing

9. Local gesture

Orientation plays a significant role for many navigation-related tasks. Technically it is possible to align a 2D map and its labelling dynamically with the actual moving direction of the user, frequent rotations, however, are ergonomically uncomfortable. The alternative solution with a 3D perspective scene viewed from the actual user location may guide an individual user more intuitively. Yet 3D perspective scene makes it hard for the user to judge the relative distances in addition to typical problems caused by occlusion. With regard to these known drawbacks, local orientation gesture such as arrows or animated objects integrated in the static scene proves an inexpensive and more flexible solution. Being guided by the local orientation gesture the user does not have to change his cognitive orientation model established through his prior map reading exercises. Meanwhile, the availability of a static reference invokes the feeling of safety. Furthermore, such an egocentric map can be shared by a group of users moving around in the same scene. Fig. 7.7 illustrates a scene of group dating where the actual location and moving direction of every group member are visually highlighted upon a static background. In fact, this is a sharable egocentric map for every individual involved in the dating event.

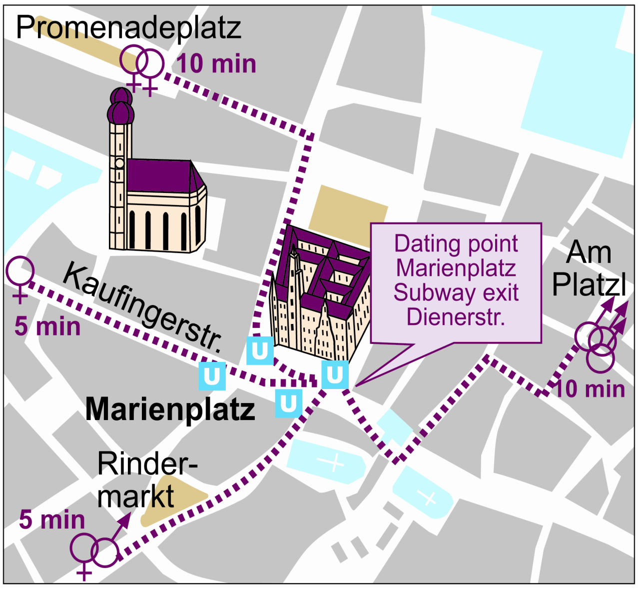


**Fig. 7.7.** An egocentric map shared by eight people who are approaching from different locations to a dating point (see the colour figure on CD)

## 7.4 Concluding remarks

In cartographic practice hitherto, a map is usually judged by its functional and aesthetic quality. The functional quality has to do with the scale-dependent geometric precision and semantic completeness, whereas the aesthetic quality is closely related with perceptual as well as cognitive capabilities, common-sense knowledge and visual literacy of an average user. Special or personal user requirements remain either unknown or ignored partly out of economic concerns of map designer. With a growing mobile population and the wide spreading of geo-services, individual persons have increasingly become the decisive factor for the successful service design. Consequently, there is a growing demand on personalised map services or egocentric maps because most, if not all of the mobile tasks are sensitive to location and/or time and map use is always a personal activity. It is particularly true when the human-map interaction tends to take place on a hand-held device with its miniaturaised screen space. Unlike the allocentric maps that serve all purposes and all users in a balanced manner, an egocentric map is intended for an individual person for his task at hand. Therefore, no compromise is necessary. The cartographer enjoys the freedom to apply various design patterns to highlight the accessible egocentric information just as Ludwig Wittgenstein once stated that anything which can be expressed at all can be expressed clearly (in *Kuhn* 2004). However, an egocentric map that is expressed clearly to its intended user may be disliked by other users. For this reason, the usability of the egocentric map can only be reasonably judged by its target user who has special and personal requirements of either pragmatic or hedonistic nature. While the allocentric map design strives for the ultimate goal that sounds like "what you see is what you want (intrinsically and extrinsically)", the egocentric map design focuses on the goal that may sound in a reversed order "what you want (intrinsically) is what you see". Egocentric maps do not attempt to replace the allocentric maps. Rather they will serve as a more usable means to support the individual user tasks, especially those in a mobile usage context.

## 7.5 Acknowledgement

The author would like to thank Mr. Geiß for his valuable help during the design of map examples

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# 8 Adaptation to Context – A Way to Improve the Usability of Mobile Maps

L. Tiina SARJAKOSKI, Annu-Maaria NIVALA

Department of Geoinformatics and Cartography, Finnish Geodetic Institute

**Abstract.** This chapter examines the usability of topographic maps on mobile devices. To evaluate this usability, field tests in a national park were arranged with a group of test users as a part of the GiMoDig project[5]. The purpose of the evaluation was to identify preliminary design principles for maps on small displays, as well as the main benefits and obstacles in using topographic maps on mobile devices. As a result of the user test, the mobile contexts relevant for topographic mobile maps were identified. Regarding mobile map services, the most important context of use is currently the location of a user. However, several other contexts worthy of attention were: system, purpose of use, time, physical surroundings, navigational history, orientation, user, and cultural and social contexts. How some of these contexts were considered for the implementation of adaptive maps, is also described. As is normally seen in the iterative process of user-centred design, the implementations presented here will also be evaluated, and the experiences gained will be used in the second round of user-centred design cycle.

## 8.1 Introduction

Mobile cell phones have become commonplace tools and multimedia phones are also emerging. There are already a couple of commercial applications for maps on mobile devices, in which the maps are displayed on the screen of a personal digital assistant (PDA), or a cell phone. Most of the applications are for car navigation purposes, but there are also products for off-road navigation for cyclists or walkers (*Navman GPS 3300 Terrain* 2004; *Outdoor Navigator* 2004; *TomTom CityMaps* 2004; *Falk City Guide* 2004; *MapWay* 2004). In general, most of the services so far provide the maps in raster format, but vector formats are also emerging, mainly because of the higher quality visualisation and interaction possibilities available.

Usability is defined as "the effectiveness, efficiency, and satisfaction with which specified users achieve specified goals in particular environments" by the ISO 9241 standard (1997). Another definition according to ISO standard 9126 describes usability as "the capability of the software product to be understood, learned, used and at-

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tractive to the user, when used under specified conditions". The standard was updated later on and the ISO 9126-1 (2000) now uses the term 'quality in use', which means the capability of the software product to enable specified users to achieve specified goals with effectiveness, productivity, safety and satisfaction within specified contexts of use.

The ISO 13407 standard (1999) provides guidance on human-centred design activities throughout the life cycle of interactive computer-based systems. User-centred design is seen as an iterative process that starts by recognising the potential users of the system, and continues by identifying their specific user requirements. This information is used in the design of the usability goals for the product and construction of the first prototypes. The next step is to illustrate the design for the users and, based on the user feedback, to evaluate the design against the goals that were set earlier. By doing this, user requirements may be refined or new requirements may be identified. The feedback may also lead to changes in implementation. The iterative process continues until the usability goals are achieved.

Kraak and Ormeling (1996) described maps as interfaces to geographic information systems (GISs). Kraak and Brown (2001) stated that because of the multimedia nature of the Web, maps can be seen as interfaces or also as indices to additional information. Peterson (1995) also suggested that the word interface can be related to maps in two ways: maps are firstly interfaces to the world and secondly are composed of user interface (UI) elements. The layout of the map, the legend, its colours, sectioning and folding are all aspects of the map's UI and there is interaction between map and user when the map is used. Therefore a map on a mobile device can be treated as a graphical user interface (GUI), from which it follows that the methods used in human computer interaction (HCI) can also be brought to cartography.

During the first stage of map applications on mobile devices, the fastest way to provide maps was typically to use the same visualisation as for desktop and internet applications. However, the main problem turned out to be the presence of totally different usage situations. Maps on mobile devices are often used in outdoor situations, which means that their visualisation and information contents should be totally different compared with indoor situations at office desktops. Like in designing new products in general, it is essential to know beforehand what the real needs of the mobile map users are. Users need right types of maps, on a suitable scale, and with the symbolisation adapted for the specific usage situation.

So far few results have been published on the usability evaluation of topographic maps on mobile devices; existing studies are mainly focused on tourist and route maps. Some cartographic research, however, is being undertaken on mobile guides that consider the usability issues in their product development. The IST programme (*IST* 2004) is strongly oriented towards the concept of user-centredness, and as a consequence the projects involved are also oriented to user-centred design, e.g. GiMoDig (*Sarjakoski et al.* 2002), WebPark (*Edwardes et al.* 2003) and LOL@ (*Pospischil et al.* 2002). Usability evaluation of mobile maps can be done in many ways, either by the project developers or by bringing the users into contact with the product (*Bornträger et al.* 2003; *Heidmann et al.* 2003; *Melchior* 2003; *Schmidt-Belz and Poslad* 2003).

'Intelligence' in UIs could be described e.g. as a way to make the system more adaptive and flexible for each situation and user. Lieberman and Selker (2000) stated that a considerable portion of artificial intelligence or good design in HCI amounts to being sensitive to the context. In other words, intelligence could be implemented into UIs by making them aware of the context. Cheverst et al. (2000) have studied how context awareness can be utilised in a tourist information system, although maps play a minor role in their study. Baus et al. (2002) describe a system that determines the location of the user and adapts the presentation of route directions according to the characteristics of the user's mobile device as well as to the cognitive resources expected of the user. Reichenbacher (2001) studied the process of adaptive and dynamic generation of map visualisations for mobile users.

Here the usability issues concerning topographic maps on mobile devices are examined. This chapter is based on previous works by the authors, which point out that by adapting the visualisation and information content of maps to the different contexts, more intelligent and usable maps can be offered to the users of maps on mobile devices (*Sarjakoski and Nivala* 2003; *Nivala and Sarjakoski* 2003a,b; *Nivala et al.* 2003). The following Section 2, Preliminary User Requirements Based on Field Testing, describes the information collected by arranging usability evaluation field tests in Nuuksio National Park, Finland, to determine user requirements. The evaluation results were used to examine context awareness from the mobile map point of view and to develop design principles for adaptive maps. Contexts relevant for topographic maps on mobile devices are listed in Section 3. Examples of the maps that are adapted to some of the contexts are shown in Section 4, and finally, suggestions for further development of context-aware adaptive maps are given in Section 5.

## 8.2 Preliminary User Requirements Based on Field Testing

Direct user feedback is widely recognised as a necessary element in a human-centred design process. At the time of preliminary field testing the GiMoDig project did not yet have any real prototypes to test. Therefore, it was decided that the maps available with already existing hardware and software would be used in the test to identify at an early stage of the development the most problematic issues concerning topographic maps on mobile devices. The evaluation was conducted in cooperation with the KEN project (Key Usability and Ethical Issues), one of the horizontal support projects in the Finnish Personal Navigation (*NAVI* 2003) research and development programme.

A group of appropriate test users was brought to Nuuksio National Park in Espoo, southern Finland, and asked to complete predefined test tasks using topographic maps shown on a PDA. Nuuksio National Park is an area well known for hiking and camping. The test is briefly described in the following paragraphs, a detailed report can be found in Nivala et al. (2003).

### 8.2.1 Aim of the field study and test method

The main goal of the field testing was to examine the usability of topographic maps currently available, to derive preliminary user requirements for the GiMoDig service (*Jakobsson* 2002), and to identify the design principles for adaptive maps to be implemented on mobile devices. Some examples of the questions for which we wanted answers were: What are the deficiencies of the maps? Are the symbols and feature types easily understood? Can the user recognise the map symbols?

The tasks that the users were asked to perform were based on the following user scenario:

***Hiker in Nuuksio National Park***

A hiker goes on a camping trip in Nuuksio National Park. She uses topographic maps on a mobile device (PDA) that are provided by a map service. With the aid of maps of different scales she finds the nearest campsites, is able to determine her position, navigate to other locations and obtain information on restricted areas and different features on the map, etc. She is also interested in skiing, so she wants to know if it's possible to do that there in wintertime, and if so, where?

A controlled, experimental field-testing method was chosen, one that would allow for the same conditions and tasks for each user. The field test was a compilation of the three usability methods: thinking aloud, observation and interviews.

The users were informed of the Nuuksio scenario and were asked to complete predefined tasks using topographic maps on a PDA. Two observers monitored the users during the test and interviewed them in the usage situations. The users were asked to think aloud, especially in situations where they believed they were having problems. The tests were recorded on minidisk and videotape. One pilot test was conducted to practise identifying any problems that might arise in field situations and to determine test duration.

### 8.2.2 Test users, material and equipment

Since our concern was to gather preliminary qualitative data and elicit the thoughts of the users, the study's user group was relatively small. We had one pilot test user and six actual test persons. The test users were selected to represent the average users of map services and included both genders and were from 24 to 60 years of age, both novice, and expert map users. Each testing procedure required a relatively long time period, about three hours.

The mobile maps used for the test were derived from the Topographic Database (TDB) of the National Land Survey of Finland (1:10 000). Raster maps on four different scales were derived from the TDB, to simulate a 'zooming function' on the map display. The cartographic presentation on the maps used in the test was partly the same as in the present topographic map (1:20 000), and partly altered (e.g. colour of the paths). Some improvements were made to the information content, e.g. symbols of campsites and routes were manually added on the maps in the Adobe Illustrator program (Figure 8.1).

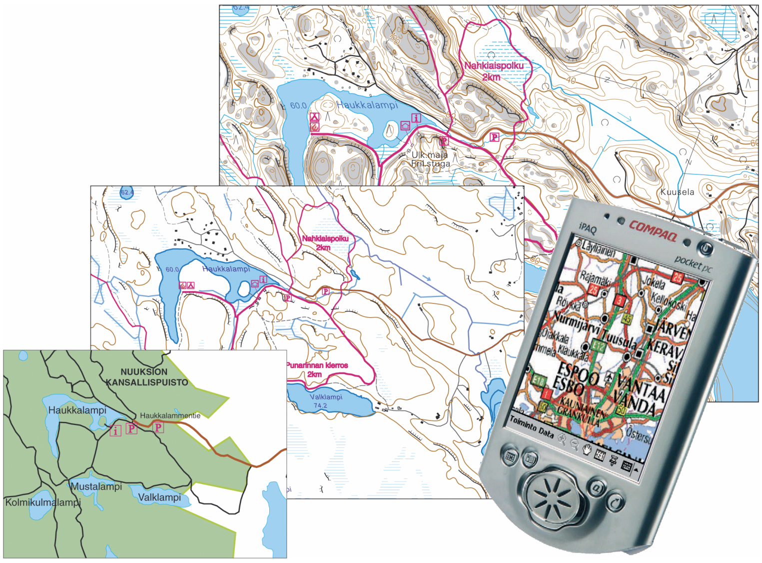


**Fig. 8.1**. PDA with navigation software and examples of maps used in the Nuuksio field tests.

The mobile device used in the field evaluation was a PDA (Compaq's Pocket PC), with a 64-colour image, 240 x 320 resolution display, and a keyboard, stylus and touch screen input methods. The navigation software used for showing the test maps was Genimap® Navigator LT, which supports raster maps and Global Positioning System (GPS) receivers, and enables map-handling operations such as zooming and measuring distances.

### 8.2.3 Pre-defined tasks

Users were given two 'orienteering' tasks, the first of which was to find a suitable campsite for a tent. They were asked to describe their impression of the campsite they planned to visit, based on information from the map. After planning the route they were asked to estimate the distance to the chosen campsite and then calculate it with a measuring tool. Other questions related to the information content and cartographic design of the map were also asked. Finally, the users were asked to navigate to the chosen site. During this first task the GPS was not connected to the PDA.

While hiking, the users were asked several times to establish their location and show it on the map. They were asked about the landmarks they used for locating themselves. The use of different map scales was also observed during the test. After arriving at the campsite, they were asked how well their earlier impression of the map corresponded to the real situation.

The second 'orienteering' task was performed with the use of the location information received from the GPS module. The users were asked to return to the parking area where the test began, using a route different from the outward route. They were asked to evaluate the topography of the area. At the end of the field test the users were asked questions on matters such as the symbols of the maps and users' desires for improvement.

### 8.2.4 Results

Since our concern here is how the usability of the topographic mobile maps could be improved, we mostly focus here on map-related results. For the other results of technical issues and experiences on testing, the readers are referred to Nivala et al. (2003). The main results on map symbols are summarized in Table 8.1.

**Tab. 8.1.** Examples on map symbols that users commented on or had problems with during the Nuuksio tests (*Nivala et al.* 2003).

| Symbol | Meaning of the symbol | Feature type | Colour | Users' comments |
|---|---|---|---|---|
|  | Deciduous tree | Point symbol | Black | Believed to be a small contour line. |
| | Coniferous tree | | | Tree symbols should be more illustrative or displayed as a coloured area. |
|  | Boulder | Point symbol | Black | Symbol unknown to all the users, not descriptive enough. |
| | Precipice | Line | Black | Symbol unknown to some users. |
| | Outcrop | Area | Light grey | Symbol unknown, not seen very well in bright sunlight. |
|  | Contour lines | Line | Brown | Indistinct from the path symbols. Should be more descriptive: several users suggested shadowing of the slopes. |
|  | Weir | Point symbol | Black | The symbol for the weir was unknown to all of the users. Suggestions for more picturesque symbols for the human-made structures (e.g. houses, bridges) were made. |
| | Residential building | | | |
| | Outbuilding | | | |

The users found it difficult to understand some of the map symbols, most of which were either unfamiliar or not clearly and distinctively different from the other symbols. Examples of such symbols included those for outcrop, contour lines, paths and hiking trails. The link in these misunderstandings seems to be the colour of the symbols, since the contour lines and path markings were both brown and the hiking trails and main roads were both presented in red. When using the same colours as paper maps, the symbols may become unclear, especially on a small display.

The fact that mobile maps are mostly used outdoors, and in our case in bright sunlight, can make it more difficult for users to recognise the different colours. Light colours were also difficult to recognise, e.g. yellow and light grey. This means that the symbols' colours should be even more distinct from each other, compared with paper maps.

The legend is an important issue when maps on small displays are being scrutinized. The users suggested that there should be a choice over whether or not to display the legend. Some of the users commented that the information pertaining to map symbols and their meaning could be displayed as interactive links. Some users believed that more descriptive symbols would make maps more comprehensible and the question of the legend could be avoided. One suggested the idea that maps could be like drawings in fairytale books, where visualisation would describe the surrounding environment to make them look like 3-D maps.

The users believed that the greatest advantage of mobile map services (in addition to the GPS) would be the possibility of combining information from different sources and presenting it as an overlay on the topographic map data. This demand for additional information shows that there is a clear need for data integration. From the users' point of view, topographic datasets in different scales are not enough.

The users also believed that one of the main advantages was also the possibility of zooming between different map scales. The users wanted the step between the scales to be smooth enough so that no one would lose his sense of being in the area, implying that this step should not show the user a totally different-looking view. Visual representation should be consistent between the scales, but users also believed that this step was not needed unless the information content changed.

It was also noted, quite naturally, that the small-scale maps were used for planning a route and the larger-scales once for walking along the route. The overview map should contain general information on the terrain, routes and services in the area. With larger-scale maps people were interested in seeing more specific information on nearby areas and also on the available services. The large-scale maps were also expected to provide detailed information on the landmarks in the area.

The scale should be indicated in a way that would make it immediately usable to everyone. The users could not easily interpret the traditional number scale (e.g. 1:20 000) on the maps. A more suitable way would have been some type of scale bar. A light grey grid was also believed to be a possible way of helping the users to understand distances on the map.

While compiling the test, we did not intend to focus on the hardware or software, because the main interest was in the mobile maps and the usability testing itself. However, during the test the users raised several problems and usability issues concerning the technical aspects. The most severe ones were thoroughly documented by Nivala et al. (2003).

The most interesting test result was identification of the different context elements around the user during this mobile usage situation. It was observed that the actual environment surrounding the user essentially affects the use of maps. The map is strongly related to situations in which the user tries to find his/her way in an unfamiliar environment, and the adaptation of map presentation and contents within the usage context greatly improves the usability of mobile topographic maps.

## 8.3 Categorisation of Contexts in Mobile Map Applications

In general, 'intelligence' could be implemented into UIs e.g. by making them aware of the context. We suggest here that this also applies to mobile map applications. In the following we first examine the meaning of context awareness and how it is classified. This is followed by the categorisation of context awareness needs in mobile map environments, based on the field tests.

### 8.3.1 Definitions of context

Chen and Kotz (2000) defined context as "the set of environmental states and settings that either determines an application's behaviour or in which an application event occurs and is interesting to the user". Dey's (2001) definition of context is not much different: "context is any information that can be used to characterize the situation of an entity, where entity means a person, place, or object, which is relevant to the interaction between a user and an application, including the user and the applications themselves". Dey also classified the system as being context-aware if it uses context to provide relevant information and/or services to the user, in which the relevancy is dependent on the user's task.

Chen and Kotz (2000) defined two classes of context-aware computing: active and passive, in which the first influences the behaviour of an application by automatically adapting to the discovered context. By passive context awareness they mean that an application presents new or updated contexts to an interested user or makes the context persistent, enabling the user to retrieve and use it later.

During map usage situations, active computing may be relevant in some cases due to the mobility of the map usage situation. When navigating and moving at the same time, the user may not be willing to perform extensive operations and input context information for the application. The situation may be different, e.g. when the user is planning a navigational trip at home, during which he may have time for making even complicated decisions and inputs (e.g. personalisations) to aid navigation in the field.

More specific context definitions were suggested, e.g. by Schilit et al. (1994), who stated that context could be divided into three categories. The first is computing context (such as network connectivity, communication bandwidth and nearby resources such as printers and displays). The second category is user context (such as the user's profile, location, people nearby and the current social situation) and the last category is physical context (lighting, noise levels, traffic conditions and temperature). Chen and Kotz (2000) proposed a fourth category consisting of time context (such as time of day, week, month and season of the year), and they also mentioned context history.

### 8.3.2 Contexts relevant for mobile map usage situation

Based on the field test results, the contexts relevant to mobile map usage situations were reclassified by Nivala and Sarjakoski (2003a). When a map is used in the field, the surrounding contexts define the type of map the user needs, see Figure 8.2. The centre of everything is the user and the purpose of the use: Who is he? Is he hiking or going fishing? The location and orientation of the user are also relevant information: In which direction is he moving? Time may also play important role: Is it day or night, winter or summer? The physical, social and cultural surroundings may also affect the map: Are there many hills around or many rivers to cross? In which country is he? Is he alone or with the group of people? And finally, what type of mobile device does he have?

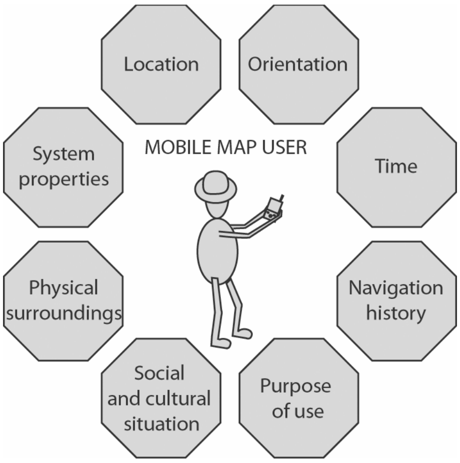


**Fig. 8.2.** The surrounding context of the mobile map user is composed of different elements.

The following describes some mobile contexts that can be used to create future intelligent maps for mobile devices. The examples are actual recommendations and ideas for improvement suggested by users during the Nuuksio field tests.

### *Context – Location*

During the field tests, the users clearly indicated that the most important advantage of mobile maps compared with traditional paper maps is the real-time information on the user's current location. Users believed that without it there could be no critical difference between the benefits gained with traditional maps or mobile maps.

Information on the user's location could also be used when the user is navigating along the planned route. The system could offer a new route if the user wanders further from the originally planned course. The maps could also take advantage of information on the user's location by providing different types of information on to the user's surrounding area for navigational aid.

### *Context – System*

The variety of mobile devices is growing and users expect to be able to use the same services on the various devices. The system properties of the devices vary, though, which means that the service providing the map should recognise the end-device from which the map request originates and should return the information in the right format so that the map is suitable for the current device. When a map is being adapted to different mobile devices relevant system properties also include the size of the screen, function buttons, input method and screen colours.

### *Context – Purpose of use*

One of the most challenging contexts to be considered is the user's purpose for using the map. In the field tests, the user suggested many different usage situations in which they could have needed specific maps. The maps that professional orienteerers may desire, would probably need abundant detailed topographic information (on rocks, waterways etc.), whereas a family with four children may only need information on the main tracks, campsites and beaches in the area. Some users also believed that maps showing the best areas for picking cloudberries or mushrooms might be sometimes useful, as would maps with good fishing places. It would be useless to show all this information on each person's map; thus the maps could be adapted to every particular situation and purpose of use.

### *Context – Time*

There are at least two main categories included in the time context: time of day and time of year. The awareness of the time of day could affect the map, e.g. in situations where the map would only show the cafeterias open at that time.

The time of year may also constitute important information from the user's point of view. Maps from areas such as Nuuksio National Park could be totally different during summer and winter seasons. The points of interest (POI) along the route may also differ greatly.

### *Context – Physical surroundings*

The user's physical surroundings can vary widely when maps are used on mobile devices. Whether by day or night, the map colours and background illumination should be adapted to the surrounding brightness. Information on the weather was also found to be useful, with integration of user location and local weather forecasts possibly being one way of presenting the map. Intelligent route suggestions in the field could also take account of the surrounding landscape (lakes, hills etc.).

### *Context – Navigation history*

Clearly, the most important requirement for navigating is to know your own location on the planned route. Optional routes to the destination and more detailed information on the services and POIs available along the routes, as well as at the destination, may also be of interest to the user. The map application, which takes account of the users' previous navigational targets and other previous requirements for the route, may be useful in some usage situations.

### *Context – Orientation*

When users were being observed during field tests, it was noticed that most rotated the map while walking, so that the actual view in front of them corresponded to the map view on the mobile device. One of the most useful context awareness themes may be information on the user's orientation. The map could then be displayed in the right position with respect to the user's line/direction of movement.

### *Context – Cultural and social*

Sometimes the usage situations of mobile maps can also differ, due to user's current cultural and social situations. The social situation appears to be very difficult to measure or sense, but some needs concerning social context awareness were revealed. When people were searching for a peaceful campsite, they often commented that the map could also show all the other mobile devices in the area, enabling the user to choose the site with the fewest campers. In a different situation the map could show only those cottages with sleeping accommodation left.

### *Context – User*

In addition to the purpose of use, one of the most difficult characteristics to interpret is user context. The differences occurring among users may include: physical abilities (e.g. height, age, left-, right-handedness, speed at which the keys are pressed), cognitive and perceptual abilities (e.g. memory, learning, problem-solving, decision-making) and personality differences (e.g. gender, attitudes towards computers, habits, personality types such as extroversion vs. introversion, emotional states).

## 8.3.3 Summary of context categorisation

Table 8.2 summarizes the context categorisation described in this section. Categorisation is divided into general contexts (compiled from *Chen and Kotz* 2000 and *Schilit et al.* 1994) and those contexts that are relevant to the mobile map applications, based on our tests. A set of features belonging to each category is listed in the third column.

**Tab. 8.2.** Categorisation of contexts and their features for mobile map services (*Nivala and Sarjakoski* 2003a)

| General context categories | Context categories for mobile map | Features |
|---|---|---|
| Computing | System | Size of display<br>Type of display (colour etc.)<br>Input method (touch panels, buttons)<br>Network connectivity<br>Communication costs and bandwidth<br>Nearby resources (printers, displays) |

| | | |
|---|---|---|
| User | Purpose of use<br>User<br>Social<br>Cultural | User's tasks<br>User's profile (experience etc.)<br>People nearby<br>Characters, date and time formats |
| Physical | Physical surroundings<br>Location<br>Orientation | Lighting, temperature, weather conditions, noise levels<br>Surrounding landscape<br>User's direction of movement |
| Time | Time | Time of day<br>Week, month<br>Season of the year |
| History | Navigation history | Previous locations<br>Former requirements and points of interest |

## 8.4. Implementation of the GUI and Adaptive Maps

In this section the results of the user test are elaborated further and reflected in the implementation of the GiMoDig UI and adaptive maps.

### 8.4.1 Personalisation of the service

Based on the results of field testing the GiMoDig PDA UI implementation includes personalisation of the following features: identity, activities, time, place and device. These features correspond to the studies on mobile contexts described in Table 8.2. However, the user is not forced to define the user preferences if she/he so wishes, in which case the application sets the default parameters automatically.

#### *Identity*

The methods of personalising the service according to the identity of the user include: choice of language and a user's age group. The choice of language reflects the language of the UI itself; in our case the languages of the countries participating in the GiMoDig project are included in addition to English. The choice of age group, in turn, reflects the requested map's content and layout.

#### *Activities*

Activities here refer to the service's implemented use cases that are hierarchically organized. After the user has made her/his selection, the Activity-menu is automatically personalized according the user's favours and shows only her/his own preferred activities. In the GiModig service the following use cases are implemented: Outdoors, Cyckling, Emergency and Expert use.
The user may define the season and time of day (day/night), according to which map information she/he is interested in displaying. If no specific user preferences are given here, the default time is always the current time.

### *Place*

The user's location at the centre of the delivered map is used as the default location for the displayed map. However, other areas may also be of interest to the user and may be selected by using an overview map. Additionally, an expert map user may define the coordinates for the area of interest.

### *Device*

For demonstration purposes the user is able to choose from among the PDA and PC devices. However, the type of device could be set by the system automatically in the final client application.

## 8.4.2 Adaptive seasonal maps

Following the story line for a 'Hiker in Nuuksio National Park' given in Section 2, some examples for implemented adaptive  mobile maps are shown below. The general service architecture and the funtionality of the GiMoDig map service is described in the Chapter by Lehto and Sarjakoski (2004). For implementing the preliminary client UI and the adaptive maps on a PDA Scalable Vector Graphics (SVG) was used. Our implementations on a PDA, as earlier described by Sarjakoski et al. (2004), were carried out with a Mobile SVG viewer called Embedded Scalable Vector Graphics, eSVG (2004) from Embedding.net, belonging to EXOR International Inc.

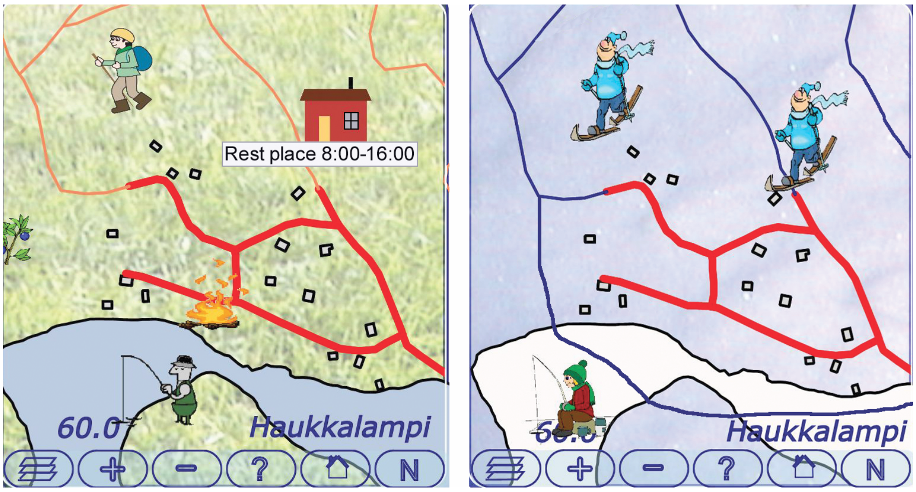


**Fig. 8.3.** Adaptive seasonal hiking and skiing maps for a user in the 11-17 yr. age-group shown as screen shots.

Studies of small-display cartography were conducted in the first phase of the GiMoDig project (*Nissen et al.* 2002). Further development and studies for the seasonal maps regarding the map layout were performed. In Figure 8.3 the user has received in real-time adapted seasonal maps on the PDA responding to the user preference 'Time'. The options 'Summer' and 'Winter' with the current time are used, as well as the ‘Activity’/’Outdoors’. When the user clicks the symbol for cottage, he obtains additional information for the current moment: ‘Rest place open 8-16’.

The topographic map data received from the GiMoDig server are displayed in vector format (SVG), together with the POI symbols on top of it. As was observed during the Nuuksio field tests, the users were occasionally very unsure of the map symbols. The layout here takes into account our desires for more illustrative and drawing-like map symbols. For example, the important café-house is displayed on the map enhanced compared with the other buildings. The skiing routes are also believed to be better understood if there is a picture of a skier by the route. The background of the map also adapts to the season; during wintertime it is displayed with a snow texture and during summer with grass. Since the GUI was personalized in our example for a user group between 11-17 years, we have used a kind of photo-realistic presentation style, familiar from the game world.

It can also be seen how the information on the outdoor map changes while the season changes. Hiking tracks are displayed in the summer map on the left, while in winter the user is only interested in the skiing tracks on the right. The tracks for hiking and skiing differ partly from each other. The map is adapted for the time of the year – fishing in winter is also possible on the ice, as is skiing, shown by the tracks that can naturally also be found on the ice.

In Figure 8.4 the outdoor maps are adapted for the user groups between 18-44 and 45-64. The symbols in the latter group have white backgrounds to improve the contrast.


**Fig. 8.4.** The GiMoDig- service deliveres maps in real-time to the mobile devices. After personalisation of the service, the maps are automatically adapted to the different users in different usage situations.

## 8.5. Further Development of Context-Aware Adaptive Maps

Mobile users desire increasingly 'intelligent' systems that are easy to use. Since the IST programme is strongly oriented towards the concept of user-centredness, the UIs developed within it should be evaluated from the usability point of view throughout the application development projects to make possible improvements at an early stage of the process. In the project presented we try to follow this concept, although the GiMoDig service will be a prototype system resulting from a research and development project. Therefore, many of the context-related features currently implemented aim only at demonstrating the capability of a mobile map service.

We suggest that one way to compile intelligent maps from the user's viewpoint could be to embed context awareness in them. As shown in this chapter, adding context awareness to map applications would expand the traditional possibilities for presenting and using information, compared with traditional topographic maps. Within mobile map usage, context awareness could also aid in map reading and navigation, and the usability of the map may be improved.

There are several limitations in the results presented here. Firstly, although a relevant issue, it was beyond the scope of this study to examine the technical feasibility of how to bring context awareness to mobile applications. We have made some preliminary implementations that take account some of context elements. But it is clear that all the context awareness needs listed here cannot yet be implemented in practice, but they might be implemented in the future. The examples given also showed that topographic datasets alone will not bring satisfaction to users. Much more enriched information (POIs, additional information, linked information sources) related to our surrounding world is needed in addition to the topographic map data to meet the demands from users. Even if information on some of the contexts may already be available for map applications in mobile environments (e.g. location), utilising them is still far from being very effective and remains a challenging problem for mobile map application developers to solve.

By using the context information available, the map service could adapt the visualisation for different usage situations and individual user needs. The results presented here were the actual needs identified and described by users and it is obvious that the designers should at least be aware of these issues when designing future mobile map applications. As usual with the iterative process of user-centred design, further implementations will also be evaluated, and the experience that has been gained will be used in the second round of the user-centred design cycle.

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# 9 Focalizing Measures of Salience for Wayfinding

Stephan WINTER[1], Martin RAUBAL[2], Clemens NOTHEGGER[3]

[1]Department of Geomatics, The University of Melbourne,
[2]Institute for Geoinformatics, University of Muenster,
[3]Institute for Geoinformation and Cartography, Technical University Vienna,

**Abstract.** This chapter reviews a model of measuring the salience of a specific class of spatial features—façades of buildings—for adaptation to abilities and preferences of user groups of wayfinding services. The model was intentionally designed to be open for such adaptations, and we will report on ways, experiences, and limitations of doing so. We will prove the hypothesis that focalization, i.e., adaptation to different decision situations, can be sufficiently modelled by weights of predetermined salience measures to increase wayfinding success. The long term goal is to identify sets of weights for typical foci of user groups.

## 9.1 Introduction

Navigation services calculate routes and present instructions to follow such routes to the user in a geometric format. A typical example might look like this: "Take Street A and go/drive for 150 m; turn left to Street B and go/drive for 70 m; …" Communicating wayfinding information in such a way is not intuitive for the user. Research in spatial cognition has demonstrated that people use landmarks during spatial reasoning and communication of routes (*Denis et al.* 1999). It is therefore necessary to integrate landmarks into route instructions to enhance their user-friendliness and cognitive plausibility.

Recent work has shown a way of automatically extracting salient features from datasets and using these landmarks to enrich wayfinding instructions (*Raubal and Winter* 2002). The model of landmark saliency is based on three categories of attraction measures, i.e., *visual*, *semantic*, and *structural*. A case study in the city of Vienna was used to demonstrate the applicability and usefulness of the method. Subsequent work included human subject tests to prove the cognitive plausibility of the model (*Nothegger et al.* 2004).

This model described a *general* approach of measuring the salience of features but it has been applied to a limited case only, i.e., a specific user group (pedestrians in a dense urban environment) travelling in day-light and using specific features (façades of buildings) as landmarks. In principle, the model can be expanded and refined by applying it to different user groups, features, travelling modes, and environments. The goal here is to investigate the fit of the model to different user groups.

People in different decision situations focalize on different elements in their environment, i.e., the ones that are relevant to their individual decisions (see also *Zipf and Richter* 2002). This chapter tries to map people's focalization to the proposed measure of salience. This measure of salience selects features assumed to be in people's centre of attention during wayfinding situations. It was developed with the option of being adapted to different wayfinding concepts by modifying the component weights of the global measure of landmark saliency. Here we investigate this possibility through experiments with human subjects. These tests focus on people's landmark selection during wayfinding by day and night, and on the differences in measures used for the two conditions.

Section 2 explains landmark-based wayfinding and the measures in the model of landmark saliency under investigation. In Section 3 the notion of focalization during route finding is described. Section 4 investigates the possibility of representing different focalizations through weights of salience measures. In Section 5 we present the study conducted to investigate people's selection of landmarks under different conditions. Its results are discussed in Section 6. Section 7 presents conclusions and directions for future research.

## 9.2 The Measure of Salience

Landmarks are inevitable means for people to memorize and communicate route information. Hence, automatically generated wayfinding directions could be improved in their cognitive accessibility by the use of landmarks. However, there is no formal definition of landmarks so far. This section summarizes an approach to quantify the *landmarkness* or salience of a feature, based on distinct qualities. Quantifying salience, the most salient feature in a neighbourhood can be identified and used in a wayfinding instruction.

Human wayfinding and landmarks are discussed more extensively in (*Nothegger et al.* 2004, *Raubal and Winter* 2002). Wayfinding is the process that takes place when people orient themselves and navigate through space. Wayfinding behaviour is considered as purposeful, directed and motivated movement in large-scale space, i.e., towards a destination that cannot be directly perceived by the person. We further assume that the route to the destination is unfamiliar to the wayfinder, i.e., she needs symbolic information about the route to take. Here, we concentrate on landmark-based piloting where the success of wayfinding depends on the recognition of landmarks and the correct execution of the associated wayfinding directions. Landmark-based wayfinding instructions are the natural choice in human communication of routes (*Cornell et al.* 1989, *Denis et al.* 1999, *Lovelace et al.* 1999, *Michon and Denis* 2001) because they are cognitively easier accessible than instructions based on distances and directions only (*Deakin* 1996, *Freundschuh et al.* 1990, *Tom and Denis* 2003).

Landmarks support the building of a mental representation of an advance model of the route. Landmarks can be located at decision points of routes, along route segments, or distant from the route. People use landmarks preferably at decision points; distant landmarks are exploited only for overall orientation. Lynch (1960) characterizes landmarks by their singularity, or contrast to the background, which is a concept from Gestalt theory (*Wertheimer* 1925). Sorrows and Hirtle propose to distinguish three qualities of features that can contrast to their neighbourhood: visual qualities, cognitive qualities, and structural qualities (*Sorrows and Hirtle* 1999). This slightly modified classification is used by Raubal and Winter to propose sets of measures for these qualities for an initial class of features, i.e., façades (*Raubal and Winter* 2002).

In this model, the visual qualities of façades are captured by measures for the façade area, shape, colour, and visibility. A façade is considered as visually contrasting or salient if its area, shape, or colour differs from the façades in its neighbourhood, or if its visibility area is larger. Semantic qualities are captured through measures of cultural or historical importance, and through the identifyability by marks (e.g., signs). A façade is considered semantically salient if it reaches high measures compared to its neighbours. Structural qualities are not defined in this model, but left open for other feature classes.

The overall salience of a façade is computed by a combination of the individual measures. For this reason the individual measures of a façade need to be scored against the distribution of each measure for all façades in the neighbourhood. The statistics for scoring is described in (*Nothegger et al.* 2004); it is not trivial because of skewed measurement distributions with means close to zero, and deviations from the mean in both directions considered salient in some cases. For instance, façades with a relatively large area might be considered salient (“huge building”), but also ones with a relatively small area (“tiny hut”). The total score for a façade is the weighted mean of the individual scores of its visual and semantic qualities.

This model was implemented and tested for some street intersections in Vienna (*Nothegger et al.* 2004). In the test, automatically identified most salient façades were compared with human choices from panoramic photographs. Being short of other evidence, the individual measures of a façade were aggregated with equal weights to a subtotal for visual and semantic qualities, and then further to an equally weighted overall measure of salience. Note that this way a single visual quality weights less than a single semantic property, having five visual, but only two semantic measures. However, the tests showed a high correlation between the automatically selected and human selected façades, even in the ranking. The model – chosen measures and their equal weighting – seemed to be cognitively plausible for the given situation.

The set of measures was later extended to include a route-specific visual quality, i.e., *advance visibility* (*Winter* 2003). According to this proposal, the selection of a façade depends on two qualities – its overall salience and its advance visibility along a route. For a street intersection in the course of a route the system selects a façade that is at the same time relatively salient and early visible for the advancing traveller, instead the most salient which might be not visible until approaching the intersection. Advance visibility is introduced as a compound measure of route coverage of the visibility area, and orientation of the façade with respect to the direction of the approaching traveller. This extension of the model could also be proven to be cognitively plausible, and superior with regard to wayfinding success compared to the original one.

Other approaches to identify salient features are reported by Burnett et al. (2001) and Elias(2003), the latter being influenced by the model described above. Zipf (2003) proposes a function for the relevance of features for focus maps. The function has a term for the salience of features, but this is not carried out further. The present model could be used in future to fill this term. In contrast to automatic selection of salient features, current commercial navigation services construct their wayfinding directions from distances, orientation, and street names; some of them include preselected landmarks or points-of-interest[6]. The selection criteria of points-of-interest within these services are not transparent; hence we assume their selection process is not based on a cognitively plausible model. With cognitively plausible salient features one can expect a better success rate in wayfinding with a smaller cognitive workload.

This chapter, as the previous papers, does not discuss the communication of the selected features, i.e., the ways they are used in wayfinding directions.

## 9.3 Focalizing in Route Piloting

In the above described model, overall salience is introduced as a weighted mean of the individual scores of its visual, semantic, and structural qualities. However, salience is not a global property. People choose different features as references when they are in different decision situations. Their focus of attention is different, and thus, we need a method to *focalize*—to change between foci or select a specific focus –when providing route directions. Focalization will be investigated in this section, and the next section will approach it by weighting the measures of salience.

In the earlier paper (*Raubal and Winter* 2002), the model of salience of façades was developed within a specific decision situation: "Assume that you are spending a few days as a tourist in Vienna. You have just enjoyed a cup of coffee in one of the traditional coffee houses, the *Café Diglas*, and you start thinking about dinner. Your tourist guide recommends one of the current in-restaurants, *Novelli*. Unfortunately, what you get is only the address, not the shortest or any other route from the *Café Diglas* to *Novelli*. This is a typical scenario for a navigation service, a special case of a location-based service (LBS). Calling the service should provide a route guide, delivered in real time and tailored for the user's needs, in our case a pedestrian." (p. 243). The human subjects in the test were asked to imagine this situation when ranking the façades at intersections.

The necessity to describe the decision situation with that detail, i.e., the expectation that people focalize according to the decision at hand, gives reason to design a model that adapts to specific decision situations as well. People will focalize for the simple reason that in different situations the environment offers different affordances (*Gibson* 1979, *Raubal and Worboys* 1999). Thus the above description of a decision situation is interesting with regard to three aspects: it specifies (a) the mode of travelling: pedestrian, (b) the role of the traveller: tourist, and (c) the environment: dense urban area. It does not mention (d) the aspect of individual spatial and cognitive abilities of people, which are different in general and should be included as well.

[6] See for example: http://www.blaupunkt.com.au/3.asp, http://www.mapquest.com, and http://www.whereis.com.au.

### 9.3.1 Mode of travelling

Travelling as a pedestrian implies a certain perspective on the environment, a certain set of concepts of spatial features in focus, and, as a function of speed, a certain level of detail of perceptions. All of these are functionally dependent on the types of actions a pedestrian performs to solve the wayfinding task. A pedestrian moves in the street network with relative freedom, being not forced to stay on lanes or in directions. However, decisions how to proceed occur mainly at street intersections. In wayfinding directions for pedestrians, a single street intersection is referred to by salient features such as façades. These are features of spatial granularity similar to intersections, which form—if salient—a unique reference to an intersection, and are better to distinguish than the intersections themselves.

A different mode of travelling changes both visual perspective and focus (*Timpf* 2002). A traveller in the subway conceptualizes the urban space in the form of lines that link places. Actions of a subway traveller are staying on board, transferring between lines, and leaving the subway network. The travel speed is too high to make decisions only at decision points, therefore other things come into focus, such as the names of stops, displays in the subway, and announcements.

### 9.3.2 Role of the traveller

The role of a traveller determines her focus, too. A tourist will in most cases be unfamiliar with the place, and thus paying attention to her environment. One might argue that a tourist performs wayfinding with a preference on visual clues, including visible semantic clues (signs), whereas structural qualities of a feature do not play a major role. In contrast, the attention of a person with some familiarity of the place, but in a hurry and therefore looking for the shortest route using a navigation service, is more focused on the network and its connectivity, and less on the visual attraction of the environment.

This argument refers to the fact that the two wayfinding problems are different: a tourist searches for attractive or scenic routes, whereas a local person looks for a time optimal route. Focus is related to the task at hand.

### 9.3.3 Environment of the traveller

The environment of the traveller offers clues to support the wayfinding task. In a dense urban area one can assume that sufficiently many façades are located at each intersection to identify a salient one. In loosely built-up areas, in areas where front gardens separate façades from the immediate environment of travellers, or in rural areas the role of façades as reference features diminishes, and other feature classes, such as signs and landscape features come into focus.

Another factor is time. Consider a dense urban environment: visual clues, and hence, salience, depend on the time of the day. At daytime, travellers perceive any visual quality, but in the evening or at night only illuminated parts of the environment can be perceived. Illumination might change over time, and is itself a function of the built-up structure. A department store is illuminated during shopping hours, a cultural landmark is illuminated until late in the evening, and main streets are illuminated until dawn.

### 9.3.4 Spatial and cognitive abilities of the traveller

People's spatial abilities seem to depend mainly on four interactive resources: perceptual capabilities, fundamental information-processing capabilities, previously acquired knowledge, and motor capabilities (*Allen* 1999). These resources support different wayfinding means. Resource limitations within different groups of people such as handicapped people or people of different age have a definite impact on the success of wayfinding. As for the spatial abilities, the cognitive abilities also depend on the task at hand. Finding one's way in a street network (*Timpf et al.* 1992) uses a different set of cognitive abilities than navigating from one room to another in a building (*Gärling et al.* 1983).

Differences in abilities of travellers lead to a change of their foci of attention. The average tourist can spend undivided attention to the visual attraction of her environment, while a handicapped tourist is distracted by getting over various obstacles in the environment. A blind tourist finds her way by using other senses than the visual one. Similar considerations will require taking into consideration the age of the traveller, her personal experience or wayfinding strategies, and her degree of local knowledge.

Without claiming to be complete, the discussion of these aspects defining a decision situation shows that any factor in the situation could require an adaptation of the proposed model of salience. If people focalize, the automatic selection model needs the same ability with the same behaviour. There are three degrees of freedom in adapting the model: one can choose (a) other feature classes than façades, (b) other measures for visual, semantic, and structural qualities, or (c) other weights for these measures. In this chapter we will focus on the third option. This means that in the following we do not change the environment and consider only the mode of walking on the surface of the earth. Then a change of weights allows some adaptation to different situations.

## 9.4 Focalizing by Weighting the Measures of Salience

Weights seem to be one key to focalization, according to the previous discussion. In this section we will show the relation between weights of measures and focalization. We investigate the possibilities of modifying the weights, and the theoretical expressiveness of doing so.

Determining salience with adaptive weights is computationally feasible if the weights are constant for a specific focus. The expensive part is computing the measures for each feature from its qualities. Let us assume that these measures (currently seven) are available for each feature (see *Nothegger et al.* 2004). Then one can determine the overall salience of each feature on the fly, by summing up seven multiplications of measures with their weights.

The basic assumption is that a specific focus is reflected by a constant, global set of weights. This means it is expected that people consistently use a set of weights when choosing landmarks along a route for a specific mode of travelling, role of the traveller, environment, and specific abilities and preferences of the traveller. The assumption will be tested in the next section.

Under this assumption there are several strategies to determine a set of weights for a specific user group or individual: (a) reasonable assumptions of the service provider, (b) specifications by the user, (c) by learning from real behaviour. In principle, all these strategies can be run discretely, leading to Boolean weights or subsets of measures, or continuously, leading to weighted measures of finer differentiation.

### 9.4.1 Specifications by the provider

The provider can specify a set of weights for each focus she wants to cover in her portfolio. Staying with Boolean weights this means a selection from the given set of measures, turning off other measures. Continuous weights allow a finer differentiation.

Let us assume that the service provider misses for an area some datasets that are necessary to calculate the given measures. The provider can decide to go without these measures, setting their weights explicitly to ‘0’, instead of delivering flawed results or searching for the missing data in third-party databases.

In Nothegger (2003) the weights for all visual attractions are set equal, and also the weights for all semantic attractions. But not all the measures are of the same importance for the overall salience. This observation comes from the fact that not all measures produce the same spectrum of results: where some qualities occasionally appear to be salient, others might never. The set of never salient qualities might change in areas with other characteristics, however, for specific areas one might decide to turn off some measures on principle, to save the costs of computation.

Besides the provider perspective, considering availability or profitability of measures, the provider can take the user’s perspective. In this case she wants to specify the weights according to the focus of the user. If, for example, experience teaches that a specific weight set is successful for a specific region or a specific homogeneous user group then the service provider can offer differentiated sets of measures. However, there is no obvious relation between focus and weights that would allow specifying the measures in a straightforward way. The only strategy is by trial and error, where specified weights could be adapted later on the basis of feedback.

### 9.4.2 Specifications by the user

The provider can ask the user of a service for her preferences. From introspection, a user might choose to be guided only by visually salient qualities, or only by semantically salient qualities. This is again realizable with Boolean weights, or gradually by continuous weights. However, the user might start with an arbitrary set and adapt it later on the basis of satisfaction. In addition, her focus might change, such that the complexity through the degrees of freedom explodes.

A more realistic model is to let the user choose a focus from a given list, if it cannot be determined automatically. Each focus would be linked to a set of weights, which leaves the problem of determining such a set.

### 9.4.3 Learning from behaviour

People can be observed when they select features as landmarks for given decision situations. Large samples of triples {*focus*, *location*, *selection*} will allow identifying weights that reflect best people's behaviour, if the test area is sufficiently discriminative. Having identified a set of weights for a specific focus, this set can be applied outside of the training area. If needed, a feedback loop can be established to further improve the weights.

With this approach other investigations can follow. The standard deviation of matches between people's selection and the identified set of weights is a measure for the narrowness of the focus, or of consistent behaviour among a group of persons. A sensitivity analysis may demonstrate how variations of single weights influence the overall salience of the features. It may also tell how separable the different foci are.

## 9.5 Test of Weighted Salience

To investigate whether different focalizations can be represented by different sets of weights for the salience measures, we conducted a human subject test that focused on people's landmark selection during wayfinding by day and night (first part of the test), and on the differences in measures used for the two conditions (second part of the test). We addressed several issues in this study: What are the differences in landmark selection between different user groups (with respect to age, gender, familiarity with the environment)? What are the differences in landmark selection between wayfinding in daylight and in the night? What is the relative importance of each salience measure? Can these differences be modelled through weights for the given criteria?

Participants had to fill out an interactive web-based questionnaire. First, each subject was asked to specify age, gender, and familiarity with Vienna's central district. In the first part of the test, subjects were shown 360° panoramic images of four intersections in an interactive viewer. These intersections form a subset of the material for the test mentioned earlier (*Nothegger* 2003). The user had the possibility to either look at the rotating image or change the view manually by moving the mouse in various directions. The temporal aspect of the situation was chosen randomly. Half of the participants were faced with the daylight images, the other half was presented the same intersections but photographed at night. Subjects were not informed about this duality of the test. The following question was asked for each intersection: "Which of the façades do you find prominent according to its characteristics? Assign 10 points overall. The more exceptional the characteristic, the more points. 0 points = not exceptional." (Figure 9.1).


**Fig. 9.1.** Screen shots from the survey: scene from an urban panorama by night and by day (the subjects have seen either the night scene or the day scene). The subjects should distribute 10 points between the seven facades of this intersection.

The second part of the test focused on finding out which of the given five salience measures (area, shape, colour, visibility, and signs) subjects used to decide on the prominence of a façade. In addition, sketches for the measures were given for clarification of the terms (Figure 9.2). The following question was asked: “Rank the following façade characteristics with regard to their importance of singling out one façade against another (1 = most important, 5 = least important).” Finally, subjects had the possibility to name additional criteria and write down comments.

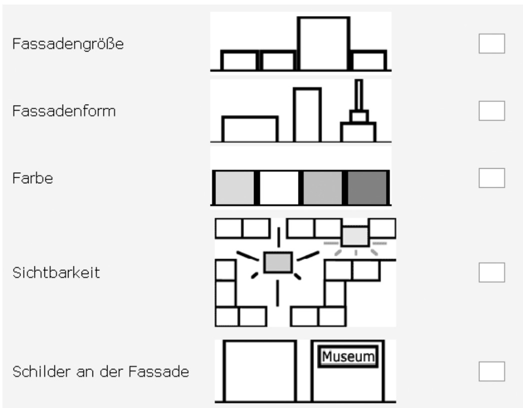


**Fig. 9.2.** Screen shot from the second part of the survey: ranking of five salience measures (from top: area, shape, colour, visibility, and identifiable use). Subjects should rank them.

Participation in the survey was anonymous, voluntary, and unpaid. The link to the questionnaire was distributed broadly to students, colleagues and friends, and the data was collected during December 2003. According to the distribution channel the majority of the participants were relatively young: 67% were under 29 years old, and 79% under 39. In total, 92 complete datasets were received (Table 9.1).

**Tab. 9.1.** Distribution of the 92 valid and complete datasets.

| **Gender** | | **Age** | | | | **Familiarity** | | **Scene set** | |
|---|---|---|---|---|---|---|---|---|---|
| *f* | *m* | *-29* | *-39* | *-49* | *>50* | *n* | *y* | *day* | *night* |
| 31 | 61 | 62 | 11 | 8 | 11 | 60 | 32 | 45 | 47 |

## 9.6 Results

The results from the above survey were subject to statistical testing. Several hypotheses were tested, regarding whether people choose different landmarks by day than by night, whether they apply different criteria, and whether the differences in behaviour can be mapped to weighting of measures. Here the findings are reported.

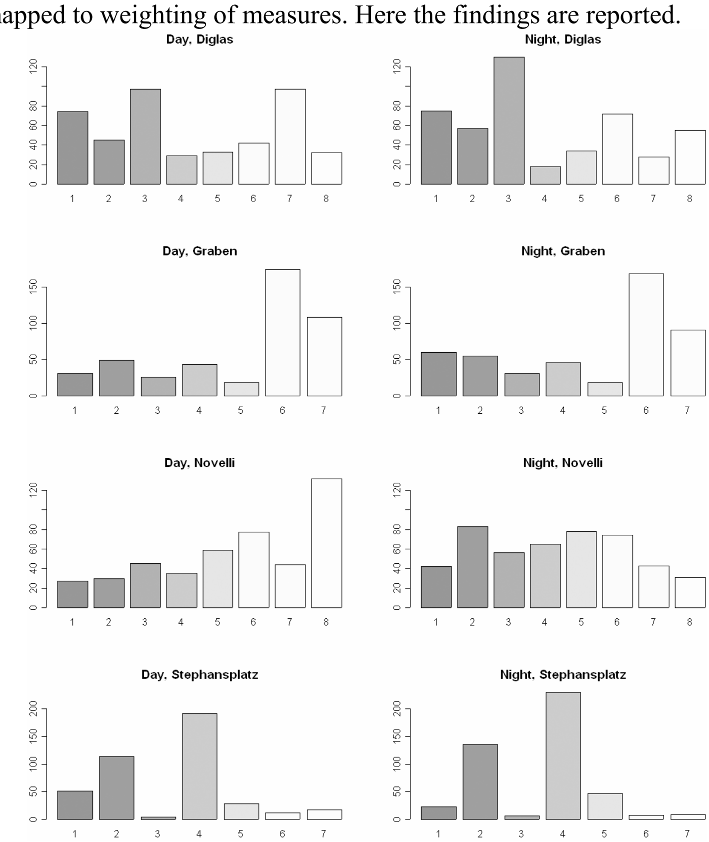


**Fig. 9.3.** Total scores of the façades at four street intersections, at day and night.

The first investigated question is: Are choices of landmarks different between day and night? It turns out that for several façades the total score at daytime is significantly different from the score at night. This is visible in Figure 9.3: While, in the 'Diglas' scene, at day the façades 3 and 7 are comparably prominent, at night the score for façade 3 boosts. In the 'Novelli' scene, the ranking even inverts: While at day the façade 8 is the most prominent, at night it does attract the least attention. Instead façade 2 becomes prominent at night, which does not attract at daytime. The question can be answered positively: people choose different landmarks at day and night.

Further it can be studied whether there exist gender differences in scoring the façades. A multi-factor variance analysis shows significant differences in the perception of female and male subjects. In Figure 9.4, the results are demonstrated with selected façades for the two factors *daytime* and *gender*. In some cases, the gender difference cannot be overlooked (e.g., 'Bräunerstrasse 9'), in other cases the perception of the genders is different more at daytime or in the night (e.g., 'Wollzeile 6-8', 'Wollzeile 11', 'Stock-im-Eisen-Pl 4'), and again in other cases there are no remarkable gender differences (e.g., 'Stallburggasse 1'). Other factor combinations appear significant, too, but in these cases the sample sizes are too small to yield reliable results.

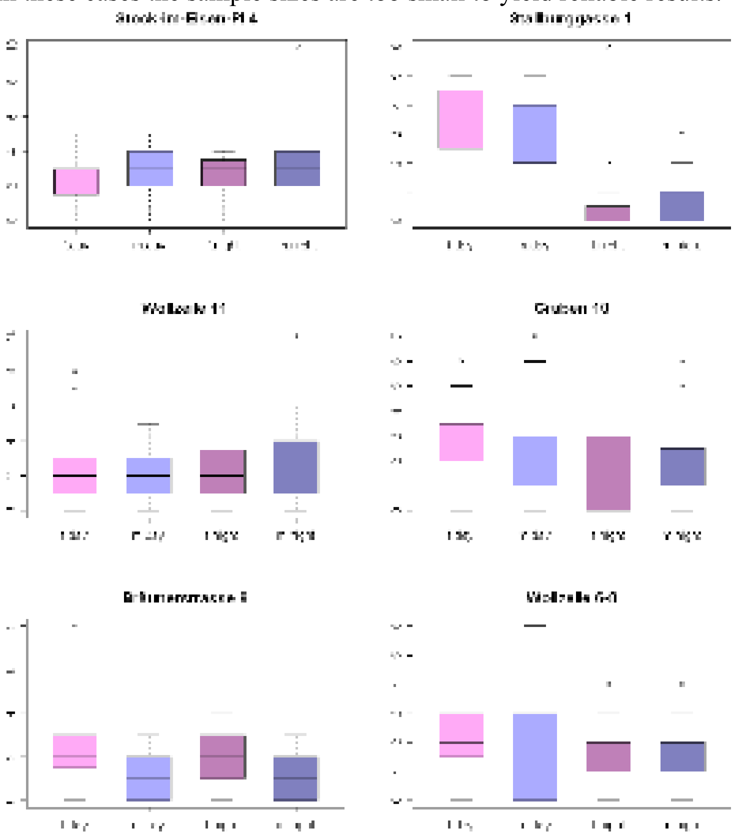

**Fig. 9.4.** Gender differences in scoring selected façades by day and by night (*y*-axis: score 0…10). The boxes show the median score and its interquartile range for the individual groups.

The following investigations concern the second part of the questionnaire: the ranking of the criteria. Here, the most interesting question is whether the ranking of the criteria is dependent of the time of the day. A variance analysis with the two factors *daytime* and *criterion* shows a *P*-value of 0.1: it is just under the significance level. Although not significant, some differences between the rankings of the criteria according to daytime exist: at night, façade area and visibility lose, and use of the building gains. However, the rankings of the criteria support the hypothesis that not all criteria are of the same importance. Figure 9.5 shows the rankings with a scale from 1 (not relevant) to 5 (most relevant). The semantic criterion, identifiable use of the building, is significantly ranked lowest. Visibility turns out to be the significantly most prominent criterion. The others ranked approximately equally. These results do not harmonize with the intuitive scorings given in part 1, as will be shown next.

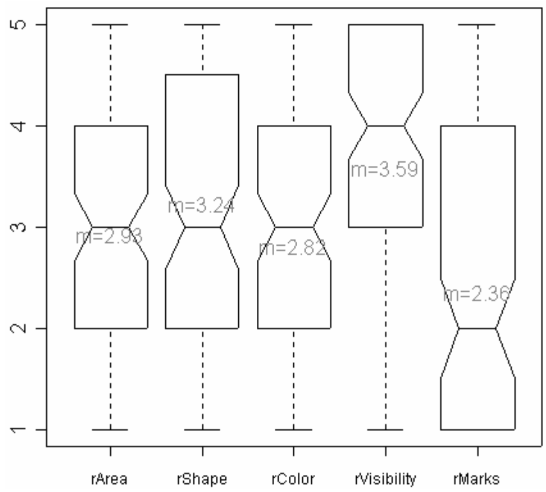


**Fig. 9.5.** Median rankings ($y$-axis: rank 1…5) of the five criteria façade area, façade shape, façade colour, façade visibility, and identifiable use of the building.

The final question is how weights of criteria determined from the scoring of the buildings in the first part of the questionnaire correlate to the ranks of the criteria given in the second part of the questionnaire. Weights were calculated by a regression approach with a robust estimator, separately for day and night. The results are given in Table 9.2.

**Tab. 9.2.** Weights for the criteria façade area, shape, colour, visibility, and discernible use of the building, determined from the scoring of the buildings in part 1.

| | **Area** | **Shape** | **Color** | **Visibility** | **Marks** |
|---|---|---|---|---|---|
| **Day** | 0.11 | 0.15 | 0.37 | 0.26 | 0.12 |
| **Night** | 0.26 | 0.0 | 0.21 | 0.23 | 0.30 |

The multiple regression coefficient is significantly different from 0, which means there is a significant correlation between the criteria (predictors) and the ranking by the subjects (response). However, there is no correlation between the determined weights of the criteria (Tab. 9.2) and the rankings of the criteria by the subjects (Figure 9.5). The weights show some influence of the criteria colour and visibility, accompanied by night by the discernible use of the building. Further, compared to the ranking of the criteria, there is a significant difference between weights at daytime and at night.

## 9.7 Conclusions and Outlook

The chapter discusses the possibilities to model different foci onto urban space by weighting visual and semantic salience criteria, and it investigates the proposed method in a thorough human subject test. With the design of the survey we could investigate first steps of a focalization. Staying within a specific user group, only one factor was varied, the time of the day. The factor varies the perception of the urban environment. We found evidence that this variation already changes the behaviour of the users – they select different landmarks –, and that the variation of behaviour can be modelled by a different weight set for the automatic selection of salient features. The latter was statistically significant and acceptable in its explanatory power, but not completely satisfying. It is subject to future research whether this result can be confirmed in cases of larger variations of the focus of influence. It is also subject to future research whether other criteria can be identified that would increase the explanatory power of different weights.

It could be observed that people choose landmarks without being (too) conscious about the selection criteria. The ranking of the criteria we asked for in part 2 is not correlated with the focus (here: time of day), although the subjects chose different landmarks. Furthermore, the ranking is different from the weights calculated by regression analysis. We assume that the ranking result, especially the highest ranked visibility, is influenced by the survey design. Subjects being asked to rank criteria might have had the last decision situation in memory, which was a strong case for visibility (St. Stephen's Cathedral). We also assume that the rank of the only semantic criterion, discernable use of the building, is distorted. Comments from subjects let us suppose that the wording in this case was taken too literally ("Schilder an der Fassade": marks on the façade), and thus, distorts the relative ranking. The weight of this criterion, derived from the real selection behaviour of the subjects, is noticeably higher, especially by night.

Future research will show whether different sets of weights can be determined and recommended for different foci of wayfinders. It is uncertain whether the different weights we have found can be reproduced at other street intersections, and therefore we refrain from proposing them as a universal set of weights in the sense of (*Zipf* 2003). However, the change of the weights seems reasonable for this change of the focus: the increased influence of the semantic criterion makes sense because it is related to the illumination of the building. The decreased influence of the criterion shape at night is reasonable because the shape of a building gets lost in darkness.

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# 10 Adaptive egocentric maps for mobile users

Tumasch REICHENBACHER

Department of Cartography, Technical University of Munich

**Abstract**. This chapter describes the need for geovisualisation services that support mobile users in their everyday activities. Following an overview of different geoservices the author anylyses the context of mobile geographic information usage which is is the major information source for the personalisation of services. The core of such a personalisation, the context adaptation of maps is derived from the context analysis followed by a discussion of egocentric maps as a form of personalised maps. The focus is on adapting maps according to the current user activity. The examples of egocentric maps clarify the concepts discussed before and offer a starting point for the conclusion.

## 10.1 Introduction

Being bound to the desktop platform the usage of modern mapping technology has been characterised by immobility for about the last decade. With the availability of small yet powerful mobile devices the usage of geographic information where needed is empowered. The progress of this mobile computing technology has favoured the renaissance of mobility in cartography. The technological advancements are partly accompanied by and partly the motor for different social trends. One trend, globalisation, is tightly coupled to an ever faster, mobility-defined life. Mobility leads to the fact that more and more people travel and move in areas unfamiliar to them. A world, however, which becomes increasingly global and spins faster and faster calls for order and security. In such a modern world people do not necessarily have more freedom, instead theyy are forced to manage their individual lives and their everyday activities which get more and more complicated. Most of these everyday activities are associated with mobility. Modern life implies a mobile lifestyle: we work, live, shop and entertain ourselves at separate places. Activity programmes, i.e. lists of activities to be performed in a specific time period, e.g. eating, working, or going to a concert, need to be scheduled. Scheduling of activities include decisions about location, time, and sequence of activities, how to connect them, and how to embed them in existing programmes (*Wang and Cheng* 2001). The organisation of this accelerated daily life requires supporting tools and information. This is especially the case for geographic information that is attached to almost any everyday activity.

Recently the use of digital geographic information has entered into mobile life. The spatial tasks associated with everyday activities have been solved so far solely with paper maps and other analogue means. These tasks can now – at least partially – be solved with digital means. Falling prices of mobile information devices have made mobile geographic information usage affordable for a wider public. Improved positioning techniques (GPS and radio network based) have shown their benefits in new technologies like Location-based Services (LBS). These services provide the user with relevant information based on the current position and offer the potential to adapt information presentation to the current location, i.e. device position, in order to achieve a more user focused service. However, this is not the end of the line, since there are many more aspects of a mobile usage situation which a service can be adapted to. Moreover information itself is not the sole target of adaptation. User interface, presentation, and technology can be adapted as well. The objective is to shift the focus from LBS to context based services.

The challenge for modern cartography lies in supporting as many people as possible with mobile usage of geographic information to better conduct these everyday activities. The support is effected by providing analytical spatial functions, being aware of the user's context and characteristics, and communicating personalised geographic information. This kind of mobile assistance is the only way to ensure also for future times an efficient communication of geographic information and to prove the usability of new mobile technologies. In the cartographic community only a few exponents have addressed these problems, e.g. (*Zipf* 2002; *Edwardes et al.* 2003; *Nivala and Sarjakoski* 2003; *Urquhart et al.* 2003; *Reichenbacher* 2004).

A possible solution to these challenges is an adaptation in the sense of providing the user with more relevant, detailed, and accurate and thus adequate information meeting his/her needs better. There are three reasons for this. First, the increasing quantity of information and the danger of over-stimulation urge a suitable channelling of the information stream. Second, adaptation could lead to greater acceptance of new, yet partially still immature technologies. Third, new value-added (web) services which users have to pay for need customisation to guarantee user satisfaction. Cartography ought to provide new and enhanced services that can be combined with existing services, thus bring added value to users and eventually close the gap between the benefits of web mapping or online GIS and the freedom of mobility.

This chapter looks first on geoservices for everyday activities followed by a review of context-adaptation of such services. The concept of egocentric maps is discussed and elaborated with the adaptation to mobile user activities and illustrated with several examples.

## 10.2 Geoservices for everyday activities

Everyday activities in modern life are in the most cases embedded in mobility patterns or require a mobile behaviour. To manage such activities different types of spatial knowledge are involved. The more complex the activities, the more spatio-temporal information has to be processed. Mobile cartography seeks to support mobile users to engage with their activities by providing adequate information for a successful and easy carrying out. Although the number of possible activities is enormous, they share a set of elementary spatial user actions that justify concentrating first on these few. Figure 10.1 shows a set of typical spatial questions of mobile users and their corresponding elementary spatial actions: locating, navigating, searching, identifying, and checking. According to activity theory (see for instance *Dransch* 2004, *Reichenbacher* 2004) activities are built from these elementary spatial actions combined with other actions. To support these actions in a highly dynamic mobile environment static map products are in general insufficient, no matter whether they are analogue, e.g. a paper map, or digital, e.g. an electronic atlas.

A service-oriented concept of geographic information delivery is more flexible to meet the mobile user needs. Services meeting any kind of space-related needs are commonly known as geoservices. Although there are other forms of geoservices, they are understood here as web services that provide, manipulate, analyse, communicate, and visualise any kind of geographic information. Web services in return are a basic concept in IT. They are built as distributed pieces of software with a limited functionality communicating over standard interfaces. Geoservices integrate *data* and *functionality* or *processing* and are directed towards a specific purpose. There are several types of such geoservices, not all of them aimed at mobile users. Examples are services that allow to find the nearest branch of a bank dependent on the input of an address or to plan travel routes. The basic geoservices are derived from fundamental GIS functions: positioning services rendering locations, geographic search service for any geographic features, geocoding services obtaining coordinates for relevant POIs or addresses, reverse geocoding service delivering geographic features for specific coordionates, proximity services that find the nearest POI or POIs for a position or address, routing services that calculate routes and direction instructions, directory and catalogue services, and presentation services.

A well known instance of a geoservice mainly targeted at mobile users is the type of location-based services. LBS are accessible with mobile devices through mobile networks and utilize the ability to make use of the location of the terminals to provide mobile users with information dependent on their current location. Often, but not in any case, part of that information is communicated through maps. Geoservices that provide maps or other kinds of visualisation of geographic information are known as geovisualisation services. Other names reflecting a broader, i.e. not necessarily map-based understanding, are *portrayal* (ISO 19117) or *presentation service* (OGC). A service-oriented understanding of geovisualisation differs in many regards from traditional map products. The trend to more flexible, on-demand delivery of geovisualisation initiated through web mapping will get even stronger in the mobile Internet. According to their level of functionality web services as well as geoservices can be classified into low-level services that offer simple functions and complex or high-level services that combine several functions within one service. Complex and enhanced functionality can be achieved by bundling basic services. The web service architecture provides a mechanism called service chaining where the output of one service acts as an input for other services. Such an approach offers great flexibility to combine several distributed services in a way as if it were one powerful service. The prerequisites for service chaining are a description of the service, well defined interfaces, and syntactic and semantic interoperability. Several standardisation organisations have developed architectures defining service interoperability, e.g. the ISO 19101 classification of geographic services with the Extended Open Systems Environment (EOSE) model for geographic information, the OGC Open Web Services (OWS) framework, or the OGC Open Location Services (OpenLS) specification. Along with these architectures several specifications such as Web Map Server (WMS) and Web Feature Server (WFS) as well as XML based formats for modelling and presenting geographic data, Geography Markup Language (GML) and Scalable Vector Graphics (SVG), have been put up. Many frameworks for geovisualisation services based on Open Source software have recently been developed, e.g. (*Lehto and Sarjakoski* 2004, *Edwardes et al.* 2003, *Reichenbacher* 2004, *von Hunolstein and Zipf* 2003).

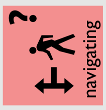
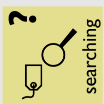
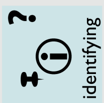
| action | | questions | objective | operations | service | parameter | support |
|---|---|---|---|---|---|---|---|
|  locating | **orientation & localisation** locating | where am I? where is {person\| object}? | localise people and objects | positioning geocoding geodecoding | deliver position of persons and objects | coordinate object address place name | orientation in space |
|  navigating | **navigation** navigating through space, planning a route | how do I get to {place name\| address\| xy}? | find the way to a destination | positioning geocoding geodecoding routing | deliver routes and navigation instructions | starting point, destination point, and waypoints as locations | finding the way through space |
|  searching | **search** searching for people and objects | where is the {nearest\| most relevant\| &} {person\| object}? | searching for people and objects meeting the search criteria | positioning geocoding calculating distance and area finding relationships | discover available services; find persons/ objects | location area/radius object/category | finding relevant objects; finding people |
|  identifying | **identification** identifying and recognising persons or objects | {what\| who\| how much} is {here\| there}? | identify people and objects; quantify objects | directory selection thematic/ spatial search | deliver (semantic) information about persons/ objects | object | information about real world objects of the usage situation |
|  checking | **event check** checking for events; determining the state of objects | what happens {here\| there}? | knowing what happens; knowing the state of objects | | deliver object state information and event information | time location object | finding relevant events; information about the state of real world objects in the usage situation |

**Fig. 10.1.** Elementary spatial user actions (*Reichenbacher* 2004)

## 10.3 Context-adaptation in geoservices

### 10.3.1 Context model for mobile geovisualisation services

To adapt geoservices to different needs arising in mobile usage situations the context of the mobile user has to be understood. One of the most adopted definitions of context in the field of context-awareness is from Dey and Abowd (1999, p. 3f.): “Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.” However, this definition is too unspecific for the purposes of mobile cartography. Context can be seen as a rather general concept embracing the more specific dimensions like situation (location and time), user, activities, information (e.g. co-located objects, physical environment conditions), and system (see Figure 10.2) that have many and complex inter-relationships. Dey and Abowd develop a hierarchy of primary and secondary context elements, where the primary elements such as place, time, identity, and activity work as indices to secondary context elements, such as meetings, weather conditions etc. This is an attractive alternative to approaches relying on several sensors measuring physical quantities to obtain context information. For the non-physical qualities, the primary context elements can be input to other services providing related context information. The location can be used to fetch co-located objects with a proximity service. Time together with location indicates season and illumination states (daylight or darkness). Time can also indicate other states, e.g. opening of shops, time table of public transport, or traffic jams. Time and identity may serve as input to a personal time management service scheduling appointments and to-do lists. The user identity sets the context for many services utlising user profiles by parsing them and getting the user preferences, interests, roles etc.

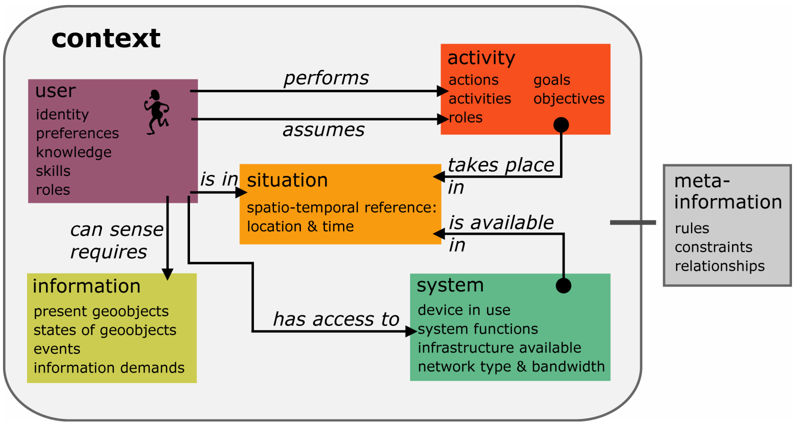



**Fig. 10.2.** Context model for mobile cartography

The major difficulty with context here is to select from the vast amount of possible context dimensions or parameters those that are relevant for mobile cartography and have a significant impact on the mobile geospatial information usage. Cartographic literature reveals many proposals for relevant context dimensions (e.g. *Dix et al.* 2000, *Zipf*, 2002, *Reichenbacher*, 2003, *Nivala and Sarjakoski* 2003, *Graham and Kjeldskov*, 2003). They differ in their extent. Nivala and Sarjakoski (2003), for example, list apart from the dimensions mentioned so far purpose of use, social context, cultural context, physical context, orientation context, and navigation history context. However, there seems to be a general agreement on the major context factors, the physical, task-related, and system factors. A basic distinction can be made between 'objective' and 'subjective' context. The former encompasses location, time, other physical parameters such as temperature, light, co-located objects, and system parameters. The latter comprises user preferences, roles, activities, and intentions. Of course, objective context factors are potentially easier to capture and model than subjective ones. For a start, subjective parameters could be selected by the user from a list of atomic values. A first attempt to formally model context for mobile cartography based on a model from HCI is described in (*Reichenbacher* 2004).

To study the influences of user mobility on mobile cartography it is necessary to take a more systematic approach to mobility and movement. There are two notions of mobility: first, mobility leads to ever changing contexts and second, mobility has several intrinsic characteristics relevant to geographic information usage. Although there are many forms of mobility, e.g. user mobility, or device mobility, or both, here the focus is on mobile users carrying around personal, mobile devices like a PDA. Such a continuous mobility where a service is more or less continuously available during movement is different from discrete mobility where the service is only available at certain places (e.g. access points like office or home). The structure of the user movement is constrained or influenced by the movement medium (i.e. road, water or rail track) and the movement mode (e.g. walking, driving, or sailing). The latter has an influence on density, scale, and the choice of landmarks of a mobile map. The structure of movement can be analysed in terms of geometry, topology, directionality, continuity, and permanence (*Coffey* 1981). Naturally mobility is influenced as well as characterised by many other physical, psychological, and social factors. With regard to mobile information usage two other important issues of mobility are the problem of the increased distraction potential due to overwhelming stimuli (e.g. noise) and the fact that the user is performing an activity apart from pure geographic information usage, i.e. the user is doing something else. On the other hand this user activity is a central part of the mobile geographic information usage context. Activities are associated with an objective and can give thus hints at information demands. Furthermore they can indicate other context parameters, because they are feasible or sensible only within a specific context. As Dransch (2004) illustrates, activities are composed of a set of sequential actions. Actions are the basic meaningful unit of human behaviour directed to objects with goals guiding them. The same action can be performed by different persons differently or by the same person in different roles. According to activity theory an action is always performed and to be understood within a context. To support mobile users in their everyday activities with spatial tasks it is necessary to model the mobile spatial user actions as elaborated in section 10.2.

### 10.3.2 Adapting geovisualisation to mobile usage context parameters

Based on these context dimensions Reichenbacher (2004) proposes a first attempt to incorporate context parameters in the process of ad-hoc map design and generation. The parameters are used in controlling the adaptation of the geovisualisation, i.e. the fitting adaptation objects (e.g. symbolisation) to the adaptation target (context).

The combination of different context dimensions has several advantages over a more one-sided approach such as LBS. The sole use of location as context parameter does not always lead to value-added solutions. A more comprehensive approach that includes time, personality, user activity, co-located information, etc. has a better chance to enhance the overall relevance of the service and thus the user satisfaction. Yet the use of additional temporal context information is fruitful for LBS. This argument is supported by a statement of Miller (2003): "[…] LBS can benefit from time geography and activity analysis available through a people-based GIS. One possible benefit is supporting space-time queries. Queries such as 'Which locations can I reach in 15 minutes?', 'Who can attend this event?' or 'Can I meet my friends at the pub this evening?' […]." The use of more than one context parameter also facilitates the interoperability with other services which can further enforce the effect of relevance improvement. The consultation of a multi-dimensional context allows for generating egocentric geovisualisation beyond the spatial notion of ego-centre. Such an approach becomes necessary for mobile geoinformation usage.

The most important task in producing mobile maps, i.e. adapting the geovisualisation is focusing on the most relevant information to allow a fast and effortless capturing of the information essence. The relevance of information is strongly dependent on the usage context invesigated above. Like context, relevance is a fuzzy concept. Relevance has to do with information needs, information seeking, and information use. Rees (1966) in (Greisdorf 2000, p. 67) defined relevance as "the criterion used to quantify the phenomenon involved when individuals (users) judge the relationship, utility, importance, degree of match, fit, proximity, appropriateness, closeness, pertinence, value or bearing of documents or document representations to an information requirement, need, question statement, description of research, treatment, etc." Despite the soft concept of relevance and context, Schmidt and Gellersen (2001) proposed a formal approach for determining the validity of context based on space and time that can be easily applied to relevance modelling. The main postulation of the approach is that with increasing spatial or temporal distance from the existence of a context instance its validity is decreasing. The application of fuzzy set theory in this approach can be used to model the spatio-temporal relevance as well. The basic assumption of the fuzzy set theory is that the membership of sets is not binary, i.e. crisp, rather elements belong to a set with a certain degree $\mu_A(x) \in [0,1]$. For the temporal relevance it is assumed that the context arises at $t_0$ and with further temporal distance from $t_0$ the relevance decreases. These distances are mapped to the interval [0,1]. Finally it is assumed that beyond a certain temporal distance ($t_{\max}$) the relevance is zero (*Schmidt and Gellersen* 2001). The following trapezoid membership function ($\mu_A$) can be applied to model the temporal relevance:

$$\mu_A(x) = \begin{cases} 0 & \text{if } x \geq t_{\max} \\ \dfrac{t_{\max} - x}{t_{\max} - t_{\min}} & \text{if } t_{\min} < x < t_{\max} \\ 1 & \text{if } x \leq t_{\min} \end{cases}$$

where $t_{\min}$ marks the distance up to that the relevance is 1 and $t_{\max}$ is the distance from which on the relevance is 0. To model the spatial relevance a trapezoid membership function using the spatial distance $d_s$ of the features to the context origin location is applied. At $l_0$ the relevance is maximal, 1, and with increasing spatial distance the relevance decreases constantly up to a maximal distance ($d_{\max}$), from there onwards the relevance is zero.

Zipf (2002) and Reichenbacher (2004) propose methods to model the relevance of geographic objects for focus maps and mobile maps repectively. Zipf's approach is based on the calculation of a dominance value. Reichenacher follows the method of Schmidt and Gellersen (2001) and presents an example for the determination of relevance of events (e.g. cinema, conecert, theatre play etc.) for a mobile user. For the user's location $l_U$ and the current time $t_c$ the euclidean spatial distance $d_s$ between the event loscations and the user location is calculated. The temporal distance $d_t$ to the events is calculated with the following function:

$$d_t(e_i) = \Delta t = |t_i - t_c| = |((hour_i - hour_c) * 60) + (mi_i - mi_c)|$$

where events $t_i$ is the time of the event $e_i$ and $t_c$ is the current time of usage; *mi* are the minutes of the respective times. The topical distance is calculated with the following function:

$$d_{top}(e_i) = \begin{cases} 0 & \text{if } eventtype \neq eventtype_{query} \wedge category \neq category_{query} \\ 0.5 & \text{if } eventtype \neq eventtype_{query} \wedge category = category_{query} \\ 1 & \text{if } eventtype = eventtype_{query} \wedge category = category_{query} \end{cases}$$

The spatial and temporal distances are normalised using the following function: $d_{norm}(e_i) = \min(d_i \ldots, d_n) / d_i$

The total relevance is: $rel_{tot}(e_i) = \sum d_{snorm}, d_{tnorm}, d_{top}$ and normalised with: $rel_{tot\_norm}(e_i) = rel_{tot}(e_i) / \max(rel_{tot}(e_i), \ldots, rel_{tot}(e_n))$

These relevance values are mapped to opacity values for the event symbol shown in the map presentation. Figure 10.3 shows a map example where the relevance values (relevance of Bars and Restaurants) are mapped to opacity values of the point symbols. The less relevant features are represented with a lower opacity.

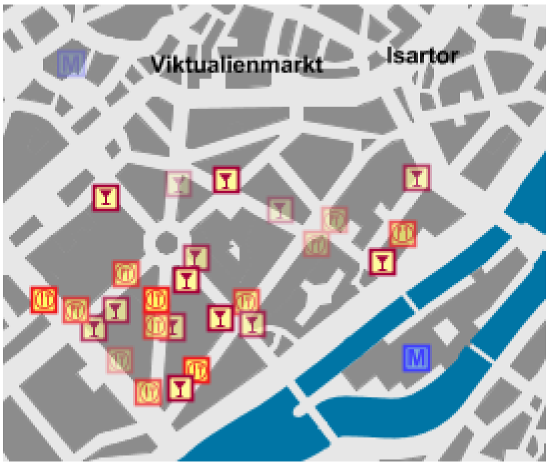



**Fig. 10.3.** Relevance values represented as different opacities

Opacity is only one graphical means to put a visual emphasis or focus on a feature. Other promising means are colour and crispness. Of course animation and acoustic variables are important means though they have not been evaluated for their distraction potential or noise sensitivity in mobile environments. Further methods for adapting the visualisation of geographic information are discussed in section 10.5.

### 10.3.3 The process of map adaptation

The adaptation of mobile maps to external context factors described above is called external map adaptation and can best be described with the 'Chameleon' metaphor. As a chameleon is capable of adapting to its surroundings by always changing its look, mainly the skin colour, to suit its current environment, an adaptive map is one that alters its content, symbolisation, and/or interface according to changing contexts. Figure 10.4 shows altering contexts of geoinformation usage over time and the adaptation of maps (illustrated with different greyscale values)

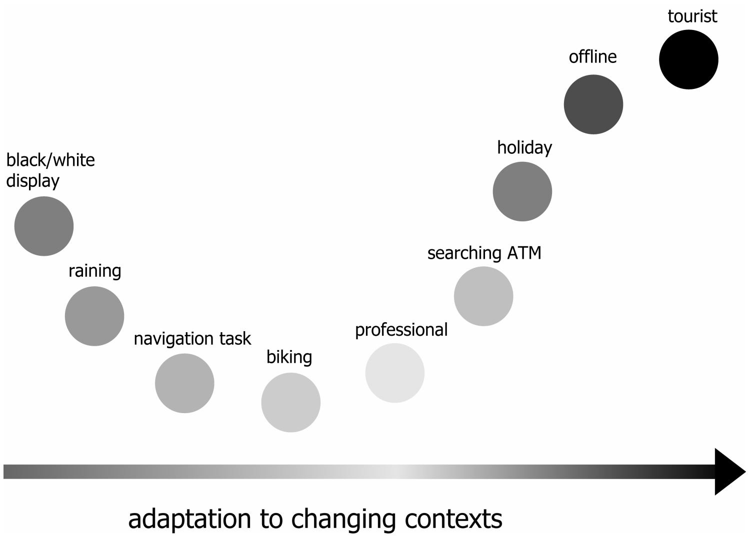



**Fig. 10.4.** The chameleon character of adapted maps

The ecological concept of niche occupation can be transferred to cartography. Figure 10.5 illustrates the relation between the design space and adaptation space of maps. The basic assumption is that a map has a certain fitness for use in one or several usage contexts. A map functions or works for a set of environmental factors that are compound under the term 'map purpose' in cartography and covers a subset of the possible design space. These environmental factors or variables can be grasped as a multi-dimensional space. Cartographers try to optimally match the environmental requirements imposed by the map purpose to the design space.

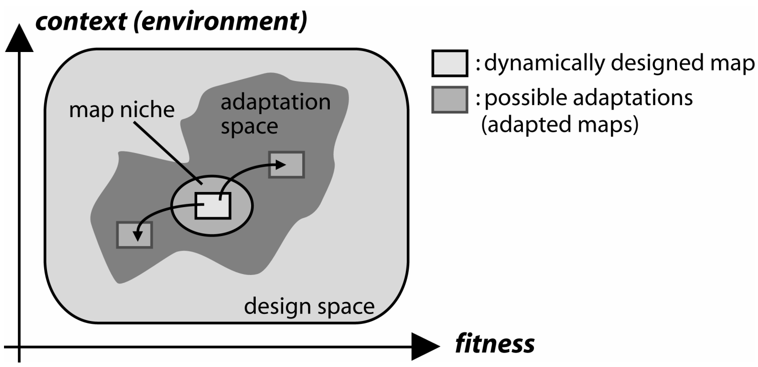



**Fig. 10.5.** Map niches and adaptation space (based on Bowers et al. 2000)

Changes in the environment, i.e. the context of map usage, lead to a gap between purpose and design. However, if these changes are not too dramatic, the map is still working. This area is called the map niche. If the changes exceed a certain amount, the map cannot function properly, i.e. the usability of the map is decreasing substantially. Adaptations to the changed environmental factors widen the area of possible map usage. This widened area is the adaptation space. By adapting to the requirements of new context factors the map fits better and the usability of the map increases.

Methodologically the adaptation in mobile cartography occurs on different levels: the information content level, the technological level, and the presentation level. On these levels different adaptation objects can be distinguished that are adapted to context elements. Figure 10.6 shows the process of map adaptation. Either all or parts of content, user interface, presentation form or encoding of a map can be adapted to the context factors identified above. The map adaptation process is triggered if context change measures (e.g. speed or user identity) exceed a threshold value or take a different value. First, a check is executed, whether an adaptation should take place at all. Next, the decision engine selects an adequate strategy that is followed in the adaptation engine. This engine is responsible for selecting the objects to be adapted, the proper methods, the setting of the parameters, and the execution of the adaptation. In an iterative process, the map is adapted to its usage context.

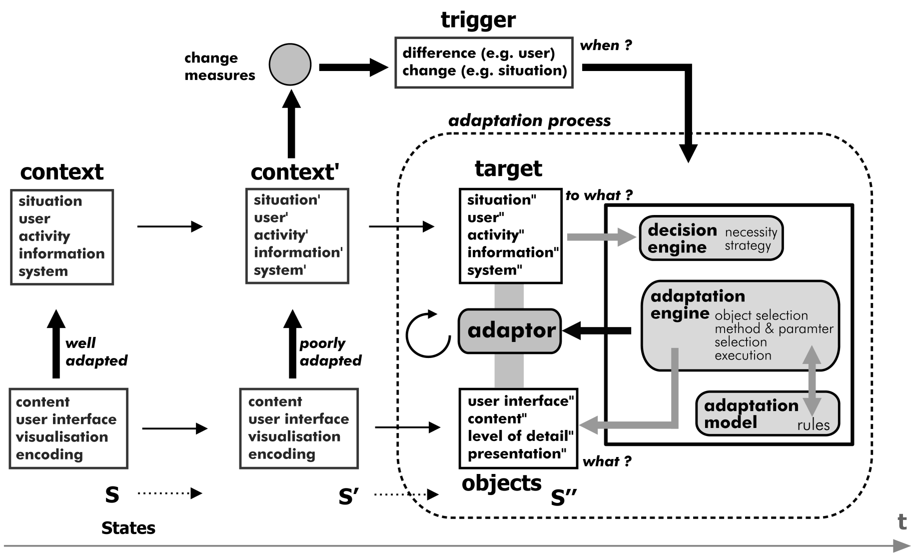



**Fig. 10.6.** Map adaptation process

Apart from this external adaptation, a map itself can also internally be adapted. An example is the adaptation of text and symbol placements in order to avoid overlaps. An internal adaptation could be understood as a self-adaptation resulting in complete self-adaptive maps. An approach to self-adaptive maps is the introduction of constraints. Constraints have been successfully applied in map generalisation. Since adaptation and especially internal adaptation is closely related to generalisation the combination of the two concepts leads to enhanced mobile maps.

## 10.4 Egocentric maps

The most common notion of ego-centre is a spatial one. In spatial cognition egocentric representations of space showing more local and route-based geographic information are opposed to allocentric or exocentric representations giving survey information (*Montello* 1992). The distinguishing feature is the referential point, the individual or the world. An egocentric map is commonly known as a map depicting geographic information from the user's position. Several authors have studied the design of egocentric maps and the possible advantages for mobile users regarding the usability (see e.g. *Hermann et al.* 2003). However, apart from a spatial definition an egocentric map is characterised by other dimensions. An egocentric map could as well be understood as a more personalised or individualised form of map representation, depicting geographic information from the user's perspective that can be more than the mere spatial position and could include interests, physical abilities, needs etc. The representation is directed in temporal, topical, intentional, or action-based respect to a specific user, i.e. an *ego*.

The aim of such processes is to enhance the personal relevance of maps and thus improve the usability. An important criterion for map usability is utility in the sense of being useful for conducting the current activity. Hence the main purpose of adapting egocentric maps is fitting them to the activities at hand. There is no consistent terminology for maps that are specifically designed for user activities or abilities: egocentric maps, focus maps (*Zipf and Richter* 2002), aspect maps (*Barkowsky and Freksa* 1997), topic maps, or activity-based maps (*von Hunolstein and Zipf* 2003). Here, an egocentric map is understood as a personalised, activity-focused map adjusted to the current mobile user activity that focuses on one or more included elementary spatial action (locating, navigating, searching, identifying, and checking) and shows a certain adaptive behaviour. Rosson and Carroll (2002, p. 81) call such a design of a product or service around the user's activity " […] 'activity design' because it emphasizes the broad scope of what is being designed: people carrying out activities with the support of computer software. It is essential to design software systems in a usage context, always considering whether and how they will support human goals and activities." The idea of supporting users acting in geographic space within their everyday life needs to address immediate user needs within that mobile context. Such an idea is supported by Fuhrmann and Kuhn (1998) who coined the term everyday map: "[…] web-based maps will become available to anyone and will soon function as the public sources of spatio-temporal information for everyday purposes like wayfinding, shopping, dining out, and travelling. It appears justified to introduce the term to 'everyday maps', because the contents and functions of these media cannot be explained and defined using traditional map definitions. […] Thus, an everyday map is 'a geographical image of the environment which is suitable for ordinary days or routine occasions'."

Activities can be defined as a motivated sequence of coherent actions carried out at a specific location for a certain time. They bundle the associated goal and information demand in a compact approach and it is this user activity that should be supported with adequate maps. An activity assembles the three major dimensions of mobile spatial related questions: an activity captures information about *what* the user is doing *where* and *when* he or she is doing it. For example, dining is an activity carried out at a restaurant. There is a plethora of different activities mobile users conduct and for which appropriate information visualisation techniques have to be developed. McCullough (2001) proposes a preliminary typology of everyday 'situations' relevant for mobile services. The four main 'situations' are *at work*, *at home*, on the town, and *on the road*, each associated with activities such as crafting, collaborating, watching, cruising, eating, shopping, sporting, hoteling, touring, driving, walking, etc. According to McCullough (2001, p. 345) "design that recognizes how these activities occur 'habitually and in a state of distraction' has a better chance toward usability, assimilation, and getting out of the way." A more formalised way for establishing an activity ontology is described by Kuhn (2001) using the example of actions found in German traffic code. The ontology is derived from textual descriptions and models the relationships between actions and objects. In addition an ordering of the actions in a hierarchy of traffic actions is accomplished.

One consequence of mobility, or more precisely the possibility of geographic information usage while being mobile, is an increasing demand for individualisation. It is technically possible and, due to the inherent characteristics of mobility (e.g. changing contexts; different movement modes), often necessary to individualise the map presentation. Modern cartography must provide not only static map products, but flexible geovisualisation services that support the user in his everyday activities and his spatial questions caused by mobility with a minimum cognitive effort. Mobile cartography therefore needs to incorporate personalisation methods to adequately portray relevant information during mobility. Such information can be landmarks for navigation (c.f. *Elias et al.* 2004), points of interest (POI) related to specific activities, social life related information and so on. As mentioned before, most important is the relevance according to the current activity. The actions introduced in Figure 10.1 can be used for an initial attempt to adapt to user activities and generate egocentric maps. This adaptation happens in the process of geovisualisation service personalisation according to the parameters of the usage context, i.e. in a certain sense the ego-centre. First attempts of geovisualisation service personalisation have revealed a great potential; see for example (*Zipf* 2002, *Reichenbacher* 2004).

## 10.5 Adapting to mobile user activities

Egocentric maps are composed of general public geographic information populating the *reference information layer* and private, more personalised geographic information populating the *private* (or personal) *information layer*. High-level methods that adapt the geovisualisation to the user activity range from simple selection and reduction of information content and density over configuration of map components to re-symbolisation and encoding methods (see *Reichenbacher* 2004).

The adaptation objects, i.e. the objects which are actually adapted, can be attached to different levels of adaptation. High level adaptation affects for instance the visualisation method, encoding, and scale of a map. Low level adaptation affects colours, fonts etc. This level of adaptation is closely related to the granularity of the adaptation objects. In addition, one could also distinguish between morphological and structural adaptation depending on the objects affected. The morphological adaptation basically influences changes to the visual appearance in any way. The structural adaptation affects the functionality or the internal structure of the map. Examples are the grouping and linking of map features or data structures not dependent on symbolisation. Informational adaptation encompasses the information content per se.

More general design recommendations for mobile egocentric maps would be to keep information density of mobile maps at the minimum and generalize them to a high degree. The design should be controlled by the primacy of relevance over completeness. The map graphics should adhere to a poster-like style with drastically enlarged minimal dimensions and self-explaining, pictogram-like symbols. Especially fine design elements used in paper maps should be omitted and text must be used thriftily and only with sans-serif fonts.

In more detail, a plethora of design methods can be utilised as high-level adaptation methods. A far from comlete list of methods that have been organised in design patterns by Meng (2004) encompasses:

1. focusing single feature: highlight relevance of an object
2. focusing several features: apart from emphasising a single object, these methods allow for visualising a relevance order. This method is very useful for rendering symbols for POIs with different opacities depending on their relevance. Examples of computing relevance values for mobile maps are presented in (*Zipf* 2003, *Reichenbacher* 2004). Total relevance values of events can be directly mapped to the opacity value of the SVG style attributes and reflect the relevance to the user in a synoptic manner. The result set of a search can contain geospatial objects, people or events and can be sorted according to different criteria. Relevance is only one example. Others are availability, costs, etc.
3. changing map section: auto-centring map based on position information
4. changing scale and/or level of detail: map scale changes can be accomplished with different levels of detail; adaptive zooming is described in (*Brühlmeier*, 2000)
5. visualising search results
6. changing map symbolisation

These high-level adaptation methods referred to above use in turn a broad palette of low level techniques from GIS, visualisation, and IT. Figure 10.7 shows the most important of these techniques. The most important adaptation method in geovisualisation is highlighting important features to emphasise their importance or relevance.Apart from the techniques illusttrated in Figure 10.7 techniques for visually emphasising or focusing map elements are:

- highlighting the object using a signal colour, e.g. pink or yellow (colour)
- emphasising the outline of the object
- focusing the object while blurring the other objects (crispness)
- enhancing the LoD of the object against that of the other objects
- animating the object (blinking, shaking, rotating, increasing/ decreasing size)

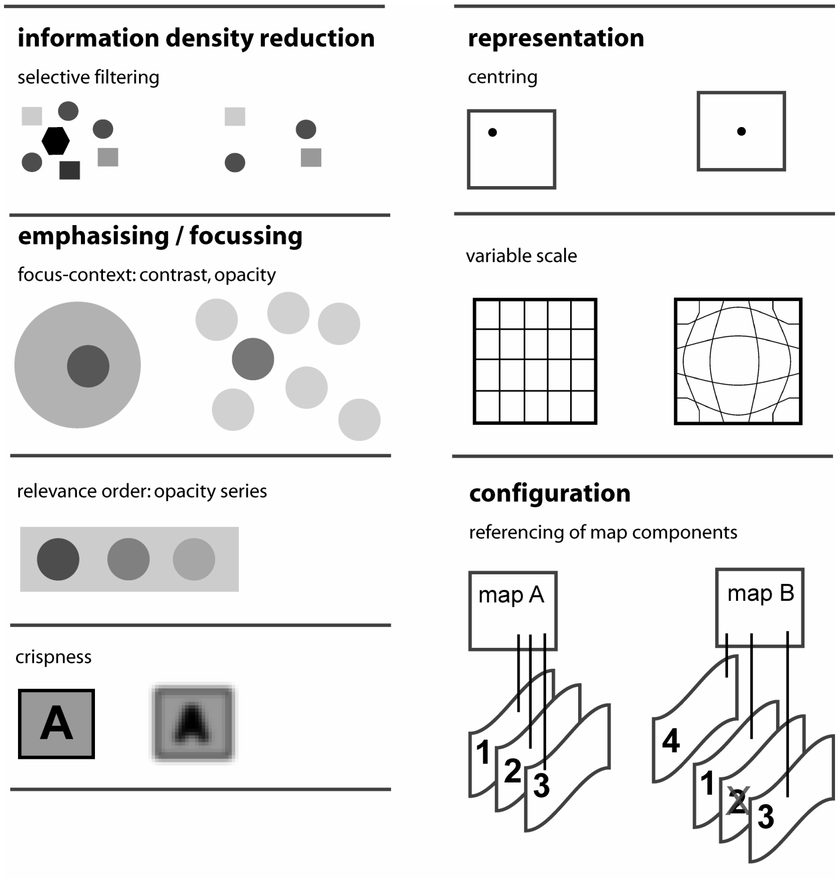



**Fig. 10.7.** Design methods and techniques for egocentric map design

Further techniques of visualising the spatial relevance of map features are buffers or zones that can be transparently overlaid over the actual geographic information depending on the spatial relevance measure. Besides, other information types could be overlaid as additional semitransparent layers, e.g. a compass for orientation purposes, the map scale as a distance ring or buffer or temporal reachability as time rings (for examples see *Reichenbacher* 2004). The user may interactively switch on and off such information.

Less important or less relevant information can be displayed as layers or groups of map features with lower opacity or lighter colour. This moves the more important information in the visual centre. Again, this could be interactively initiated and reversed by the user. Similarly the base map could be dimmed out radially from the user position or bi-directionally for routes towards the edges of the map enhancing the spatial focus (for examples see *Zipf and Richter*, 2002, *Reichenbacher* 2004). To visually highlight the area of interest or focus, an activity zone or a search area, the method of overlaying a transparent polygon or circle can also be applied. This is useful for route visualisations where the route and the landmarks are in the visual focus and the other information should only function as the connecting geospatial frame. Figure 10.8 shows two examples of adapted maps where some of the graphical techniques discussed above have been applied and implemented with SVG.


**Fig. 10.8.** Graphical means for egocentric map design

Many platforms for geovisulisation services have been proposed or implemented in the past, e.g. (*Zipf* 2002, *Edwardes et al.* 2003, *Lehto and Sarjakoski* 2004). An implementation of a geovisualisation service capable of simple adaptation can be found in (*Reichenbacher* 2004). An intermediate step towards the practical realisation of adaptive geovisualisation services is the construction of personal adaptor tools through the user. The idea behind adaptor tools is that the user can configure his/her own 'map adaptors' for known contexts on a desktop computer and take these adaptors with him on the mobile device and plug them in an existing service in the respective context. In analogy to electric power adaptors, these map adaptors are designed a priori. In that sense they represent a compromise between adaptive and adaptable maps. Instead of adapting the map in the moment of usage, the user creates an individualisation tool that provides adaptive behaviour in the respective context of map usage. Such map adaptors can include e.g. profile, preferences, filters, style, etc. As a pragmatic solution they might relax certain usability deficiencies of current geovisualisation services.

## 10.6 Conclusions

The concept of egocentric maps is valuable for the proliferation of map-based mobile services. Further research is needed in modelling and formalising context for mobile cartography, the design of adaptation methods along with establishing rules and constraints for governing the adaptation process. Furthermore, activity ontologies have to be defined for the generation of egocentric maps or activity-based maps. And finally, the usability of different adaptation versions/alternatives have to be tested in practice with usability test series.

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# 11 Cartographic Location Based Services

Georg GARTNER, Susanne UHLIRZ

Research Group Cartography, Institute for Geoinformation and Cartography, Vienna University of Technology

**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 visualisation (guiding and navigation for pedestrians) are given.

## 11.1 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.

## 11.2 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.

### 11.2.1 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 particularly 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).

### 11.2.2 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 adaptations
- 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 (*Reichenbacher 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 visualisation. 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.

### 11.2.3 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 symbolisation, 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.

## 11.3 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).

### 11.3.1 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.

### 11.3.2 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.

### 11.3.3 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).

## 11.4 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.

### 11.4.1 Active Landmarks

#### *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.

#### *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).

### 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.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[7]. 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.

### 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

[7] Wireless Local Area Network

range data transfer and system optimisation for PNS in general have not yet been answered and will be discussed in future research projects.

### *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 Figure 11.1). 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*).

## 11.4.2 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).

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 Figure 11.1). 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.

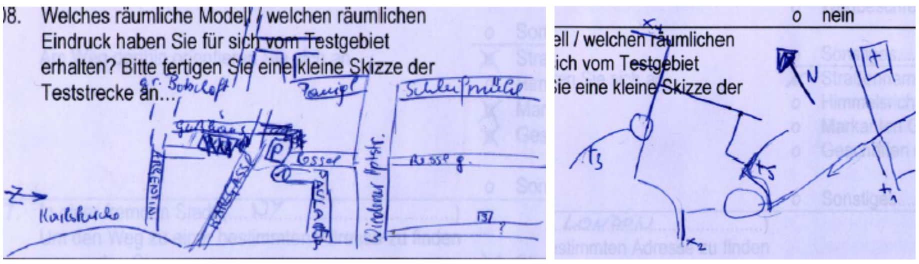


**Fig. 11.1.** „Sketch Maps“ drawn after navigation by textual instructions (left side) and by map –based instructions (right side): creation of a topological mental map model vs. a topographical mental map model (*Reichl* 2003)

### 11.4.3 Cartographic support for wayfinding

Based on the description of the potential of various presentation forms for transmitting route information (section 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.

## 11.5 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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# 12 XML in Service Architectures for Mobile Cartographic Applications

Lassi LEHTO, Tapani SARJAKOSKI

Department for Geoinformatics and Cartography, Finnish Geodetic Institute

**Abstract.** XML-based methods are becoming increasingly important in the development of GI-related Web services. This chapter describes the use of XML techniques in the context of open, layered service architecture designed to support mobile cartographic applications. The XML solutions discussed include data modelling and validation, spatial data encoding and linking, data transformations and map visualisation. The technologies are introduced, their application in the GI domain further elaborated and the role of each technique within layered GI service architecture described. The responsibilities of each of the service layers in the proposed five-layer architecture are also discussed and the relevant, internationally accepted GI standards briefly introduced. Finally, as a case study the service architecture implemented in the GiMoDig project is presented.

## 12.1 Introduction

Web-based solutions for processing and delivery of geographic information (GI) are becoming a mainstream phenomenon. Organisations see the Web environment as an essential means for disseminating the geospatial datasets they maintain. Thus, the number of on-line maps and geospatial data services is rapidly growing. Application developers are busy improving their products to support distributed use in a networked environment. Solutions are often proprietary, since legacy systems are widely used as a basis for developing new Web products. Requirements related to interoperability, one of the most important features in networked computing systems, are frequently neglected.

The introduction of mobile technologies adds a new dimension to the puzzle of distributed geospatial computing systems. Service providers need to support a new type of client platform having drastically reduced facilities for map display and user interaction. On the other hand, new opportunities have emerged for adapting the service output to the dynamic context parameters, such as the user's current position or the actual time of day.

The ever widening set of Web-based GI services and the end-user platforms applied to access them call for introduction of a flexible service architecture. The roles of the data provider and the service provider are becoming increasingly distinct. However, on-line services require constantly up-to-date information sources to be available. The use of widely varying client display facilities - from the high-resolution screens of current desktop computers to the miniature displays available on modern tiny hand-held devices – makes it necessary to separate the presentation characteristics of the service from the information content it is based on. A well-designed service architecture should facilitate the GI services in supporting varying user needs with most current data.

The parties responsible for Web technology development and standardisation have recognised the increasing use of the Web as a platform for processing and delivering various types of data. The introduction of the Semantic Web concept is an important step in this evolution (*W3C* 2004a). According to initial Semantic Web ideas, the semantics is to be attached to the Web content by means of Extensible Markup Language (XML) technologies.

Generic XML techniques can also be adapted to the processes involving GI. This chapter discusses the XML solutions for data modelling and validation, spatial data encoding and linking, data transformations and map visualisation. The technologies are introduced first, after which their application in the GI domain is discussed. Finally, the role of each technique within layered GI service architecture is described.

Many of the findings of this chapter are based on work carried out in the "Geospatial Info-Mobility Service by Real-Time Data-Integration and Generalisation" (GiMoDig) project (*Sarjakoski et al.* 2002). In this chapter we concentrate on the system architecture issues and especially on how XML has been used in implementing the prototype system in the project. The chapter by Sarjakoski and Nivala (2004) gives a detailed study on how the issues of map interface, adaptation to context and usability has been approached in the same project.

## 12.2 XML Basics

### 12.2.1 General

One of the most significant Web standardisation-related activities is the work carried out by the World Wide Web Consortium (W3C) in developing the XML specification (*W3C* 2004b). The work on XML was launched around 1996 with the goal of developing a simplified Web-adapted version of the widely used Standard Generalized Markup Language (SGML), a language defining a markup syntax for structured text documents. XML is widely regarded as the next-generation encoding language for the Web. The specification is aimed at generic data transmission, rather than simply text document processing, as is the case with popular HyperText Markup Language (HTML).

XML specification deals only with the logical structure and exact syntax of language; it does not fix individual tags used in the markup. As such, XML can be regarded as a metalanguage, i.e. a language for developing other languages. The rapid proliferation of XML vocabularies, adapted to various areas in society, has been a natural consequence of this flexibility. These vocabularies, once widely accepted and supported, allow the semantics of the data to be indicated, further enabling the Web to become a vast repository of 'smart', self-describing data. The W3C recommendation for the next version of HTML specification, Extensible HTML (XHTML), has also been developed as an XML application (*W3C* 2001a).

Being an international cross-vendor specification, XML can be expected to gain support from many Web application developers. Since the XML syntax is based purely on character encoding, the code is easy to produce and edit even with traditional text-processing tools. The wide adoption of XML in the Web community ensures that all the basic tools needed to work with XML are available free of charge on the Web. A good site to look for free XML tools is the Apache XML Project (*Apache* 2004).

XML specifies the constructs that can be used in building a structured text document. The most important construct is called *element*. An element is delimited by a starting tag and an ending tag. It can have *attributes*, which are given inside the starting tag. The content of an element consists of text passages and/or of other elements. The tags, together with a few other constructs, are called *markup*, which essentially describes the semantics and the logical structure of the document. The remaining content of an XML document is called *character data*. An XML document thus closely resembles a corresponding HTML code, although it introduces some stricker syntax requirements. The extensive, semantically rich markup makes an XML file human-readable and self-describing. The structure of an XML document can naturally be expressed as a tree (see Fiure 12.1).

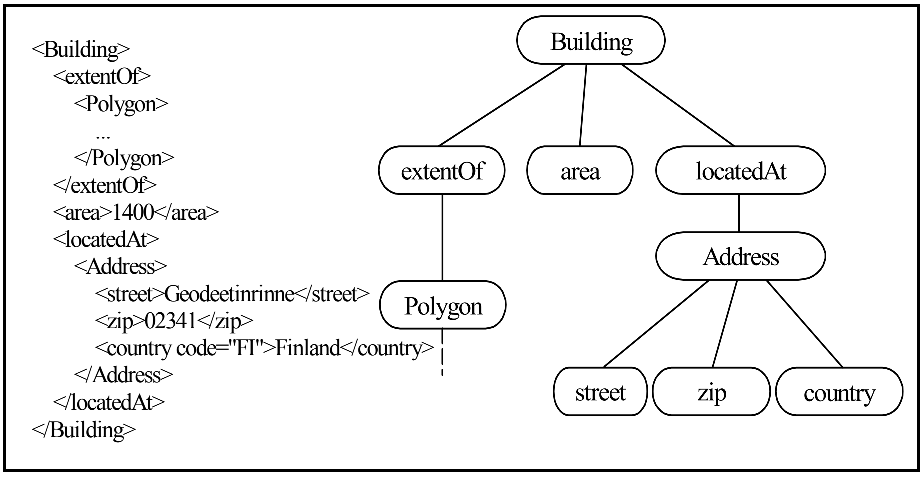


**Fig. 12.1.** A sample XML code snippet with the corresponding tree structure. The example presents a GML Feature (Building) encoded in XML syntax and illustrated as a data structure produced by a DOM parser.

An XML document that follows the syntactic rules defined in the XML specification is said to be *well-formed*. A mechanism is provided in the XML specification for defining more detailed constraints on the structure and content of a particular type of document. These constraints are typically expressed in an external file called Document Type Definition (DTD) and specify the element hierarchy allowed, as well as indicate the mandatory and optional attributes of the elements. Possible default values for the attributes can also be given. A document conforming to the constraints defined in the indicated DTD are said to be *valid*. The definitions in a DTD are expressed in a special-purpose, non-XML syntax (see Figure 12.2).

```
<!ELEMENT Building (extentOf, area, locatedAt)>
<!ELEMENT extentOf (Polygon)>
<!ELEMENT Polygon (...)>
<!ELEMENT area (#PCDATA)>
<!ELEMENT locatedAt (Address)>
<!ELEMENT Address (street, zip, country)>
<!ELEMENT street (#PCDATA)>
<!ELEMENT zip (#PCDATA)>
<!ELEMENT country (#PCDATA)>
<!ATTLIST country code CDATA #REQUIRED>
```

**Fig. 12.2.** A sample Document Type Definition (DTD) file. The DTD corresponds to the dataset illustrated in Figure 12.1 and declares the nesting of the elements, their cardinality and the possibly required attribute content.

The XML specification does not only define the document format, it also introduces a concept of a software module called XML parser and specifies in detail the responsibilities of this module. The main responsibility of an XML parser is to read an XML source and construct the above-mentioned tree-form data structure of its content. During the process the XML parser is supposed to check the well-formedness of the source document and give a report of the encountered problems. This type of parser is called a Document Object Model (DOM) parser. Another type of parser is termed Simple API for XML (SAX) parser. The output from the parsing operation in the case of an SAX parser is not a data structure, but a stream of well-defined events. If a DTD is available for the source document a parser may also check the validity of the document's content.

### 12.2.2 XML Schema

The traditional means for defining a detailed data model that a certain class of XML documents is supposed to honour has been to set up a DTD file. The facilities available in the DTD syntax, inherited from SGML, in expressing the properties of the data model are rather limited. For example, it is not possible to declare a datatype or value space of an attribute, which is an important facility in data validity checking. There is also no way of defining cardinality as something like 2-N, a rather common requirement in many application areas. To overcome these deficiencies, the W3C has developed a more powerful XML-based schema definition language called XML Schema.

The XML Schema specification is divided into two separate documents: Part 1) Structures and Part 2) Datatypes (*W3C* 2001b,c). The Structures part defines all the facilities used for constraining the logical structure of an XML dataset, providing mechanisms to constrain the hierarchical relationships between elements, the attributes allowed and their types, attribute value spaces, default values etc. The document on XML Schema Datatypes defines all the built-in primitive datatypes of the XML Schema language and establishes the mechanisms for constructing new application-specific datatypes.

### 12.2.3 XLink

The traditional Web-linking system has several serious restrictions. The current hyperlink construct in HTML is a one-way, binary relationship defined in-line at the starting end of the link. If a link points to an element within a Web document, the document requires an explicit mark to indicate the destination (the HTML document fragment identifier mechanism). There is no way of attaching metainformation to the link. For instance, the action carried out when a user follows the link is determined by the user agent (i.e. the Web browser), not by the properties of the link. All of these deficiencies are dealt with in the XLink specification, a linking system for XML documents published as a recommendation of the W3C (*W3C* 2001d).

The XLink specification defines an element called *extended link*, which enables several resources to be listed as participating in the link; a *locator* element is used for this purpose. An individual relationship between two resources is defined by a separate *arc* element. An arbitrary number of relationships can thus be defined among the locators. The specified link construct introduces the notion of an out-of-line link, i.e. a link for which all the locators are remote. Dedicated link databases could be established for storing these links. Two separate specifications, named XPath and XPointer, are addressing mechanisms that refer to the internal parts of an XML document (*W3C* 1999a, 2003a). XPointer constructs can thus be used as a Uniform Resource Identifier (URI) fragment in the *href* attribute of a locator element.

### 12.2.4 XSLT

The Extensible Stylesheet Language (XSL) specification was developed by the W3C as a tool for defining presentation characteristics of an XML dataset. As a result of this work the W3C created a specification for transforming XML documents, termed XSL Transformations (XSLT) (*W3C* 1999b). XSLT is primarily designed for transforming XML documents for presentation purposes. Typical examples include dynamic creation of the table of contents and creation of a tabular presentation of some data values in the source document.

XSLT is based on a declarative processing model. The transformation is determined in the form of templates formulated in the XML syntax. The templates contain a pattern that is matched against data items in the source document, and declare the corresponding elements to be written in the result document. The template can indicate which parts of the source document content are written to the output and which data items they are located in. In this manner, the entire document structure and vocabulary can be transformed into a completely different form, as required by the application. Typical examples include transformations from domain-specific data content to XHTML for Web display and transformations from tabular data items to graph-based visualisations in the form of Scalable Vector Graphics (SVG) images.

## 12.3 XML in Spatial Data Processing

### 12.3.1 Data encoding, GML

Recent developments indicate that significant change is occurring in the mechanisms of Web-based spatial data delivery. The general trend towards XML-based data encoding is also recognised in the spatial data domain, gradually shifting the focus away from the traditional GIS data formats. Various standardisation committees have been working to develop XML vocabularies for encoding spatial data. Among the most important ones is the Open GIS Consortium's (OGC) Geography Markup Language (GML) recommendation (*OGC* 2003). The GML recommendation establishes an XML vocabulary for representing OGC Simple Features Specification-compliant data in XML syntax. Several GIS vendors are developing GML support within their software, and some products are already commercially available.

GML standardisation work has also been initiated in the International Organization for Standardization (ISO) TC211 programme. As the ISO document number 19136, the GML specification is about to attain the status of ISO Committee Draft and is scheduled to become an offical ISO International Standard by late 2005 (*ISO* 2004). It can be assumed that future GML specifications, or some derivative thereof, will become a commonly used standard for spatial data encoding on the Web.

### 12.3.2 Map visualisation, SVG

Once the format for spatial data content encoding becomes standardised, opportunity will also ensue for the development of a standardised method for defining visualisation characteristics. The SVG specification is an XML technology developed by the W3C to create a standardised vector graphics format for the Web environment. The specification is a W3C recommendation (*SVG* 2003). The SVG format is widely seen as a probable future standard for all types of vector graphics on the Web. In texts dealing with SVG technology, maps are frequently mentioned as a typical application area for the SVG format. Currently, SVG images can be visualised on a Web browser, e.g. by using an Adobe-provided SVG Viewer plugin (*Adobe* 2003).

Future mobile terminals may be able to process vector images – however, in a short run this is not feasible. For a limited capacity terminal, the vector map can be transformed into a raster image by the service. A more powerful terminal may be able to display SVG images, thus providing much better interactivity properties for the client application. The W3C initiated a project, carried out under the title SVG Mobile, to develop lightweight profiles for the SVG specification. This development has produced two SVG specifications, named SVG Basic and SVG Tiny, that will hopefully facilitate the use of SVG images in less powerful terminals (*W3C* 2003b).

### 12.3.3 Spatial data modelling and validation, XML Schema

The facilities provided by the XML Schema language for constraining the structure and datatypes of an XML dataset are essential in applications related to geospatial data. Reliable data validation is dependent on extensive type checking, and topological integrity rules frequently necessitate the type of cardinality checking provided by XML Schema structures. An example of the use of XML Schema in a geospatial context is the OGC's GML specification, in which the exact data model has been defined as an XML Schema document.

The XML Schema specification can be used in many different stages of GI service development. In the early design phases, XML Schema can serve as a tool for describing in detail the data structures and service interfaces to be implemented. It can be utilised as a platform to develop standardised community schemas for representing particular datasets. Finally, validating XML parsers can access on-line XML Schema documents to apply validity checking on the fly during service query processing.

### 12.3.4 Spatial relationships, XLinks

Various elements in spatial datasets are frequently related to another element in the same or some other dataset. The usual cases include a link from a spatial object to its descriptive attribute information set or multimedia presentations and links indicating various topological relationships between spatial objects. A mechanism is clearly needed to explicitly indicate the existence of a relationship. In Web-based geospatial applications, a URI reference is commonly used to establish a link from a data item to an additional resource available on the network. The mechanism is the same as in hyperlinks of HTML documents.

The GML specification makes extensive use of XLinks to denote different relationships among objects in the dataset. Examples include remote spatial Features, remote properties of Features, Feature associations, shared geometry properties and shared geometric primitives. The part of GML dealing with topology is essentially based on the use of XLinks to indicate the topologic relationships.

### 12.3.5 Spatial data transformations, XSLT

XSLT-based data transformations have many possible applications in processes involving geospatial data. As described by Lehto et al. (2001), XSLT could be used to transform a spatial dataset from the domain-specific data structure to an SVG format for a 2D vector map display, or to some other relevant visualisation language, such as the XML-integrated 3D-visualisation language Extensible 3D (*X3D* 2004). Other usages considered in geospatial applications include data model transformations, coordinate transformations and generalisation of spatial data (*Lehto and Kilpeläinen* 2001).

The XSLT specification is a promising tool for carrying out the tasks encountered when integrating spatial datasets in real-time. Simple integration operations are readily available and include tasks such as changing the naming system applied, grouping data from several feature classes into one class or dividing data from one feature type into several types, changing code tables etc. More sophisticated integration operations can be added via the XSLT extension mechanism. Typical examples include various coordinate manipulations, such as coordinate reference system transformations, changes in geometric primitive types (e.g. area collapsed to a point) etc. The integrated datasets are written out as XML data presented in a common GML application schema. The extension mechanism available in the XSLT process enables arbitrary, application-specific functions to be introduced into the transformation process. Several XSLT processes can also be chained together if the task is too complicated to be expressed as a single transformation.

An example of a simple XSLT declaration is presented in the following code sample (Figure 12.3). XSLT declarations are expressed in the form of templates. The template in the example selects all elements representing buildings (‘Rakennus’ in Finnish) from the source tree that match the selection phrase (expressed in a language termed XPath), then filters out all elements the given test phrase within the xsl:if element does not compy to. All elements within the template not belonging to the xsl-namespace are entered in the result tree. For instance, in the example the element Building forms part of the target vocabulary. In this case the transformation is taking place in the naming system (from Finnish to English terms) and in the collection criteria (only buildings with area ('pinta-ala' in Finnish) larger than the threshold value will be included). Following the instruction: xsl:apply-templates, the process continues down the XML tree. The transformation continues until no more matching elements are found.

```
<xsl:template match=”Rakennus”>
  <xsl:if test=”pinta-ala &gt; 200”>
    <Building>
      <area><xsl:value-of select="pinta-ala * 10000"/></area>
      <xsl:apply-templates select="..."/>
    </Building>
  </xsl:if>
</xsl:template>
```

**Fig. 12.3.** A sample XSLT template. The code illustrates a transformation going from a Finnish data model to another representation with different vocabulary, collection criteria and measuring unit system.

## 12.4 Architecture for Mobile Map Services

### 12.4.1 Architecture layers

Mobile cartographic applications can be based on two basic computing models: off-line and on-line solutions. In an off-line application, the data and software needed for the mobile task are preloaded into the device in advance. As a result the user is not dependent on the availability of network connections while in the field. This approach is especially useful for applications that are targeted to remote rural areas, where mobile networks are less capable than in urban environments. However, the continuosly ongoing development of mobile communication facilities makes the on-line solution feasible on many occasions. In a combination of the two main approaches, an off-line application would perform periodical data updates when a communication channel becomes available, for instance at one of the increasingly popular WLAN (Wireless Local Area Network) 'hot spot' stations.

The open system architecture of an on-line mobile map service should be based on a layered service stack in which a service would make data queries to the service below, process the data in some specific way, and provide the results of the process as a service to the layer above (*Lehto* 2003). The level of detail in specifying the layers is a matter of discussion, but if the services were run on separate computers communicating through a network, too fine-grained a service definition would create a significant disadvantage in terms of overall system performance. Each clearly distinctive task in the service provision, potentially the responsibility of an individual organisation, should be put on a separate layer.

For the above-mentioned reasons, five-layer system architecture is proposed (see Figure 12.4). On the first layer, the data providers (e.g. national mapping agencies, NMAs) would run a Data Service providing original spatial data in an XML-encoded form. Above the Data Services is the Data Integration layer, the main task of which is to provide a single access point to the geospatial data sources of the participating data providers – serving data in a common data model and in a common coordinate reference system. The responsibilities of this layer thus include tasks such as coordinate transformations and schema transformations. The Data Integration layer plays a critical role in the various cross-border applications that will be developed in the increasingly integrated world.

The next layer in the service stack above the Data Integration layer is the Data Processing layer. In this layer, various types of computations can be performed on the dataset received from the Data Integration layer below. These computations could include tasks such as edge matching, generalisation and various other forms of GI analysis.

The fourth system architecture layer could be termed the Portal Service layer. Its main responsibilities could be: providing basic metadata service to the client, processing service requests arriving from the client and subsequently forwarding the request in an appropriate form to the Data Processing layer and, finally, transforming the resulting set of geospatial data into a map image formatted appropriately for the capabilities of the client platform in use.

The fifth layer contains the client applications. An advantage of the layered architecture approach is that the service results can be adapted to a wide set of varying client environments. For example, the following three client platforms could be considered: traditional Web browsing on a PC platform, various client solutions on PDA devices, and Java Mobile Information Device Profile (*Java MIDP* 2004) clients on mobile phones.

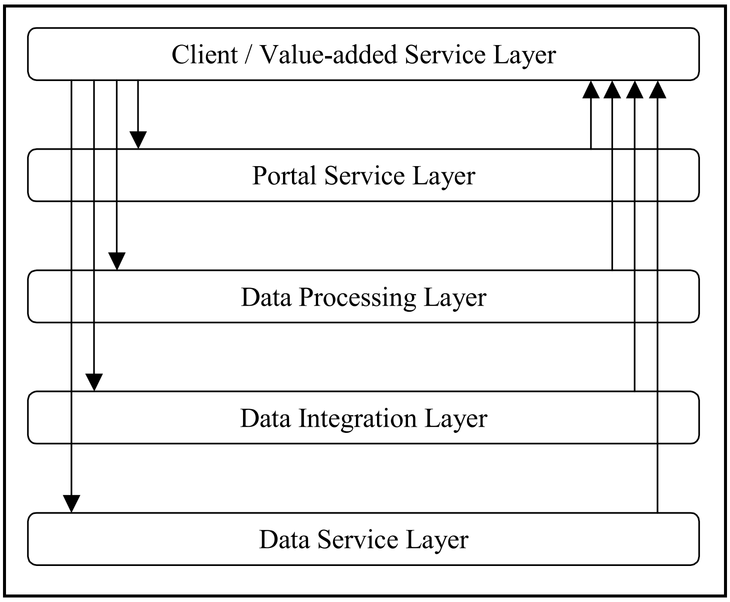


**Fig. 12.4.** The Five-layer open service stack. The figure shows how a Client or Value-added Service Layer can access any other layer underneath, not only Portal Service Layer. The other combitions have been ignored in the figure for simplicity.

Since the standardised, open interfaces are to be applied on different layers of the service architecture, the system provides a flexible framework in which clients do not necessarily query the topmost layer of the hierarchy, communicating instead with the service that provides the best support for the given task. As a result, powerful clients may directly consult the Data Service interfaces, whereas some client applications may prefer the access to a Data Processing Service, while the most restricted platforms may require the client application to rely on the Portal Service Layer providing raster map images. Instead of a client application, the fifth service layer may also be represented by a value-added service provider with access to the service hierarchy on an appropriate level and provide the resulting user-oriented service content to actual client applications.

### 12.4.2 Standardised interfaces

Open service architecture must provide standardised access methods to each of the layers in the service stack. The OGC has recently been active in developing interfaces for on-line GI services. The results of this work can be adapted for use in the layered architecture described above. The OGC's Web Feature Service (WFS) specification is clearly a candidate for the query interface on the Data Service layer. The Data Integration layer plays the role of a Cascading WFS, working as a client to other WFS nodes and providing combined results as a service to upper layers in the stack. Standardised access interfaces for the Data Processing layer are not yet available. The heterogeneous nature of the services potentially located on the Data Processing layer makes it difficult to develop generic access methods on this level of the hierarchy. Finally, the Web Map Service (WMS) on the Portal Service layer is a suitable access interface, while a proper query interface in the case of mobile applications is the Open Location Services (OpenLS) Presentation Service. In the following, each of the standards is briefly discussed.

### *WFS*

The WFS specification (version 1.0) was published as an OGC implementation specification in 2002 (*OGC* 2002). A WFS-compliant service provides the client applications with actual spatial data, geospatial Features in OGC's terminology, not with a previsualised map image as in a WMS service. It is a requirement of the WFS specification that the resulting message must be encoded according to the GML specification.

The WFS services can be divided into two separate classes. Basic WFS is a read-only server, solely providing data output facilities. This type of service supports only the GetCapabilities, DescribeFeatureType and GetFeature interfaces of the WFS specification. Transaction WFS will also let the client application update the database (create new Features, delete and update existing Features).

The GetFeature interface enables sophisticated queries to be processed on the server. The desired set of spatial Features can be limited spatially and thematically. To be able to construct a reasonable query sentence, the client application needs to know detailed information on the Features stored in a WFS service. This information can be requested from the WFS service using the message format defined in the DescribeFeatureType interface. The result of this request is provided in the form of an XML Schema document that describes the data model of the corresponding Feature type (attributes and their data types, geometries and their types).

### *WMS*

The WMS specification (version 1.1.1) was published as an OGC implementation specification in 2001 (*OGC* 2001). A WMS-compliant map service provides map data for its client applications in the form of an image. Independently of the internal data management solutions, a WMS service always delivers a raster or vector map image as a response to the received query message. The most typical application for a WMS service is when the client device is a limited-capacity terminal requiring precomputed visualisation of the spatial data in the form of a raster image. When requested, a map server must be able to describe its services in response to the GetCapabilities query. The response is expressed in an XML-formatted metadata file.

The map information is requested from the WMS service by sending a GetMap message. The content of the map is divided into themes, or map layers. The client application must indicate which layers to include in the map image. For each map layer, the server may provide a list of styles in which the corresponding layer can be visualised. The client selects the style for each layer. In the GetMap request, the area of interest is indicated by four coordinate values, given in a specified coordinate system.

The desired map coordinate system, pixel dimensions of the resulting image and the format to be applied can also be indicated by the request parameters.

#### *OpenLS Presentation Service*

The OGC has also carried out a standardisation initiative focusing on the needs of mobile applications requiring spatial data. The process is called the OpenLS initiative. The OpenLS process has yielded specifications advancing the development of interoperable mobile location services (*OGC* 2004). The work of the OpenLS initiative may affect the evolution of mobile location services even more than the above-mentioned basic spatial data service specifications. Given the application-oriented approach, the developers of various mobile services are also affected.

The OpenLS specification focuses on the interfaces related to the Directory Service, Route Optimisation Service, Geocoding Service and Presentation Service. In the Presentation Service specification, the service functionality has been somewhat extended in comparison with the WMS GetMap interface. The most important conceptual difference is that the map content is divided into two categories: the background map and the overlaid additional information. The overlay information may be points of interest (POI), optimised route, user's own location etc. The responsibilities of an OpenLS Presentation Service thus include the task of visualising the overlay geometries, provided as part of the incoming query, on top of the background map retrieved from its own database.

The second major addition is the concept of centre-point context. In the WMS the spatial extent of the map can be defined only by giving the bounding box of the area requested. In the OpenLS Presentation Service specification, the extent can also be defined by defining the centre point, scale of the map and pixel size of the screen in use (dots per inch, DPI). As such, the specification provides some basic support for taking the user's conditions into account when preparing the map.

### 12.4.3 Use of XML in the architecture

According to the general principles of the Web Services computing model, all the messages in the service invocations will be expressed in XML (*W3C* 2004c). The service interfaces defined by the OGC support this requirement quite well. The WMS GetMap request being the only exception, all the service interfaces specify XML-encoded query messages. Since the proposed service architecture also applies XML-based data encodings, all the messages to be transferred between the layers are expressed in the same syntax. Freely available generic XML tools, such as DOM and SAX parsers, together with the validation and serialisation functionalities they possibly provide, can be useful in the query processing and response generation.

According to the WFS specification, spatial data resulting from the service will be encoded in the GML format. Due to this requirement, it is also logical to employ XML technologies in the subsequent steps of the process flow. The GML file may also contain a URL reference to the on-line XML Schema document defining the GML Application Schema used. This enables automatic validation checking to be carried out by the XML parser in the subsequent service layer.

Functionalities provided by XSLT processes for the Schema translations make it a perfect tool to be applied to the Data Integration layer. Since Cascading WFS will be used as a query interface on the Data Integration layer, the resulting integrated dataset will still be expressed in GML form.

On the Data Processing layer, varying tools and technologies may be applied, since the task to be carried out is not clearly defined. Simple data transformations can be performed with XSL Transformations, but in many cases, the dataset must be read into a non-XML processing environment for more sophisticated computations. After the process, the results must again be encoded back to GLM syntax and sent to the next layer in the service stack.

The main role of the Portal layer in service result processing is to translate the modified dataset coming out from the Data Processing layer into a visual representation. This process can again be modelled as an XSL Transformation, especially if the resulting visualisation is to be encoded in XML syntax. Examples of this type of encoding include SVG images and X3D models. The use of XSLT as a tool for defining styling properties of a dataset makes it possible to employ the generic XML stylesheet mechanisms. The dataset can thus contain a URL reference to an on-line XSLT file that defines the transformation, making the data file self-describing in terms of visulisation details and still maintaining the total separation of the content from the styling properties.

## 12.5 Service Architecture in the GiMoDig project

### 12.5.1 General

The objective of the GiMoDig project is to develop and test methods for delivering geospatial data to a mobile user by means of real-time data integration and generalisation (*GiMoDig* 2004). The project aims at the creation of a seamless data service providing access, through a common interface, to the primary topographic geodatabases maintained by the NMAs in various countries. Special emphasis will be placed on providing appropriately generalised map data for the user, depending on a mobile terminal with limited display capabilities. In the GiMoDig project a prototype system has been designed and implemented for verifying the validity of the approach. A detailed illustration of the GiMoDig service architecture is shown in Figure 12.5 (*GiMoDig* 2003); the details are elaborated in the following.

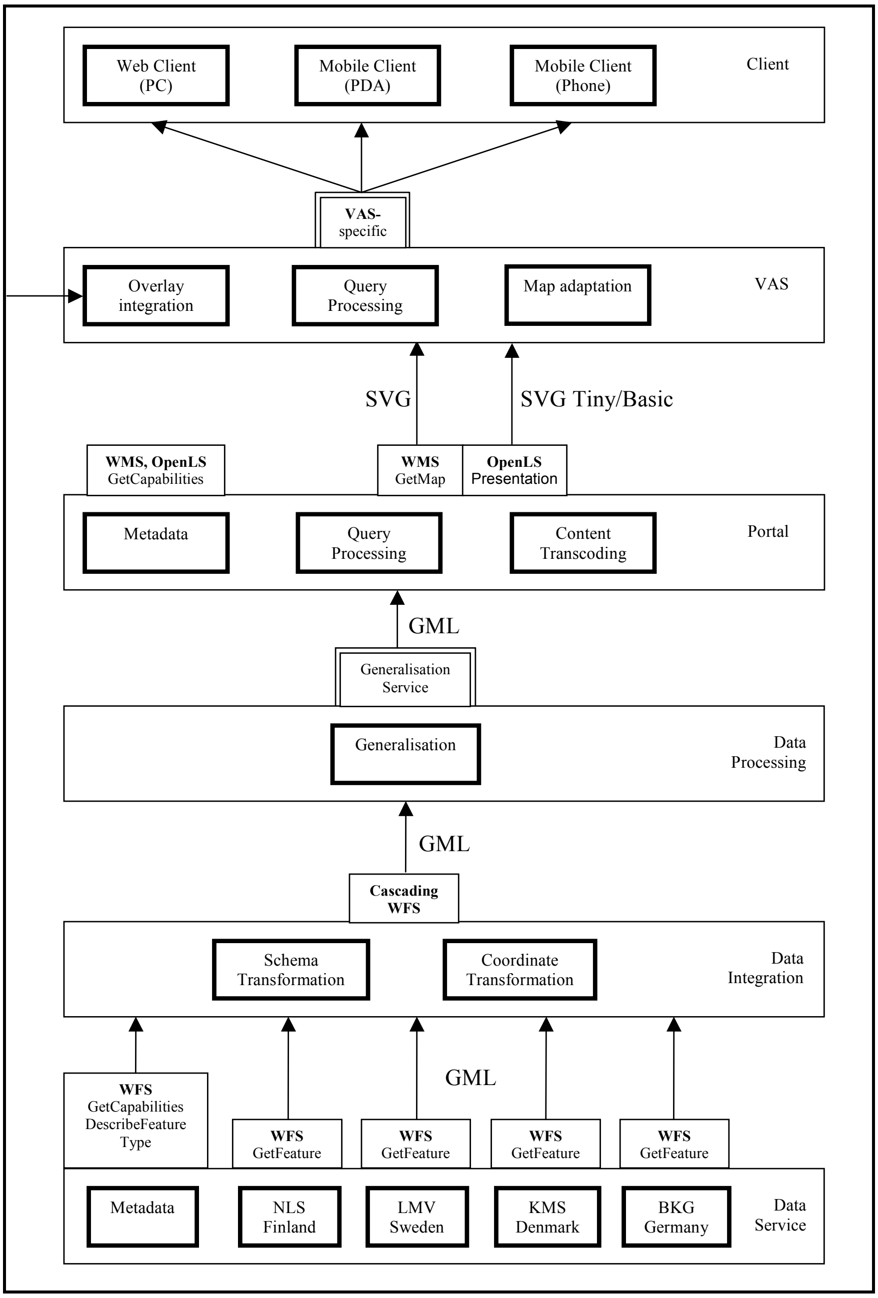


**Fig. 12.5.** The Detailed GiMoDig service architecture. The arrows indicate the direction of reply messages, while the arrows for requests have been omitted. The VAS Layer can access external databases e.g. for retrieving point of interest data. The access interfaces are based on OpenGIS Consortium Specifications, except the VASL and Generalisation Interfaces, which considerably deviate of those mentioned.

### 12.5.2 Query processing

The client platforms considered in the project include traditional Web browsing in the PC environment, a GiMoDig-specific SVG-based client run on PDAs and Java MIDP clients on mobile phones. The service access on the Value-Added Service (VAS) layer will be based on a proprietary, use case-specific query interface. One of the main research topics in this respect is the use of context parameters for adaptive map displays. These parameters could include detailed information on the user's age, position and current activity and about the mobile device being used in the query.

These context parameters need to be translated into a set of appropriate overlay queries to add required POI and other relevant information to the map display. After conducting the external queries, the VAS layer can add to the Portal Service query all the overlay information to be visualised on top of the map, as determined in the OpenLS Presentation Service specification. It is the responsibility of the Portal Service to translate the map query coming from the VAS layer into an appropriate WFS data query, expressed in terms of the GiMoDig Global Schema. At the same time, the Portal Service must decide on the generalisation to be applied, based on display scale and level of detail (LOD) information provided by the VAS layer.

Access interface of the Data Processing layer is specified in the GiMoDig project, since a commonly accepted query interface for a spatial data generalisation service does not exist. This interface will include a portion to indicate the WFS query providing the source dataset for the generalisation process, and a set of detailed instructions and parameters to guide the generalisation computations. The generalisation query interface will also provide facilities to carry over map overlay information, in case it must be included in the generalisation process.

The Data Processing layer will forward the WFS section of the Generalisation query directly to the Data Integration layer. The Integration Service must subsequently translate the incoming query to the national data models and coordinate systems as well as send the queries to the relevant national WFS nodes, as determined by the spatial extent of the query window. The transformations from the Global Schema to the national data models are carried out as declarative XSL Transformations.

### 12.5.3 Response processing

The lowest layer of the service architecture contains the four national WFS nodes, one in each of the GiMoDig participant countries: Finland, Sweden, Denmark and Germany. These services provide data in the national data models and coordinate systems, encoded in the form of a GML Application Schema. The Data Integration service and all the services above it are currently running on the GiMoDig main server at the Finnish Geodetic Institute.

Following the processes carried out by the Data Integration service, the response data are expressed in the form of the GiMoDig Global Schema and in the common ETRS89 coordinate system. XSL Transformations are defined from each of the national datasets to the common data model. A Cascading WFS interface provides a single access point to all four national topographic databases; thus the service response is encoded in GML form.

In the GiMoDig project, the main responsibility of the Data Processing layer is spatial data generalisation. The dataset received from the Data Integration layer is uploaded to the JTS Topology Suite platform, which is a processing tool providing sophisticated geometric and topologic algorithms for generalisation processes (*JTS* 2004) (*Harrie and Johansson* 2003). After the real-time generalisation phase, the results are still expressed as GML-encoded spatial data that may also include POI data as GML Features.

After receiving the generalised dataset from the Data Processing layer, the Portal translates the data into a map image, taking into account the styling properties indicated in the original Presentation Service query. This process is also carried out as an XSL Transformation. The VAS layer will acquire the resulting map from the Portal Service in the form of an SVG image. Depending on the client application's capabilities, the VAS layer may transcode the image into raster form, add user interface components, scripting code for local processing etc, and finally returns the results to the client. A sample map display of the GiMoDig service is illustrated in the Figure 12.6.

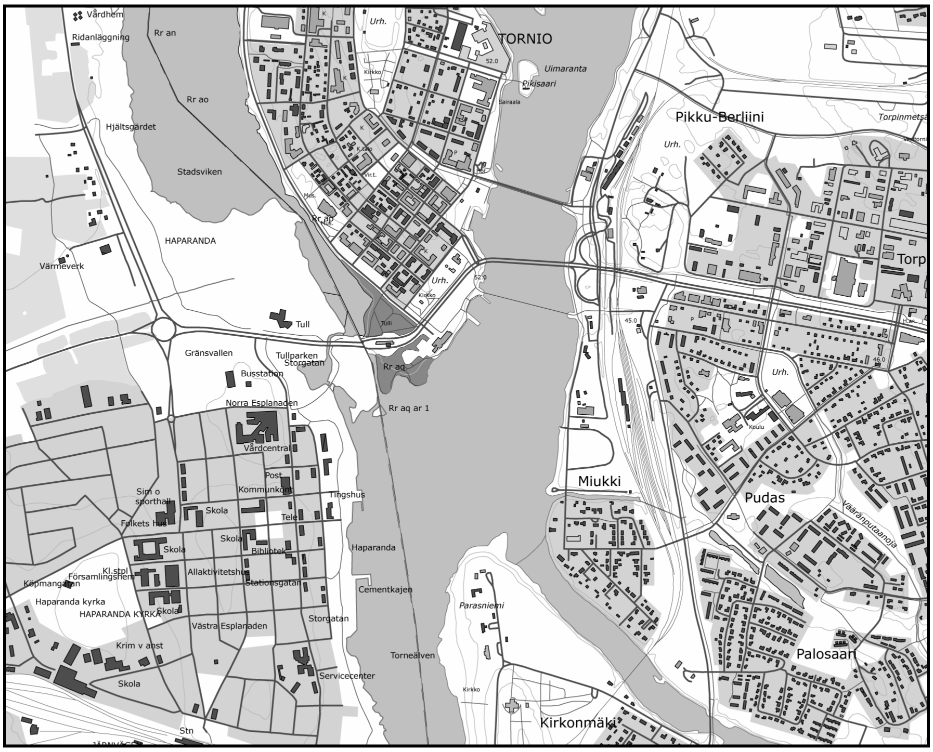


**Fig. 12.6.** A sample map display of the GiMoDig service. The left-hand side of the image shows map data coming from the GiMoDig WFS server in Sweden and the right-hand side from the server in Finland.

## 12.6 Other related studies

The use of XML techniques in the context of geospatial data has been discussed widely. Relating articles include the early work of Zaslavsky et al (2000) on the use of XML to improve spatial data interoperability, Wiegand et al (2003) on the use of XML to query heterogenous geospatial databases and the discussion of Lehto (2000) on the merits of applying XML in Web-based applications. Wei et al (2001) discussed the idea of the XSLT-based GML-SVG transformation, an approach also used in the GiMoDig Portal Service.

A service architecture similar to the one discussed here was also presented by Bernard and Wytzisk (2002) in the context of spatial-temporal simulation. Visser et al (2002) described an ontology-driven middleware called BUSTER for integrating heterogeneous data sources; an approach closely resembling the GiMoDig Integration Service layer.

The layered service architecture discussed in this chapter can be seen as a predetermined service chain, also called an aggregate service (opaque chaining). In this case, the service chain appers as a single service to the user, hiding all the chain details from the user. Two other, more flexible service-chaining architectures are called user-defined (transparent) and workflow-managed (translucent) service chains (*Einspanier et al* 2003). In both of the latter chaining types, the service workflow is not fully controlled by the service, but is composed dynamically, either freely by the user (transparent) or by selecting from a set of chains provided by the workflow manager service (translucent). Some recent research has proposed more advanced service-chaining methods, such as an ad-hoc workflow-managed service chaining, in which the chain is not predetermined, but derived automatically from the user's query sentence by means of a chain composition service (*Bernard et al* 2003).

However, as the service architecture described in this chapter is designed to be open in every service layer, flexible service chaining is still possible if regarded as appropriate. For example, a more advanced VAS layer could make use of local GML Data Services, bypassing all three central service layers. In a similar way, the Portal Service could bypass the Data Processing layer completely when no generalisation is needed, and access the Data Integration layer directly. As such, the service chain can be seen as dynamically composed, without a dedicated external workflow manager.

## 12.7 Discussion and conclusion

In this chapter we have studied system architectures for using XML in mobile cartographic applications. It has become clear that XML technology can be used extensively througout the whole service chain. The presented approach applies generic XML processing mechanisms to produce appropriate visualisations from heterogenous geospatial data sources, appropriately formatted, styled and generalised for different end-user access devices and usage situations. XML encodings are applied both for geospatial datasets and for vector-formatted map images. XML Schema is used for data modelling and online validation. A standardised generic XML transformation mechanism, XSLT, is applied for carrying out most of the necessary data transformations.

The system development is further supported by the availability of many open source software packages for XML processing. Regarding mobile client platforms, XML technology, especially SVG, can be easily used on standard laptop personal computers when high-speed telecommunication networks are available. In the case of smaller mobile devices and networks with limited bandwidth, more optimised technology is often still needed for this last link in the service chain. The situation may change quickly, however, with the development of digital technology.

The discussed open service architecture provides a flexible platform for building services that can be adapted to actual user needs and other context parameters. The use of standardised service interfaces makes the architecture accessible on every layer thus enabling the service to support widely varying client application capabilities. Each of the five layers in the architecture has a well-specified, distinct role in the response processing. The Client layer (possibly together with the Value-added Service layer) manages the user interaction. The main role of the Portal layer is to separate presentation details from the data content. The Data Processing layer is responsible for the real-time processing that somehow modifies the response dataset. The main task of the Data Integration layer is to join and harmonize datasets coming from several, possibly heterogenous sources. Data Service layer takes care of the data management and retrieval.

The presented case implementation, the service architecture of the GiMoDig project, demonstrates the benefits of the approach discussed in this chapter. The prototype service of the project provides a single access point to the primary topographic datasets from four European countries (Finland, Sweden, Denmark and Germany). The four originally heterogenous datasets are transformed into a common data model and coordinate system in a real-time process. The service also enables context-sensitive map displays that adapt to the actual conditions and preferences of the end-user. As an early demonstrative example the GiMoDig prototype envisages the future seamless Pan-European geospatial services supporting increasingly mobile travelers while navigating in foreign environments.

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# 13 A Survey of Map-based Mobile Guides

Jörg BAUS[1], Keith CHEVERST[2], Christian KRAY[2]

[1]Department of Computer Science, Saarland University
[2] Computing Department, Lancaster University

**Abstract.** In this chapter, we present an overview of mobile guides that rely on maps or map-like representations in providing their services. We discuss technical issues as well as problems related to human factors that mobile guides have to cope with in order to assist their respective users. The main part of the chapters describes a number of relevant systems in the field of mobile guides, ranging from influential work such as Cyberguide to systems that offer unique services such as TellMaris. The comparison is based on the issues we identified initially. We conclude with an outlook on future directions such as collaborative usage, new means of interaction and further personalisation of mobile services.

## 13.1 Introduction

Mobile guides and navigational assistants have come a long way since the first research prototypes (e.g. (*Abowd et. al.* 1996)). For the time being, there are not only many different research projects working on the topic (some of which we will present in this chapter), but also several commercial services available to mobile phone users and car drivers (e.g. (*Garmin* 2003)). Recent developments such as the emergence of ubiquitous computing (*Weiser* 1991) and the evolution of portable computing devices (such as Portable Digital Assistant (PDAs) and laptop computers), wireless communication (such as wireless LAN or the General Packet Radio Service (GPRS)) and localisation means (such as the Global Positioning System (GPS)) have further increased the pace of progress. The arrival of the new generation of mobile phones that provide a higher bandwidth and allow for a more precise localisation will most likely have a similar effect.

Therefore, there is a need for a survey of systems providing mobile guidance. Instead of traversing the large number of available systems, we selected systems that either offer unique features (such as resource adaptation) or have influenced the development of later systems. All systems reviewed in this chapter share one common point: they rely to some degree on maps to provide certain services. Maps are used by these systems to represent, for example, the absolute and relative location of objects of interest, their features and spatial relations. For most of the systems reviewed, maps constitute a major part of the interface, and they are also highly relevant in human cognition (e.g. for conveying survey knowledge or wayfinding (*Golledge* 1999)). Since the benefits, drawbacks and potential applications of maps in a mobile context are discussed in depth elsewhere in this book, we will focus on analysing the capabilities of existing mobile guides.

However, before we compare the different systems, it is important to introduce the notion of context-awareness we will use throughout this chapter. Various definitions for this term exist, but for the purposes of this chapter we adopt the definition provided by Dey (*Dey* 1998):

> "Any information that can be used to characterize the situation of entities (i.e., whether a person, place, or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity, and state of people, groups, and computational and physical objects."

Exploring the issues (both human factors and engineering challenges) surrounding context-aware systems was a key motivation behind many of the early mobile guide systems including both Cyberguide (*Abowd et. al.* 1996) and Guide (*Cheverst et. al.* 2000). As one might expect, the most important aspect of context to be utilised by mobile guides is that of location. Obviously, such mobile guidance systems belong to a class of systems commonly referred to as location-based services (LBS).

Mobile guidance systems provide their users with location-based services such as navigational assistance where and when they need them most. However, this convenience does come at a cost: A system aimed at supporting the user in situ requires some compromises compared to a stationary system, such as a traditional desktop computer. Firstly, the technical resources (such as bandwidth, storage capacity, display size, and computational power) available in a mobile scenario are severely restricted – a situation that is not likely to change in the short to medium term. In addition to technical resources, the user's cognitive resources are also likely to be under strain in a mobile scenario, e.g. when the user is performing a secondary task.

Furthermore, situational factors gain importance compared to a stationary setup, where the situation is more or less static (i. e. the user sitting in front of their computer). The affordances of the environment, for example, strongly influence the way, in which the user interacts with a device: if they are driving a fast car, navigational instructions should differ from those given to a slow-walking pedestrian. Additionally, the user's abilities and properties can have a strong impact not only on the way the system best interacts with the user but also on what services a user requests. For example, a deaf user has little interest in acoustic directions, and a user that is fairly familiar with an area most likely does not appreciate elaborate explanations about known sites.

A key factor for determining the current situation is the position of the user. Unfortunately, there is no technology that can measure the current position precisely at all times. For example, electromagnetic devices such as electronic compasses or accelerometers suffer from interference by electromagnetic fields, the popular Global Position System (GPS) does not work properly inside buildings or in narrow alleys (due to occlusion and reflections off the wall) and light-based systems such as infrared beacons require a tight infrastructure. Hence, mobile guides should be able to cope with positional information of varying quality.

This applies for information access in general: most systems assume a permanent and reliable connection to a server in order to work properly. However, especially wireless connections are prone to (temporary) outages. Therefore, it is desirable for mobile guides to function (to some degree) even if there is no connection or if information is partially unavailable.

A further challenge is how to best design situated interfaces that enable the user to access the services provided by a system in an intuitive way. Due to the limited resources of most mobile devices – e.g. in terms of display size, speech recognition, and computational power – this task is even more difficult than in the case of stationary systems. Moreover, situational circumstances may impose additional constraints such as audio output being inappropriate in a church.

Generally, a mobile system suffers from severe resource restrictions while, at the same time, it also has to deal with the continuously changing situation of the user. This is one of the main future challenges in designing mobile guides.

The remainder of this chapter surveys a representative selection of mobile guide systems in order to reveal to the reader some of the history of mobile guide systems and the state of the art. The survey is also used to discuss a set of issues pertinent to mobile guide systems and to highlight some of the key challenges that remain to be tackled by future mobile guides.

## 13.2 Mobile Guide Systems: A Representative Survey

There are already more mobile guides – either commercial ones or research prototypes – than we can describe here. For example, there are several EU funded projects such as CRUMPET (creation of user-friendly mobile services personalised for tourism) (Poslad et. al. 2001) or PEACH (personal experience with active cultural heritage) (Peach 2003) that aim at building navigational assistant systems. In addition, further projects are continuously initiated such as the new Special Research Centre in Stuttgart "Umgebungsmodelle für kontextbezogene Systeme" (environment models for context-aware systems) (Rothermel 2003, Hohl et. el. 1999) and virtually every car-manufacturer nowadays offers more or less sophisticated car navigation systems. Our goal in deciding which systems to review here was to select a representative subset of all projects and systems concerned with map-based guidance. Therefore, we focused on systems that offer unique services (such as the transparent transition between indoor and outdoor usage) or that have been influential throughout the field such as the Cyberguide project, which was one of the first mobile guides (Abowd et. al. 1996). We will present the systems in chronological order according to the articles cited for the corresponding project.

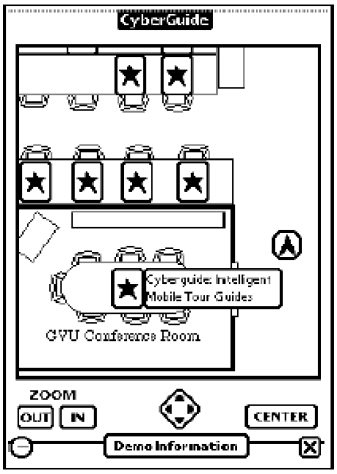


**Fig. 13.1.** An indoor-map provided by the Cyberguide system (Source: (*Abowd et. al.* 1996)).

Abowd and colleagues (*Abowd et. al.* 1996) developed the Cyberguide system, which provided simple schematic black and white maps and information services about predefined indoor and outdoor locations (see Figure 13.1). All maps and other information were static and stored on the mobile device. Indoor positioning relied on infrared beacons, and GPS was used outdoors.

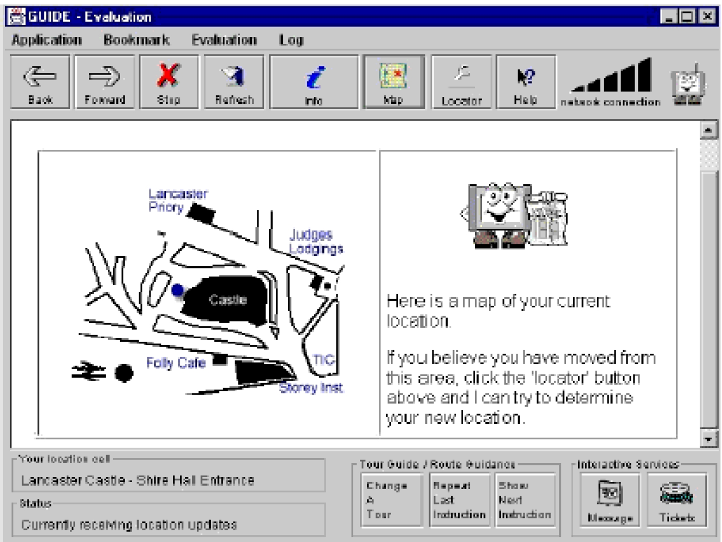


**Fig. 13.2**. Map and information as provided by the GUIDE project (Source: (Cheverst et. al. 2000)).

The second project in our overview is the GUIDE project (Cheverst et. al. 2000). The system provides information about the city of Lancaster (see Figure 13.2). The mobile component is connected wirelessly to an information server. Based on the current, i.e. closest, 802.11 access point the mobile guide senses its approximate location and provides guidance and information services through a browser-based interface.

The Hippie/HIPS project (*Oppermann, & Specht* 2000) has been concerned with the development of an exhibition guide, which provides guidance and information services. The mobile device senses infrared beacons installed near all exhibits. From these observations about the visitor's journey through the exhibition the systems creates a user profile and suggests interesting exhibits augmenting them with background information.

The project MapViews (*Rist et. al.* 2000) was a testbed to investigate how a small group of geographically dispersed users can jointly solve location and route planning tasks while being equipped with different communication devices. The approach to provide the users with appropriate information displays is to generate presentation variants – different views – from a common formalised representation of the information to be presented. A central Map Layout (ML) server provides these different views (see Figure 13.3).

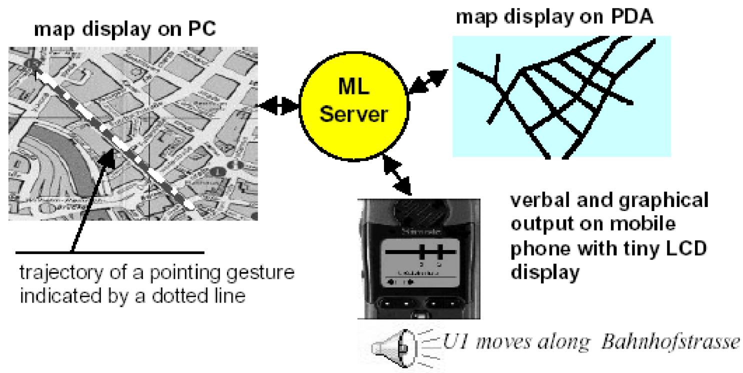


**Fig. 13.3.** Different maps generated by MapView's map server (Source: (*Rist et. al.* 2000)).

Baus and colleagues (*Baus, Kray & Krüger* 2001) developed a hybrid pedestrian navigation system in the project REAL, which provides guidance and information services. The system helps the user to find locations by generating graphical route descriptions (see Figure 13.4). Information about the users' position in the environment results from a combination of GPS/compass positioning outdoors and the use of infrared transmitters (beacons) inside buildings. The system has the ability to adapt the graphical presentations (a static map that is dynamically annotated) according to various technical as well as cognitive resource restrictions such as the quality of positional information or time pressure.

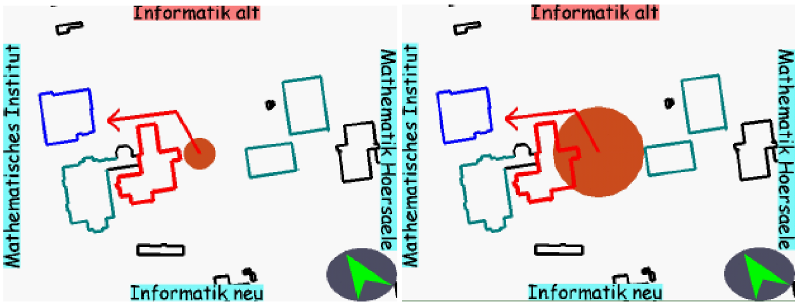


**Fig. 13.4.** Maps as used by the outdoor component of the REAL System (Source: (*Baus* 2003)) – the circles of different sizes in the centre of the pictures indicate positional information of different quality and precision.

The LoL@ (local location assistant) system (*Anneg et. al.* 2002, *Pospischil, Umlauft & Michlmayr* 2002) is a mobile tourist guide for the city of Vienna (see Figure 13.5) designed for the next generation of mobile phone networks, the Universal Mobile Telecommunications System (UMTS). It was developed at the Forschungszentrum Telekommunikation Wien and is currently undergoing empirical evaluation.

Within the SmartKom framework, where a multi-modal dialogue system allows for speech, gesture, and mimic interaction (Wahlster 2002), a mobile communication assistant is currently under development. The mobile assistant offers information and navigation services using GSM/UMTS for communication and GPS for positioning purposes. The information presentation combines maps, natural language and an anthropomorphic presentation agent.


**Fig. 13.5.** A map generated by the Lol@ System (Source: (*Pospischil, Umlauft & Michlmayr* 2002)).

The goal of the Deep Map project (*Kray* 2003) at the European Media Lab in Heidelberg was to build a tourist guide for the city of Heidelberg (see Figure 13.6). Aside from providing several services related to space, it was the first system to provide a sophisticated multi-layered approach for the determination of the user's current position, taking into account sensor data, inferred knowledge and information gathered from the user of the system.

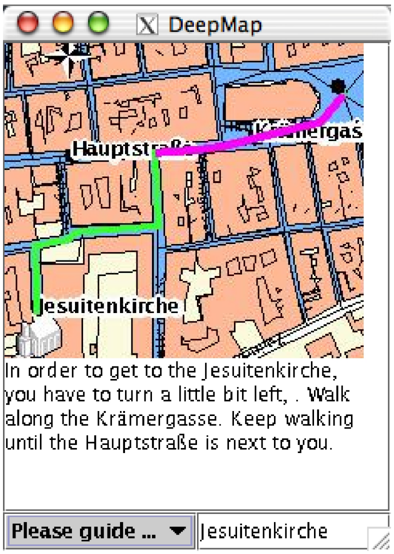


**Fig. 13.6.** A map generated by the Deep Map system (Source: (*Kray* 2003)) showing a route with the current segmented highlighted along with the corresponding directions.

TellMaris is a prototype (see Figure 13.7) of a mobile tourist guide that was developed at Nokia Research Center (*Kray et. al.* 2003, *Laakso* 2002). It is one of the first mobile systems that combine three-dimensional graphics with two-dimensional maps and that runs on a mobile device (a mobile phone). The maps and 3D models used are statically stored on the phone and are synchronised while being displayed. The first prototype was developed for the city of Tonsberg, Norway to help boat tourists in finding locations of interest (e.g. hotels). During the summer of 2002 a first exploratory field test was conducted with a small number of volunteers (see (*Laakso* 2002)).


**Fig. 13.7.** TellMaris-Prototype (Source: (*Laakso* 2002)).

Based on the experiences gained in the project REAL Krüger and colleagues (*Krüger et. al* 2004) developed the BMW Personal Navigator (BPN). The System combines a desktop event and route planer, a car navigation system, and a multi-modal, in- and outdoor pedestrian navigation system for a PDA and offers a situated personalised navigation service. Furthermore, it seamlessly integrates two- and three-dimensional maps (see Figure 13.8).

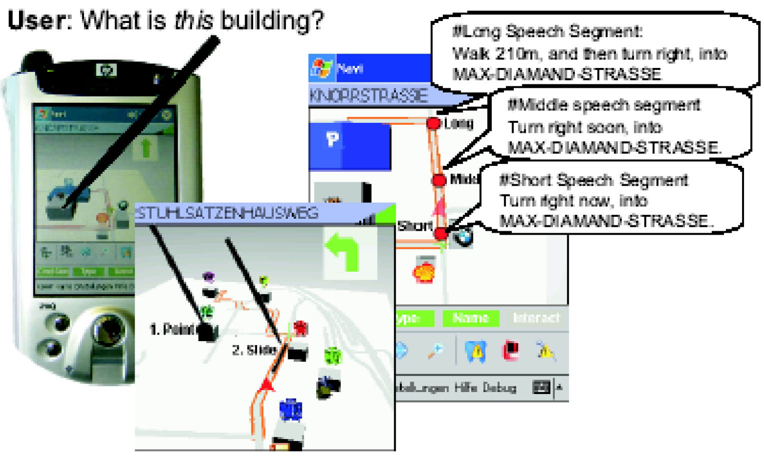


**Fig. 13.8.** The multi-modal interface of BPN (Source: (*Krüger et. al* 2004)) illustrating multimodal input using speech and pointing gestures as well as the resulting output.

## 13.3 COMPARISON/ANALYSIS

After the general introduction of the systems that we are analysing in this chapter, we can now compare them according to the features and issues identified in the introduction section. Table 13.1 summarises the main findings we will report in the remainder off this section.

**Tab. 13.1.** Summary of comparison (UM stands for user model, CM for context model, CS for client-server, IA for interacting applications, MBB for multi-blackboard and MAS for multi-agent system

| | **positioning** | **situational factors** | **adaptation capabilities** | **interface/ interaction** | **maps used** | **architecture** |
|---|---|---|---|---|---|---|
| **Cyber-Guide** | Map interaction | None | None | Unilingual | Hand-crafted 2D bitmap | IA |
| **Lancaster Guide** | WLAN, Interaction | Dyn. UM, CM | No network No position | Unilingual, User study | Hand-crafted 2D bitmap | CS |
| **HIPS/ Hippie** | IR beacons | Dyn. UM | Granularity | Unilingual | Hand-crafted 2D bitmap | CS |
| **MapViews** | Not specified | None | Display size | Unilingual | Generated 2D bitmap (3D graph) | CS |
| **REAL** | GPS, IR beacons | Static UM CM | Resources Inform user | Unilingual | Generated 2D bitmap 3D model | IA CS |
| **LOL@** | (UMTS), Interaction | None | Inform user | Unilingual | GIS generated 2D Vector | CS |
| **Smart-Kom** | GPS | Scenarios | Inform user | Multi-lingual, Multimodal | GIS generated 2D vector | MBB |
| **Deep Map** | GPS, Interaction | Static UM, Static CM | No network No position No information | Multi-lingual | 2.5D vector, rich geoencoded DB | MAS |
| **TellMaris** | Map interaction | None | None | Unilingual, 3D + 2D, User study | 2D bitmap, 3D model | IA |
| **BPN** | GPS, IR beacons, Map interaction | None | None | Bilingual, Multimodal | GIS generated 2D Vector, 3D vector | IA |

### 13.3.1 Positioning

In terms of positioning, roughly half of the systems presented in this chapter rely on GPS. Another significant category is represented by systems that use light to determine the user's current position (mainly infrared light), e.g. beacons that send out IDs, which enable the corresponding receiver to look up the location in a table/database. Some systems have been designed from the beginning to support various sensors, i.e. they are adaptable with regard to the technology used to measure the user's position.

Four systems (GUIDE, LOL@, REAL, and Deep Map) include some means of interacting with the user to determine their position. These capabilities range from simply clicking on designated alternative positions (REAL) taken from a static list to enabling the user to choose from dynamic lists based on the last known position of the user (GUIDE and LOL@). Only Deep Map includes a sophisticated model based on position history, situational knowledge, and visibility (see (*Kray* 2003)), which allows for the dynamic generation of interactions tailored to the current user and situation.

### 13.3.2 Situational factors

The consideration of situational factors is another relevant feature for systems aimed at real-world use. We therefore compared all systems in terms of whether they take into account both user and context-related information. (Due to its fundamental importance, we did not subsume the user's current position under context but rather consider it a 'basic feature' of a system.) Additionally, we analysed how they handle the impact of the user's current task. Roughly half of the reviewed systems include user-related information but they differ greatly in how this information is included. Hippie contains a sophisticated user-model, which is continuously updated, and which is used throughout the entire system. GUIDE also utilises a dynamic user model in order to track potential changes in the user's interests in specific areas such as maritime history. Consequently, the level of detail presented to the user when describing a specific location can change if the current interest value exceeds a given threshold. In contrast, the REAL system relies upon a static user model that is used to adapt the presentations it generates as well as the tour planning process. Deep Map also uses a static user model.

This comparison is nearly mirrored in the case of contextual information and its inclusion into the systems. GUIDE as well as REAL takes into account contextual information for specific tasks: presentation and content selection in the former case and during tour planning in the later case. SmartKom distinguishes three 'scenarios', which are used to adapt the presentation accordingly. Deep Map currently relies on a small static contextual model but considers contextual information on all stages of computation. It also takes into account the task the user is currently performing, e.g. in object evaluation.

### 13.3.3 Adaptation capabilities

A further, very relevant, feature set for real-world applications is the ability to adapt to changes in their physical and virtual environment. Resource limitations on the cognitive and technical side fall into this category. REAL is the only system that can dynamically adapt to the varying availability of resources. Although most other systems have been optimised for mobile use, they are – at most – resource-adapted (following Wahlster and Tack's taxonomy (*Wahlster, & Tack* 1997)).

Another common problem in real-world applications lies in the lack of relevant information: often, information (such as situational factors or database entries for world objects) is only partially or not at all available. In this case, a system should gracefully degrade instead of abruptly failing. Only GUIDE, SmartKom, and Deep Map incorporate this feature. GUIDE can handle network outages – which result in the unavailability of the central database – by relying on a scaled-down local version. SmartKom has been designed to be robust against such events: although it does not compensate for it, it is able to inform the user about the event and to continue to provide services that are unaffected by the problem. Deep Map can handle the loss of network connection in a similar way to GUIDE. However, while Deep Map's underlying model was designed to handle the lack of availability of relevant information, this part of the system has not been implemented.

Since knowledge about the user's current position is a central factor in determining their current situation, it is highly important for a real-world application to be able to adapt to the potentially varying quality of positional information. Consequently, all but two of the systems reviewed in this chapter provide some mechanism to address this issue. Cyberguide and SmartKom currently do not hold any of such adaptation mechanisms. Hippie distinguishes two levels of granularity: either the room that the user is currently located in is known, or the exhibit that they are facing is known. TellMaris entirely relies on manual navigation (although later versions will employ GPS) and can therefore operate independently of the user's current position. Both GUIDE and LOL@ provide a means to select the current position further by dynamically generating a list of street names (and also a list of sights in the case of GUIDE) based on the user's last known position. LOL@ can also communicate the imprecision of a position to the user. To do so, it displays the current position on the map as a circle, which grows with imprecision. REAL relies on the same metaphor (see Figure 13.4), and also provides some simple means of interaction: clicking on certain highlighted spots on the map allows the user to specify their current position more precisely.

While most systems provide one or more means to address varying quality of positional information, only GUIDE, LOL@, and REAL allow for some limited interaction to cope with this problem. Deep Map goes beyond this in several ways: it provides a sophisticated algorithm for dynamic interaction that is optimised for speed and minimal interaction. In addition, these interactions are not tied to a specific modus. Furthermore, it can employ induced frames of reference to address the (partial) lack or imprecision of positional information (*Kray* 2003).

### 13.3.4 Interface and user interaction

The user interface presented by a system and the available means of interaction are the parts of the system that are most apparent to its user and so clearly these factors greatly influence a user's perception of the system. Hence, we include in our review a comparison in terms of support of natural language and multi-modality. Most systems are statically tied to one language. GUIDE, REAL and BPN allow for several different languages, but are still static. Only SmartKom and Deep Map support dynamic multi-lingual interaction by introducing a semantic layer that encodes interactions in a way that is independent of the actual target language. While Deep Map relies on preverbal messages (*Kray* 2003), SmartKom goes a step further by employing a full plan-based mechanism and sophisticated language processing features.

The same is true in terms of multi-modality, since SmartKom has been specifically designed to account for various modalities such as speech, gestures, and mimic expressions. Deep Map in its current implementation as well as Hippie, LOL@, and REAL are limited to verbal/textual input and pointing. BPN with its research focus on multi-modal interaction allows the user to interact with a navigational 3D map through the combined use of speech (English and German) and stylus gesture.

Maybe due to the fact that many systems still face numerous technical and interface issues, empirical evaluation of most systems is not yet a prime concern. From the literature, it seems that only a few systems have been evaluated to some degree. The GUIDE system was used with 'real' tourists visiting the city of Lancaster, who were then interviewed and asked to rate their experience with the system. In (*Cheverst et. al.* 2000) the findings of a small user study based on direct observation, audio recording and a time stamped log of user interactions is reported. In this study the majority of users appreciated the ability to use the system as a tour guide, a map or a guidebook. In their opinion location-aware navigation and information retrieval mechanisms were useful and reassuring and they trusted the information and navigational instructions provided by the system.

Within the TellMaris project, a further study was reported (*Coors et. al.* 2003), which investigated the usefulness of combined 3D/2D presentations with a limited number of participants and a prototype. 3D maps were received positively, although some users complained that they had difficulties in comparing the 2D and 3D maps provided by the system, which they attributed to some lack of correspondence between them. In the 3D map the user had the possibility to choose between a walking level (pedestrian view) and a flying level (birds-eye view). In the study, the flying mode was found much easier for navigational purposes. Further user studies have been announced but, as far as we know, these have not yet been publicly reported.

### 13.3.5 Use of maps

One reason why a large share of mobile guides relies on maps is certainly their pervasive use in paper guides, which are familiar to most people. Mobile assistants can go beyond their paper-based ancestors in several ways. They can dynamically select what section of a map to display, at what scale and what to depict on the map as well as personalising it to the current task and user. In doing so, mobile guides can use or generate different types of maps ranging from simple hand-crafted black and white sketches (e.g. *Cyberguide*) over 2D-maps similar to paper maps (e.g. *LoL@*) to animated 3D maps (e.g. *TellMaris and BPN*). For the maps automatically generated by the different systems the databases used to produce those maps also vary greatly from simple bitmaps (e.g. *GUIDE*) over vector-based GIS server (e.g. *BPN*) to rich databases using abstract representation formats and relations to maintain a detailed model of the real world (e.g. *Deep Map*).

Maps are also used in the context of different services. Aside from navigation support and the presentation of geo-related information they also serve as a means of interaction. For example, in TellMaris and REAL, maps are used to enable the user to locate themselves by clicking on the corresponding spot or to access information about items depicted on the map.

Within the BPN project, the user can interact with 3D navigational maps using speech and gesture (see Figure 13.8). The navigational maps are visualisations of an environment model, which can be represented in a 3D perspective from different selectable views, e.g. from birds-eye view. In the Lol@ system the main interaction metaphor is that of a web browser, within which the system displays a two-dimensional map and where the user can trigger actions or request information by clicking buttons or following links.

With the GUIDE system, the user can request to view a sketch-like map of their surrounding area (a typical example of such a map is illustrated in Figure 13.2) and if the user is currently using the system to navigate to a particular attraction then (in addition to providing a textual description) the system augments the displayed map with a simple animation to highlight the path that the user needs to take.

It is interesting to note that, as part of the user studies conducted under the GUIDE project, users were asked for their opinion on the suitability of a variety of 2D map representations. In cases involving both the Compaq iPAQ and the slightly larger Fujitsu Teampad end-systems, the majority of users questioned preferred a low fidelity representation of the map rather than the kind of higher detailed representation that is produced when simply digitising a typical paper based map. Indeed, users expressed a desire for attractions represented on the map to be shown in a way that emphasised their location in relation to other attractions and other major navigation points such as cross-roads. Furthermore, it was generally felt that achieving such emphasis and salience of attractions outweighed the need to represent attractions on the map in their true scale.

### 13.3.6 Architecture

Another point of practical importance is the architecture of a system. While not being directly apparent to the user, it has a serious impact on the system in terms of extensibility and adaptability. Hence, we compared all systems with respect to what type of architecture they are built on, and how interaction between different components is realised. Although all systems rely on a modular architecture, they do so in different ways. Hippie, GUIDE, and LOL@ are based on the client-server paradigm: a 'client' (i.e. *a web browser*) accesses a 'server' (i.e. *a web server*). While this approach allows for the easy addition of multiple clients, it highly depends on a reliable connection between client and server, which is not always given (e.g. in wireless networks). In addition, the server is a single point of failure, which makes this approach less robust than less centralised ones. However, the architecture of the GUIDE system also caters for a local server component which is capable of serving pages from a local cache when connectivity with one of the main GUIDE servers cannot be established.

Cyberguide, TellMaris and BPN are built using interacting applications. BPN, for example, uses externally generated navigational information from a GIS server. This information about streets, landmarks and references to maps and 3D models is stored on the mobiles device. During a visitor's trip, the information can be updated by server access via mobile phone or a Bluetooth connection to the in-car navigation system. Although this approach is more decentralised, it has some drawbacks: applications may be specifically designed for a certain device/platform and this may hinder dynamic distribution. Furthermore, their interaction is often problematic because different programming languages may have to communicate and there is no standard on how to realise this. The architecture of REAL is a hybrid that combines a client-server approach with that of interacting applications, therefore inheriting the respective advantages and drawbacks.

SmartKom relies on an approach that was originally developed in the Verbmobil project (*Wahlster* 2002): multiple blackboards are used to enable distributed applications to interoperate. While this approach allows for easy extension, interactions between various components are implicit and hard to track. Multi-agent systems address this issue by introducing an explicit message passing mechanism and also include standardised look-up services. This enables systems relying on this approach (e.g. Deep Map) to compensate for failures of certain components, to dynamically add or remove components, and to transparently relocate components to other platforms. In addition, multi-agent systems facilitate the encoding of contents using a standard language that is explicitly defined. Aside from Deep Map, only LOL@ and SmartKom employ such an encoding scheme.

### 13.3.7 Future directions

The sophistication of mobile guide systems has certainly been increased since the realisation of the first prototypes nearly a decade ago. However, a number of areas obviously require further research and development. Obviously, the issues and solutions discussed in this book point at the one major area for future improvements: the way, in which maps are stored, generated and displayed on mobile devices, as well as how to use them properly in the context of various location-based services.

Progress in technology means that future mobile guide systems may be able to incorporate the use of traditional-looking (although with digital capabilities) paper-based maps, e.g. by employing touch-sensitive electronic paper. Combining such (apparently) traditional tourist navigation material with the latest positioning technology and dynamically updated hypermedia could certainly herald a new paradigm in mobile tourist guides.

One area that mobile guide systems need to support much further is collaborative usage. Exploring a town or city is usually a group activity as tourists travel commonly with a friend, spouse, or husband. Furthermore, a tourist will often be interested in the views and recommendations of other travellers when deciding how to best spend their limited time in a city. However, current mobile guide systems tend to restrict their functionality to the support of an individual user. In the future, we anticipate that mobile guide systems will provide enhanced support for social navigation and functionality to support friends and family when visiting a city together.

Another area where guides need improvement deals with the personalisation issue. Currently, mobile guide systems are quite rigid in the way in which they support interaction with the user. For example, some guide systems offer a push-based approach (e.g. by proactively generating output) whilst other support a pull-based approach, e.g. by enabling the user to select icons on a two dimensional map. A key future challenge will be the design of systems that perhaps offer a choice of interaction styles in order to meet a particular user's preference for combining a relaxed experience (typically associated with a pull-based interaction style) with one that does not require too much effort to find information (typically associated with a more push-based interaction style).

## 13.4 Conclusion

In this chapter we attempted to give a survey of mobile guides that utilise some form of map or map metaphor. We selected a representative set of systems that offer unique features or have been influential in the development of the field, and compared them according to several criteria such as the services they provide, or their adaptation capabilities. These criteria were derived from a number of key challenges that mobile guides have to face, e.g. the continuously changing situation of the user. None of the systems reviewed here addresses all the challenges/issues but some can already cope with a large subset.

In the future, mobile guides will have to take into account more and more situational factors in order to provide their users with a user-friendly experience. In addition, the adaptation to real-world problems such as network outages or the lack of precise positional information will greatly improve the usefulness of mobile guides. Another as yet unresolved issue is the type of architecture that is suitable for mobile guides, e.g. what are the benefits of a client-server approach compared to a multi-agent system.

Although all of the systems reviewed in this chapter use maps to provide services to their users, there are also open questions concerning the use of maps. In most cases maps come in two broad types. One type use the conventional birds-eye view of a map region as seen from above, whereas the other kind, especially the electronic ones, visualise the environment from a perspective view on the ground. This view shows how things might look to an imaginary observer following the route. Which perspective is preferred by the user or supports the user better in navigation tasks remains unclear.

Closely related to this issue are the questions of how to represent the information contained in the system, how to best present it to the user, and how to facilitate the interaction between various services.

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# 14 Position Determination of Reference Points in Surveying

Leonhard DIETZE, Klaus BÖHM

Institute i3mainz, University of Applied Sciences Mainz

**Abstract.** The localisation of reference points is a daily task in surveying. This chapter describes the results of a project for aiding localisation using a mobile service (Mobile Reference Point Localisation, MRPL). A sound concept based on the combination of context-dependent vector representation and the integration of the user position has been developed and is presented here. The implementation of the service is carried out in Java, using SVG as a structural vector format, and leads to a functional prototype. This prototype is then evaluated within the framework of a user test.

## 14.1 Introduction and state of the art

This section first describes the field of application addressed by the research project. Current developments in Location-based Services (LBS) are then considered.

### 14.1.1 Locating reference points without technical support

This research project aims at supporting the localisation of fixed control points using the so-called reference point fields which provide the basic information for further surveying work, such as the establishment of new reference points. The information on reference point coordinates administered by surveying authorities (land registry office, surveying office) is provided by a survey map and a survey station description diagram (referred to as SSDD), among others. The SSDD (cf. Figure 14.1) serves to locate a measuring point at the place involved and to confirm its inalterability as the basis for new measurements.

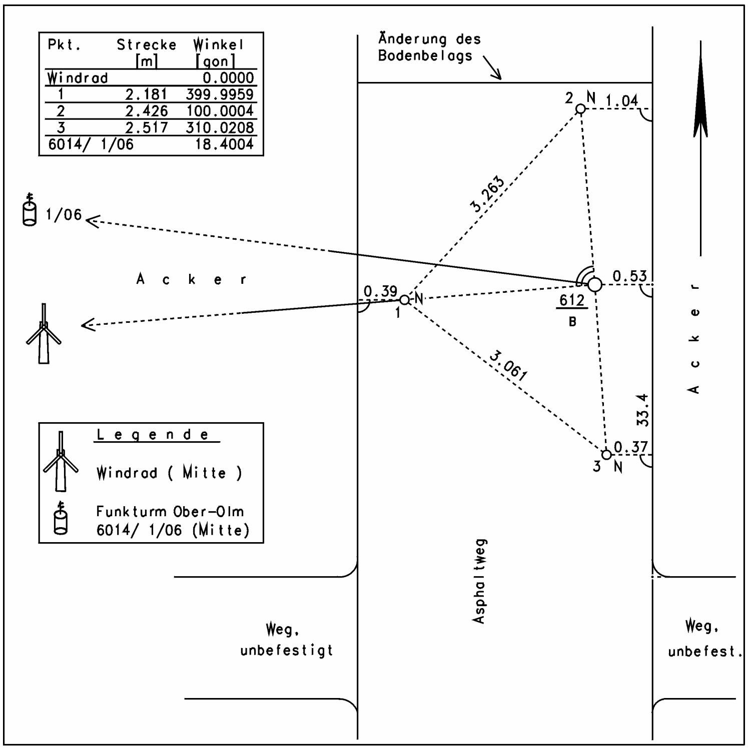


**Fig. 14.1.** Survey station description diagram (SSDD) in rural areas.

The localisation of this point of measurement is often anything but a trivial task. This is particularly true in rural areas. Localisation in urban areas can be assisted by relatively inalterable objects such as buildings or street lamps, but these are frequently lacking entirely in rural areas (e.g. when surveying new development areas). In addition, many reference points and their fallback points are located underground to protect them from damage through agricultural work, and they may be over 100 m distant from the nearest field path (which might not be asphalted).

The research project as presented here addresses these problems and attempts to develop a mobile and flexible solution for the user group of 'land surveyors'.

### 14.1.2 Current approaches using Location-based Services (LBS)

Current development is concentrated for the most part on applications in the fields of tourism, route planning and the processing of up-to-date reports such as weather and traffic information. These applications address platforms such as mobile phones, PDAs and smart phones, based on the cartographic material provided by firms such as 'TeleAtlas' or 'Navigation Technologies'.

The most widely spread type of LBS at the moment is the traffic navigation system. These systems permit traffic to be directed to a particular destination desired by the participant. The determination of the position is carried out by means of a built-in or external GPS receiver, while cartographic material is stored locally. The completeness of any further information in these cartographic sets is determined by the service provider involved and the nearest petrol stations, museums or restaurants, for example, may be contained in them. The display, in general, is either a built-in screen or a PDA. In motor vehicles systems are also used which work with speech output only and do not need a screen. Other applications permit not only traffic direction of individual cars, but can also be used by pedestrians, as they are not built into anything. An example of this kind of application is T-Zones from T-Mobile (*T-Mobile* 2003). The applications mentioned generally use a raster format and support the representation with multimedia content. A further characteristic of these applications is the read-only access to the geographical information available and its intelligent processing.

In the field of surveying, on the other hand, GPS applications are also used to record data. This means that the position of surveying points is determined which can then be used as a basis for geodata acquisition, e.g., recording terrain surfaces. By adding correction signals or using long-term static observations, high precise point coordinates (within 10 mm) can be achieved.

So far the problems described in the introduction are not adequately addressed by current approaches. The main reason is probably the orientation towards target groups in the mass market. The solutions for surveying are equally unsuitable for this application scenario, as they concentrated on extremely precise data and data acquisition with complex and expensive special equipment. For this reason it appears necessary to attempt a specialised solution for the field of activities described above.

## 14.2 Requirements for the 'Mobile Reference Point Localisation' support service

A systematic approach to conceiving a support service first requires the analysis of the demands from the point of view of the user.

The requirements placed upon the MRPL support service and specified in the following are derived from the current process of determination of fixed points. Of particular significance in defining the requirements is the consideration of the target group, their expectations with regard to maps and functionality, and the mental model with regard to the working process.

The general requirements are:

- Easy convertibility from the existing material as provided by the official surveying authorities. Only these maps contain the information necessary for the task of surveying. Widespread, visually attractive maps such as those provided, for example, by tourism LBS platforms, address a different target group and do not contain suitable information.

- The requirement for cartographic representation is the creation of the best possible visualisation solutions based on the cartographic materials hitherto in use, following the representation style as closely as possible. Additional multimedia components are more a bother in this case than a help. The motto 'reduce to the minimum' should be adhered to here.

With regard to functionality, the following requirements are derived from the work process:

- The identification of one's own current position as surveyor and its representation on the map.
- Continuous zooming function, especially from coarse to fine resolution, with a suitable level of detail in the representation.
- The selective representation of the reference points, in order to avoid information overload.
- The search for definite points, e.g. via the distance to the current position or the choice of a definite point number.
- Establishing metrical information (e.g. distance) to aid in the searching process.
- Local access to coordinates and cartographical information (offline).
- The ability to load any coordinates or plans that might be lacking (online download via GSM, GPRS or UMTS).

From the technical standpoint, the following requirement must be met:

- Platform independence as far as the end user device is concerned; this is of quite extraordinary importance, as very different end user devices may be used. Currently, the so-called 'Digital Field Books' are widely used in surveying. PDAs or Tablet PCs have a potential here, as they are much less expensive in relation to what they can do and are also smaller and lighter-weight.

## 14.3 The MRPL service concept

The fundamental concept for MRPL is the combined application of structured, context-dependent vector maps with information relevant to location (GPS).

### 14.3.1 The structured vector format

A vector-based approach in 2D is preferred for maps. Vector data permit functions such as zooming and offer flexibility, in that the level of detail can be varied at different magnifications and line thickness and symbol size can also be adapted at will. Furthermore, the memory required by similarly detailed raster data is greater.

The Scalable Vector Graphics Format (SVG (*W3C SVG* 2003)) used here is very well-suited to MRPL, as it is based on XML and, besides the 2D vector data, it shows a well-ordered structure. This specification of the W3C is already being applied in various projects. Investigation has shown the strength of this format with regard to the data volume in relation to the functions available.

In this XML-based structure, any further information can simply be added, thus permitting constantly changing maps rather than fixed graphics. The information layers can be removed from this structure as wanted, while other layers remain untouched, thus there is no need to create a completely new image. This kind of functionality would normally require an extensive program on the mobile client or on a server (e.g. a map server).

In MRPL the division into different layers in SVG is carried out according to the following pattern:

```
1 <svg>
2       <g id="roads">
3           <path .... />
4           <path .... />
5       </g>
6       <g id="points">
7           <a xlink:href="6800.svg" >
8                 <circle id="6800" ... />
9           </a>
10          <a xlink:href="6900.svg" >
11                <circle id="6900" ... />
12          </a>
13      </g>
14      <circle id="GPS" cx="143" cy="295" fill="red" ... /> ... </g>
15 </svg>
```

One possible division into SVG groups of the various types of information can be seen in this structure. Information on surveying points, streets, buildings, boundaries and street names is contained in these various groups (or layers) from a conceptual point of view. They are displayed according to context, e.g. in a rural environment one does not need street names if one's own position is known via GPS. It should be pointed out that the representation of the user position (GPS) can also be part of the SVG-DOM (cf. the source code in line 14).

### 14.3.2 Integration of the user position with GPS

Determining and integrating the user position with the help of GPS enables a significant simplification of the maps. Certain additional information can therefore be left out which otherwise would serve as an aid in determining one's own position. It is thus sufficient for cartographical representation, e.g. in field areas, to use a simple linear graphic representation with streets and points of measurement, as one's own position need not be determined. In an urban environment, on the other hand, it is necessary to represent additional information such as street names and borders on the map. Information on the user position also provides a basis for various ancillary functions, e.g. 'points at a particular distance from one another', 'calculation of distance to points' etc.

### 14.3.3 Technical background of position determination using GPS

In order to determine a position, a receiver for the NAVSTAR-GPS system (NAVigation Satellite Timing and Ranging – Global Positioning System) is used. NAVSTAR-GPS is a satellite-based location system developed by the US military, and is available to the general public.

The position is determined with the aid of time measurements. A time code transmitted by satellite is received by the GPS receiver and compared to the time of reception. The time difference permits the calculation of the distance between the satellites and the receiver. As the positions of the satellites are known and are also transmitted to the GPS receiver, the 3D position of the GPS receiver can now be theoretically determined on the basis of three distances with a spatial cross-section. Practically, this is done using at least four distances, owing to some inexactitude in the time measurements; thus, a minimum of four satellites is used for determining positions.

## 14.4 Realisation

A Java-based solution was suggested for the practical realisation of MRPL (cf. also (*Brinkhoff* 2003)), using the Java PersonalProfile, an API of the Java MicroEdition (J2ME) (*Sun* 2000), which was specially developed for handheld devices. This is advantageous because an application developed for a mobile device works on different platforms without needing modification. A Java Virtual Machine (JVM) is all that is needed. This means that the MRPL service could work both on hand-held devices (Palm and Windows CE) and on Tablet PCs, laptops and 'digital field books'. Theoretically, even smart phones would be an option.

### 14.4.1 Architecture

According to the requirements, MRPL is to be used as a 'stand-alone' application and only load any missing information when necessary.

As described above, the vector format SVG, conforming to XML, was chosen for the MRPL. The data storage within the program is centrally based on an XML-DOM (Document Object Model). The base modules for pure representation are shown in Figure 14.2. The XML-DOM is of central importance. This contains the 2D cartographical information – read via the 'load data' module. The representation of the DOM is carried out via the visualisation module.

Using this visualisation unit as a fundament, modules for integrating GPS-based positioning as well as for carrying out functions, specific to the application in question, are to be integrated. Figure 14.3 shows the additions to the visualisation modules represented in Figure 14.2 and the relationships among the modules.

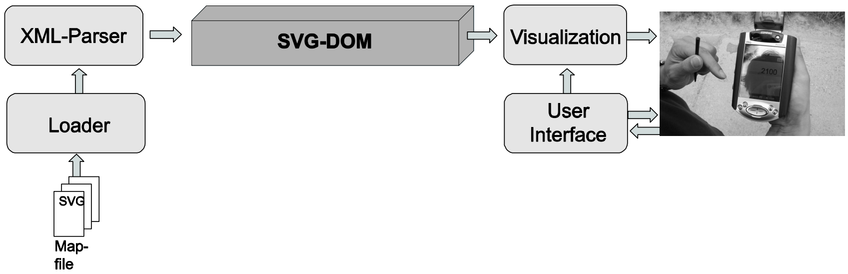


**Fig. 14.2.** The visualisation modules (fundamental functionality)

The XML-DOM remains the central component in all this. The modules for calculating the user position with GPS and the modules for the functions specific to the application in question both manipulate the DOM directly. This integration of information from different sources enables uniform access to all graphic and otherwise pertinent information on the part of the XML-DOM parser. The advantage can be seen, for example, in the viewer in the case of a selective image update of point information without completely new image creation.

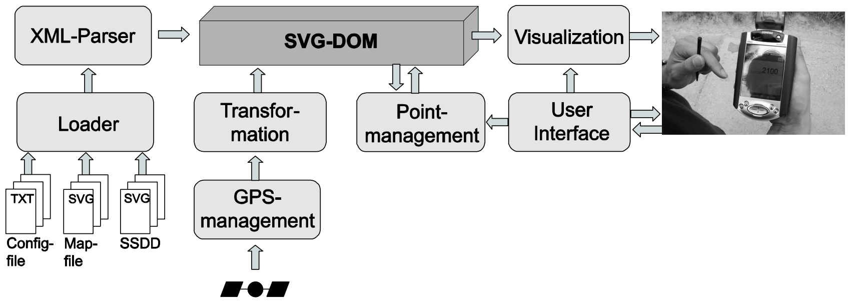


**Fig. 14.3.** All Modules of MRPL

In the following the most important modules are described concretely.

### *Module load data, XML parser, SVG/XML-DOM and visualisation*

For the visualisation unit (cf. also Figure 14.3) the TinyLine toolkit is used in MPRL as the fundamental application, as it was developed especially for mobile devices in Java. TinyLine provides functions for loading and displaying SVG files. Basic functions for navigation are also present. Further information on TinyLine can be found in (*Girow* 2003).

### *Module user interface*

This module combines the units of the user interface. It is responsible for accurate representation according to the different end user devices. A screen shot of the user interface of MRPL showing a map of rural surroundings can be seen in Figure 14.4. This user interface has been optimised for a screen size of 240 x 320 pixels to start with, a size which is supported by most PDAs. Devices with higher resolution, such as a digital field book (cf. Figure 14.6), are automatically supported as well. In addition, the calculations specific to the application in question are accessed and controlled in the module point management system. Additional information, for example ‘survey station description diagrams’ (SSDD) for each point, can be separately loaded using the ‘load data’ module.

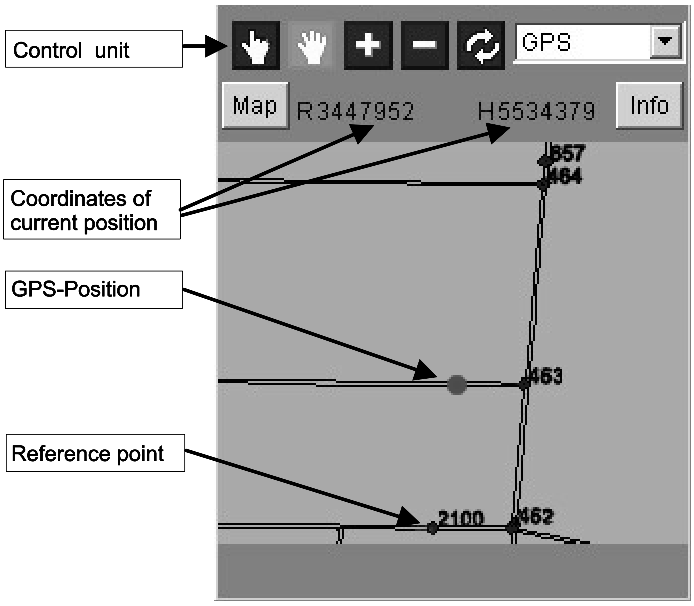


**Fig. 14.4.** Screen shot of MRPL with rural surroundings (test area)

### *Module GPS connection and transformation*

The task of the modules is to read and parse the data string from the attached GPS receiver, to transform this data into the corresponding map datum and to update the DOM for representation of the user position via the module. The GPS module is to be understood in this context as an individual, independent program unit, which interrogates the GPS device cyclically after a given period of time has passed (e.g. 1000 ms). This independent unit is realised as a Java thread.

The GPS connection module analyses the data string from the GPS receiver and thus obtains the positional and exactness data. This data string is formatted in most devices according to the internationally standardised NMEA-GPS protocol.

The transformation module reads the coordinates of the connection module and transforms them into the coordinate system needed. The values taken from the GPS receiver are geographical coordinates and refer to an internationally uniform ellipsoid (WGS84). The maps released by official surveying authorities in Germany are based on a different ellipsoid, the Bessel ellipsoid. The GPS position is transformed into this second system and then displayed or updated, respectively.

### *Module point management including additional functions*

This module makes available the basic functions for calculations specific to the application in question. It calculates the distance and direction for a specified point and updates the point information contained in the SVG-DOM. Furthermore, the attributes of the graphic elements are modified by this module. This leads to an altered graphic display on the map or, alternatively, to a textual representation as indicated in Figure 14.5. Pressing the "Info"-button would present the distance and direction values as results of the calculations.

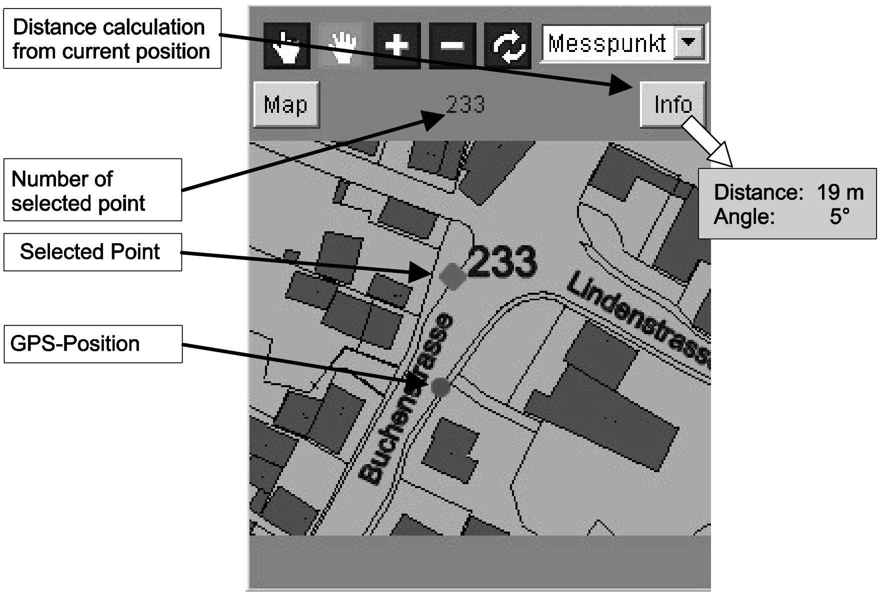


**Fig. 14.5.** Screen shot of MRPL with urban surroundings and distance calculations.

This module also contains additional functions. These are search functions for the most part, that enable e.g. a search of all fixed control points within a certain radius of the user position. The results of these searches are displayed in a list for the user.

The technical realisation is based on the direct access of the module to any points in the DOM. The DOM tree must be traversed in order to achieve this. In this way the current GPS position can be taken. In addition, all fixed points from another layer of the map (or a different branch in the DOM, respectively) can be ascertained and displayed in a list, for example. When the search is limited only to points within a certain distance, as mentioned above, then the fixed points are filtered according to their distance from the GPS position. Now only those points located within this distance will be shown.

This search function is not based on the distance along a path; rather, it calculates the direct distance from the point to the current position. This is a sufficient and required procedure for application in the fixed control point search, as the question of a point in the surroundings will pose itself for the most part in situations in which a point marked in the maps cannot be found in reality. Since an even distribution of the fixed control points is necessary for measurement, a different point in the area of that missing one must then be found.

## 14.5 The MRPL prototype

The result of the research activities was a prototype for MRPL. The prototype fulfils the functional requirements completely.

After start-up, the current position is automatically determined and represented on the map with a red circle. In order to find the way to a point, the user chooses the point wanted, e.g. using the point number. The distance and the direction from the current GPS position are automatically calculated using the coordinates. The map is then centred on the new point. An alternative display is in the form of text output of the calculation results. As a supplementary measure, a selective output of the relevant SSDD is possible.

The only deficits that can be observed are in the performance. On the PDA used (HP iPAQ 3870 with 206 MHz), no adequate performance could be achieved for the display, including the zooming function. An attempt at optimisation by means of exclusive use of integer coordinates did not lead to sufficient improvement. Since the performance on the digital field book Map500 (Pentium P2 at 233 MHz, see Figure 14.6) was very good, we must assume that the virtual machine (VM) used on

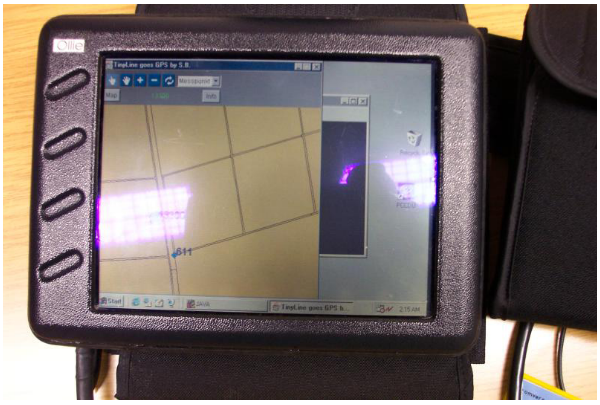

**Fig. 14.6.** MRPL on a digital field book

the PDA shows considerable weakness with regard to speed. The GPS sensor used (Haicom HI-302) delivered coordinates with an exactitude of approx. 1 – 3 m in a first evaluation. This was seen as adequate for the time being. An approach using a corrector signal is not required here.

## 14.6 Evaluation of the MPRL prototype

The MPRL prototype, the result of the research and development work has shown itself to be a stable application which fulfils the demands placed on it. The investigation into the suitability of the approach chosen, i.e. whether the software provides adequate support and possibly even improvements in the work situation as described above, can only be carried out in the form of a practical application. A comparative test between the traditional localisation of reference points and that supported by MPRL would seem to be the suitable method of evaluating the performance of the latter.

An ideal test environment for this purpose would be provided if a large number of users attempted different reference point localisations using both procedures. A test as extensive as this was not possible within the research budget available. A simplified test scenario was therefore used.

### 14.6.1 Test scenario

Two students of the field of geoinformatics and surveying, who were both trained surveyors, served as test persons. Neither of the candidates participated in the development of MRPL. The task consisted of localising 14 reference points each, starting from a central point. Each candidate was to localise 7 points using traditional methods and 7 using MRPL. In order to guarantee the highest possible degree of invariance with regard to the reference points, these were distributed in such a way that the points that were localised by the one candidate in the traditional manner, were localised by the other candidate using MRPL, and vice versa. A rural area near Mainz (Hechtsheimer Feld) and known to both candidates was chosen as the test venue. We ensured that the points chosen were not known to either candidate prior to the test. The MRPL prototype was available to the candidates on a notebook with a mobile GPS mouse.

### 14.6.2 Results

The candidates were accompanied during the test run and the time and exactitude measurements were recorded. Both were also required to fill out a questionnaire at the end of the test. In the following three important results of the test are presented.

- *The time needed to localise the reference points*: the time needed by the candidates from the starting point to each reference point was measured. The diagram in Figure 14.7 compares both procedures.

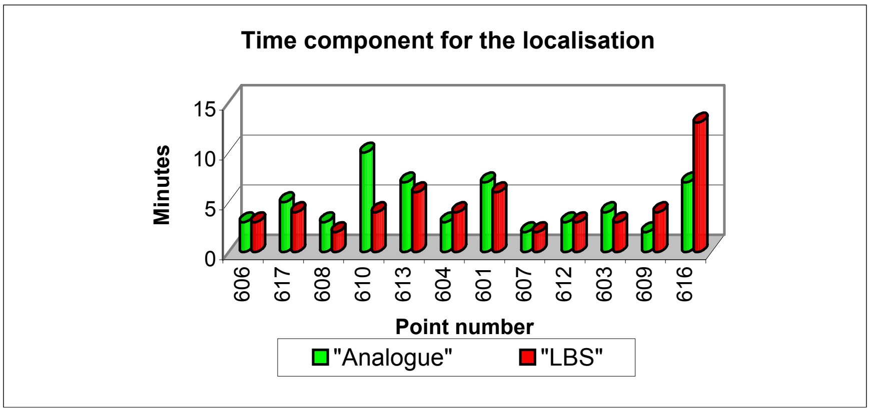


**Fig. 14.7.** The time required to localise the reference points.

In evaluating the time component, only 12 of the 14 reference points were taken into consideration, because one reference point per person was searched for with the PDA, not the notebook, and therefore could not be considered in the objective evaluation. The diagram shows a relatively homogenous result. In 6 cases the localisation using MRPL was somewhat faster, in 3 cases the traditional procedure was faster, and in 3 cases both procedures were equally fast.

- *The use of survey station description diagrams (SSDD)*: the number of points not requiring the use of SSDDs can be seen as a measure of the support provided by the system. 3 of 14 points were localised without the use of calibration sketches using traditional methods (21%). With MRPL this number improved to 9 of 14 (65%).
- *Exactness of arrival:* we investigated how close, i.e. within how many meters, the candidates were able to drive up to the individual reference points. The diagram in Figure 14.8 compares both procedures.
  The evaluation of the exactness of arrival shows that in 7 out of 14 points MRPL enabled greater accuracy, in 6 out of 14 points the traditional procedure enabled greater accuracy, and in 1 out of 14 points both procedures enabled equal accuracy. Note, however, the clearly greater standard deviation (16.006) in the case of the traditional procedure as compared with 2.627 with MRPL.

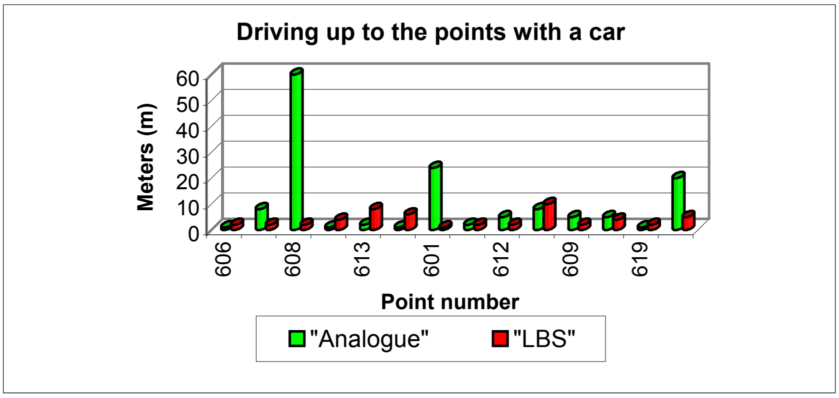


**Fig. 14.8.** Exactness of arrival with cars at the reference points.

### 14.6.3 Evaluation

The test, although not as representative as we would have liked, does show the potential of the system. It is distinguished by constancy and good exactness of arrival. For the most part, SSDDs for localisation were not needed. Merely the time required for the localisation was no shorter than that needed in the traditional method. This point does, however, demand further observations on the usability of the application. Some incorrect use of some important functions, such as panning and zooming, was observed on the part of the candidates. Optimisation of the user interfaces with regard to these problems will doubtless have a positive influence on the time factor.

It should be noted that the test scenario required the use of only a part of the functions available. Functions such as localisation of all points within a given radius, calculation of the distance to certain points etc. represent further utilities which could provide additional support of practical applications.

## 14.7 Summary and outlook

Within the framework of this research project we addressed the problems and chances of improvement involved in the localisation of reference points in surveying. To this end we developed the MRPL service, which is to render localisation for field workers easier, using mobile terminal devices. It was possible to develop a solution based on the combination of context-dependent vector representation and the integration of the user position. The implementation of the service was realised in Java, using SVG as a structured vector format, and led to the MRPL prototype. The prototype met the demands initially analysed. In an application test the prototype was successful and could be positively evaluated. The application of the system revealed its obvious potential as a support for the work process.

The results achieved can be regarded as preliminary; they show the need for further work in various areas. In the area of technology an optimisation with regard to speed is a necessity for the use on the PDA. Evaluation of further Java VMs is required, as well as a thorough analysis of the algorithms used. The MRPL service permits the required offline access to local data as well as online access based on a (radio) network. Automatic loading of special information, according to context and need, would further increase the user-friendliness. Although the MRPL service initially addressed only the localisation of reference points, the application test clearly demonstrated the need for a documentary component, i.e. a mobile editing component, for the reference points. More additional functions were addressed in the application test, which would provide further support for the process. Among these is a digital compass, which would supplement the function available, such as angle and distance calculation.

## Acknowledgements

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# 15 Dynamic 3D Maps for Mobile Tourism Applications

Arne SCHILLING[1], Volker COORS[2], Katri LAAKSO[3]

[1] Fraunhofer Institute for Computer Graphics, Darmstadt
[2] University of Applied Sciences Stuttgart
[3] Nokia Research Center, Helsinki

**Abstract.** In this chapter we describe how interactive three-dimensional maps can be implemented on mobile devices, and how they can be exploited by tourism applications. Technical problems like transmitting and displaying larger amount of data of 3D maps will be likely smoothed out in the near future with the third generation of wireless communication networks (UMTS, W-LAN) and other technical innovations. Besides these technical issues one main question remains: How can we benefit from 3D maps? Within the project TellMaris, we started to develop 3D maps for boat tourists. These maps will help the boat tourists find their way around in unknown harbours and inform them of attractions and upcoming events. This chapter gives a summary of our experiences in developing 3D maps on mobile devices and present the results from a prototype evaluation conducted in two phases. The research was carried out as part of the EU-Project TellMaris (IST 2000-28249).

## 15.1 Feasibility and Advantages of 3D Maps

A wide range of electronic tourist services includes geographic information and location-based services (LBS). Using mobile devices to guide tourists in unknown cities or simply to show the shortest way to a certain kind of store is seen as one of the most promising applications in the near future. In order to provide the necessary functionality, Geographic Information Systems (GIS) have been established in the background.

Normally, two-dimensional maps are rendered dynamically and presented to the user. However, these are not optimal in some cases, especially when only small areas at large scales are displayed and relevant details that cannot be derived from building footprints are missing.

Although the display of maps for LBS has not yet come beyond prototypical solutions, we are already in the development of 3D maps. In general, maps on mobile devices are seen as a great potential for the mobile market. The step into the third dimension is of additional value, as it enables realistic representations for the near surroundings. It can also be of help when navigating in an unknown city, as it supports much better representing visually dominant landmarks like towers or churches.

New technologies allow us to overcome certain limitations of traditional 2D maps and immerse into 3D space. Automated laser scanning methods, now at hand, will produce high quality city models in the near future. Even the large pool of available 2D geodata can be exploited using techniques that derive the third dimension from other sources.

## 15.2 The TellMaris Project

The main objective of TellMaris is the development of a tourist information system for mobile clients capable of displaying 3D maps. The system is targeted on boat tourists travelling on the Baltic Sea. For this group relevant information as well as Location-based Services (LBS) has been integrated. According to Gjesdal (2002), a relatively large number of boat tourists has already a Laptop computer or PC on board. Together with GPS and network access the conditions are given to provide them with tailored services. From the user's point of view, two applications can be distinguished.

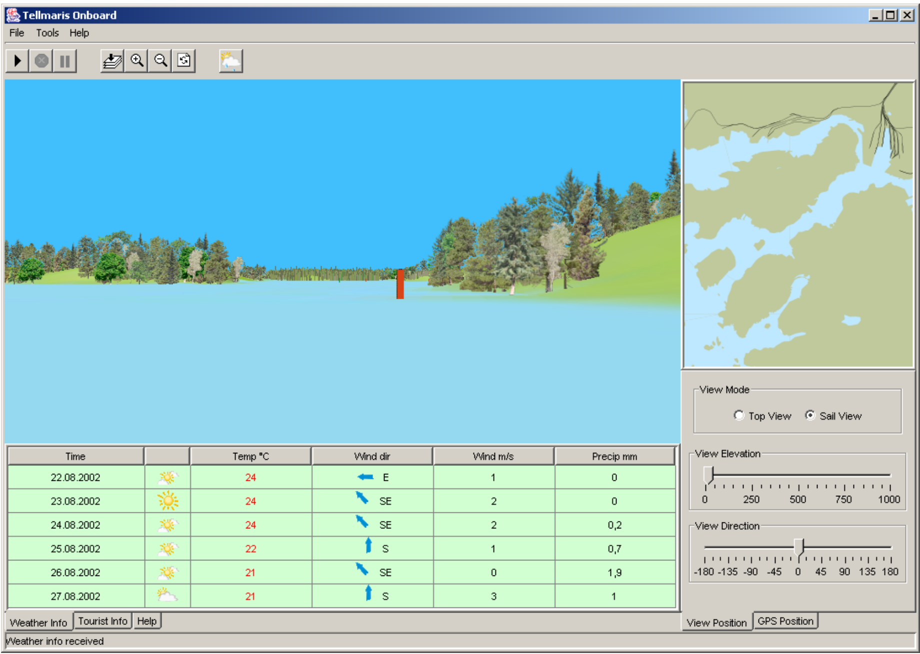


**Fig. 15.1.** TellMarisOnBoard is a navigation support system that combines realistic 3D landscape models with digitized seacharts

The TellMarisOnBoard (TOB) application supports the boat tourist directly during his trip on the sea (Figure 15.1). The system runs on a laptop and provides services for navigation and current harbour information. Basic services such as weather forecasts are also regarded as important for boat tourists. The interactive 3D visualisation helps to explore the areas where the boat tourist is planning to go and also supports the orientation when he is entering a harbour. The virtual viewpoint can either be moved to the current boat position presenting views from the boat perspective, or it can be moved freely through the scene. Recent extensions from established manufacturers of map plotters and navigation systems, that go beyond the 2D map, confirm us in our position that 3D maps are not only a nice add-on but could lead to improvements in both usability and user friendliness. One example is underwater ground models helping to navigate in shallow water.

Although the TOB was one of the most important results of our project, it will not be described in detail here, since we want to concentrate on the purely mobile solutions. The opinions whether laptops can be regarded as mobile computers or not go apart, but surely they are unpractical when they should serve as personal assistants carried around most of the time.


**Fig. 15.2.** TellMarisGuide runs on HP iPAQ Pocket PC (left) and Nokia 7650 cell phone (right)

The TellMarisGuide (TG), developed for PDAs and smart phones, assists the boat tourists when they disembark and explore the larger scale harbour surroundgs (Figure 15.2). It can be used to receive tourist information, for instance about sights or hotels, and to find the closest restaurant or other facilities of interest. The tourists can also be guided dynamically to targets of interest either from user-selected positions or, if connected to a GPS receiver, from the current position. TG is a classical LBS platform that combines GIS data with position tracking and tourist information. In contrast to recent projects like DeepMap (*Malaka, Zipf* 2000) and LoVEUS (*Karagiozidis et al.*) it is based on 3D city and landscape models and thus implicating some technical and methodical difficulties that we had to tackle.

Within the project two different prototypes for three different devices have been developed. One prototype runs on a Hewlett Packard iPAQ Pocket PC with a Microsoft Operation System (OS), and the other on the two Nokia cell phone models, Nokia 9200 Communicator and Nokia 7650, both with a Symbian OS. In the following some aspects and results of these prototypes will be described, the main emphasis lying on the HP iPAQ prototype.

## 15.3 Integration in a Distributed Environment

One important aspect is that we did not intend to create island solutions, but to embed the prototypes into a larger system so that the data storage and the user interaction can be separated (Figure 15.3). It also makes the same data accessible for different clients.

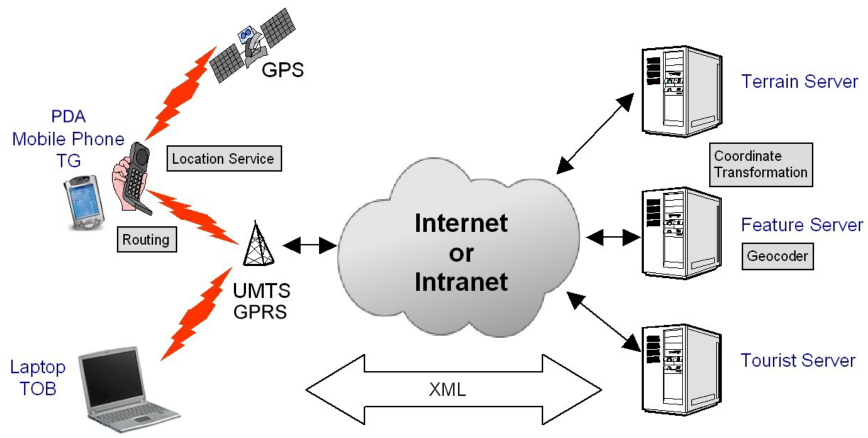


**Fig. 15.3.** The TellMaris system is composed of several components on the server and on the client side, which are developed independently, but can communicate over the Internet

The overall system comprises distributed components that communicate over protocols like HTTP and SOAP. For the 3D feature server a special 3D/4D database developed by Fraunhofer IGD (Coors 2003, Schilling et al. 2003) has been adopted. It is based on an object-relational database management system like Oracle9i. It is configured to store seamless 3D models created with modeling tools and exported to the VRML Internet standard. Other components include the provision of elevation models and tourist information, routing and the transmission and visualisation of 3D maps on mobile devices. All these developed components and other free services are integrated in the TellMaris system.

Compared to Desktop Computers the capabilities of mobile devices like PDAs or cell phones are very limited and the development of 3D graphics on such devices is just at the beginning. Especially geodata sets require lots of resources. For 3D maps designed for LBS several limitations have to be taken into account.

1. The rendering capabilities depend on the amount of memory and the chipset. Currently, small 3D graphic engines available for PDAs can render small city models with approximately 5 frames per second, but it is expected that the rendering capability will grow very fast in the future as it did on PCs and laptops in the past. 3D

graphic engines are mainly developed for entertainment purposes. However, also more “serious” domains may benefit from these.

2. Also the network bandwidth is one of the bottlenecks when moving in wireless environments. The currently available mobile network standard GPRS allows a transfer rate of 57,4 kBit/s. The upcoming standard UMTS will increase the transfer rates significantly. In addition, specialized compression techniques can reduce the amount of 3D data (Coors 2002), which enables the transmission of 3D models combined with videos and other multimedia content.
3. The small screen size and the restricted interaction possibilities require new metaphors for exploring and navigating in 3D maps. The Graphical User Interface (GUI) has to concentrate on the most relevant information allowing for these limitations.

## 15.4 Development of the iPAQ Prototype

On the iPAQ, a VRML viewer from Parallelgraphics (Pocket Cortona) is used to display and navigate in our city models. Something comparable to Java3D is unfortunately not in sight for mobile platforms. Nevertheless, Pocket Cortona cannot only be used as a mere 3D viewer, but also be embedded as ActiveX component providing some controls in order to manipulate the model more or less freely. Being one of the main criteria, it allows us to adjust the model according to the permanently changing user position without reloading yet present data. Since we were bound to implement the client software in Java, we had to switch a Java Native Interface (JNI) between Cortona and the core software enabling the necessary ActiveX controls to be accessible as Application Program Interface (API).

Figure 15.4 shows the components of the iPAQ client. Global Positioning System (GPS) devices can also be connected to the client wirelessly via Bluetooth, so that extension packs are not required. The prototype for Nokia cell phones uses other technologies, but the concept is the same. The rendering is done by a mobile 3D engine based on the OpenGL standard.

3D maps are not seen as static documents but as dynamic visualisations, being composed of an elevation model and GIS data. Since the whole dataset for one city is too large to be stored on the device, all the data are managed by a database on the server side. The client only contains meta information like spatial extent and available layers for the area of interest.

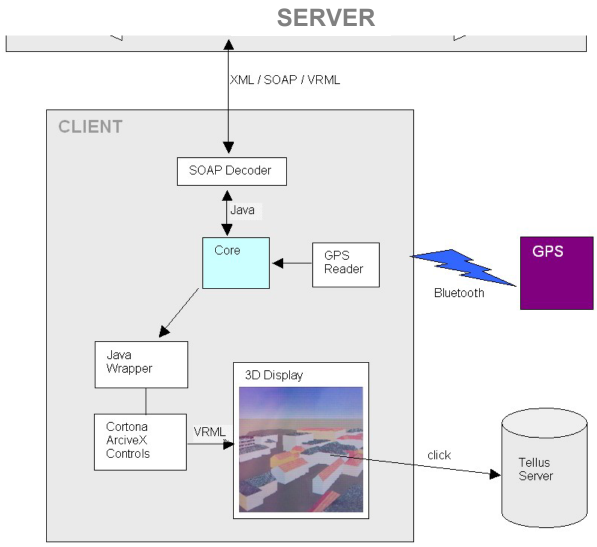


**Fig. 15.4.** Internal architecture of the iPAQ Client

The area of a city is split into cells that are aligned to a raster. Each time when the user enters a new cell and new data for adjacent cells are required, Webservice calls are constructed and sent to the server

As soon as the user approaches, these cells get visible. As a certain amount of geodata can also be cached on the device, additionally an initial download of a larger region is thinkable when the user has access to a faster network like Wireless LAN. Nonetheless, LBS typical functions like guiding the user to the next Chinese restaurant, displaying interesting locations in the near surroundings, and the like can only be accomplished with an underlying GIS which resides on the server.

### 15.4.1 Presentation Strategies

Presenting results and information such as street names or labels usually available in paper maps requires new strategies. The GUI allows switching between the 3D view and the 2D vector map providing a smaller scale overview (Figure 15.5). The 2D map is based on Scalable Vector Graphics (SVG) and displays the current position as well as points of interest (POI). In the 3D view the user can choose between three different view modes. One option is the so-called "walking mode", in which the user can immerse into the scene and walk around with a pedestrian perspective. Another possibility is to have a look from above, which creates a similar experience as viewing a 2D map. In the final option, so called "flying mode", the user is looking slightly downwards giving him a bird-perspective, as showed in Figure 15.6. According to our studies, the last alternative seems to be the most useful, as it gives an overview of the near surroundings, which the pedestrian normally cannot see from his perspective.


**Fig. 15.5.** According to the situation it might be useful to split the screen showing a 2D map in parallel to the 3D model (left), or to concentrate on the 3D view (middle). In both views hints can be given to find selected destinations (right).


**Fig. 15.6.** In 3D view flying mode is most useful for navigational purposes. TellMarisGuide on Nokia 9200 Communicator

From the tourist database a list of hotels and sights has been extracted in order to demonstrate the destination search function. In both 2D and 3D views selected targets are highlighted and the direction where to go is displayed. In 3D view an arrow indicates the direction to the target, so that the user sees directly whether maybe he has to turn left or right. In 2D view also the current position and the walking direction is displayed. So far the 2D map is always oriented to north, so that all directions have to be compared to viewing direction. Due to reasons of economy we did not integrate a true routing service so that the user has to find out by himself which path he has to take. Therefore a street map is still a valuable addition.

### 15.4.2 Connecting Tourist Data and GIS Data

Maps produced by GIS are not only useful for navigation purposes. Another advantage is the possibility of connecting GIS data to text and multimedia contents. Several projects have already proven the usability of such systems. The concepts can also be adopted in 3D. In TellMaris a link between the 3D geodatabase and the tourist database from Tellus has been established. The Tellus database contains a repository of locations relevant for tourism, including, for instance, hotels, museums and monuments. For these destinations short descriptions as well as addresses, opening hours and contact details are maintained. The Internet server creates HTML pages from this data according to given stylesheets that can be sent to web browsers (Figure 15.7). The city model only contains the URL addresses that are attached as hyperlinks to the buildings. Tapping with the pen on these objects with hyperlinks provokes the client software to open a new instance of the Pocket Internet Explorer in the lower half of the screen. Due to the small screen size the page cannot be displayed completely so that the user has to scroll up and down.

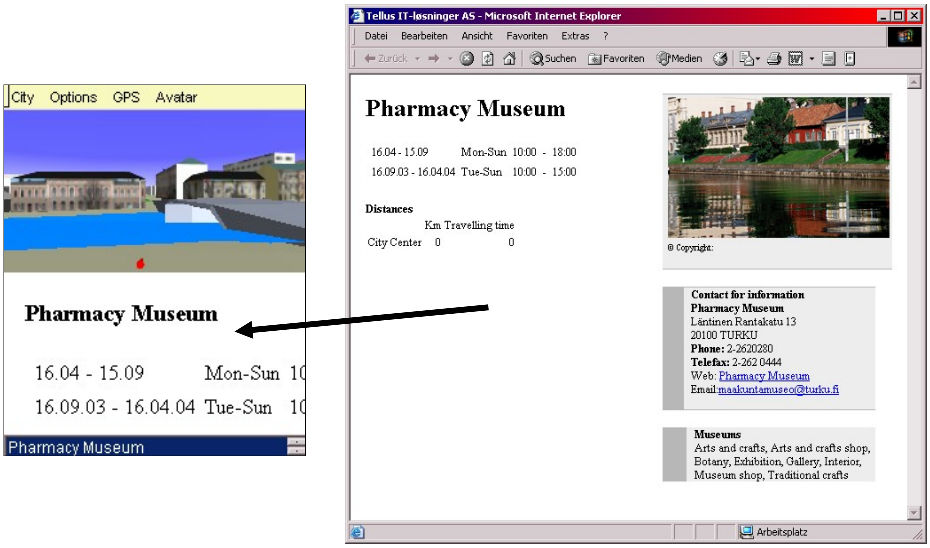


**Fig. 15.7** Further information on buildings are generated by the Tellus server and can be presented using the split screen mode (on the right side displayed with a desktop browser)

### 15.4.3 Spatial Database for 3D Geodata

The mentioned 3D database has been deployed due to the huge amount of geodata that have to be managed. It contains so far models from two cities in the Baltic region, where our evaluation sessions took place, namely Turku in Finland and Tønsberg in Norway. For Turku and its Archipelago region, we had access to a very detailed textured center model and a vector map containing building ground plans, streets and land use areas. These data sets have been kindly provided by Auria and the National Land Survey of Finland.

In respect to our mobile clients the center model had to be simplified. Especially textures have normally too high resolution, which couldn't be exploited by the small screens. They can be scaled down and put together. For lower levels of detail, the vector map has been used to generate simple block models, and the land use areas have been automatically draped on the terrain model so that they are also available as objects without texturing.

For the database a schema has been developed that allows us to store almost arbitrary models as features in an object relational database system. In order to do this, nodes, edges and faces are broken down and inserted in tables. Since it allows hierarchical structures complex architecture models can also be handled, although this has been avoided in TellMaris. The block model and the center model have been integrated in order to produce several representations for one building. The connection to the Internet is done by a webservice interface. Unfortunately, a standardised format like OGC's WMS specification does not yet exist for 3D maps. Therefore we use VRML encoding which can be directly forwarded to the Cortona Viewer.


**Fig. 15.8.** Small scale landscape models are generated from 2D GIS data. Left side: View from ESRI ArcView, right side: terrain model combined with water, vegetation and buildings. Courtesy of National Land Survey Finland.

Figure 15.8 shows on the left side a part of the original dataset in ArcGIS. The SVG map has been produced with an extension of this standard GIS product. Since isolines are also part of this dataset, a terrain raster could be derived from them. Although rasters are in many cases not optimal for representing the earth surface because of performance issues, they allow an easy partitioning into tiles that can be managed by the client. Buildings and two-dimensional features like vegetation and water areas have been adjusted to the terrain surface using self developed components (Schilling, Zipf 2003).

### 15.4.4 Technical Results

As stated in the beginning, the preconditions for the development on PDAs or smart phones are not the same as on desktop PCs or notebooks. The HP iPAQ implementation and design was done with Java. Unfortunately Java does not enjoy the same significance as other technologies, at least on the PocketPC platform. The available Java version was 1.1.8, which is pretty out-dated. Although the functionality was sufficient, the runtime environment, which is responsible for the execution, is not from Sun and its development for newer iPAQ models has not been continued. The prototype runs on the iPAQ H3870 model with 266 Mhz. The newer model H5450 with 400 Mhz could not be used due to software incompatibility.

The rendering performance was just sufficient in order to navigate in models with approximately 0,4 square kilometres, comprised of a terrain with 20 m resolution, a block model and textured buildings. It would have been interesting to see the prototype on a 400 Mhz device.

At the time of writing this chapter UMTS is still unavailable. Only test areas in city centres have been covered with broadcast stations so far. Since GPRS is hardly capable of transmitting the required data in a reasonable time, we worked with W-LAN. Being a very powerful transmission network, it has at the same time drawbacks in terms of limited transmission ranges. It's doubtful, whether the number of public W-LAN access points in city centres will increase such that a continuous connection will be possible. On the other hand UMTS splits the maximum transmission bandwidth among several users. The practice will show what rates can truly be used by one user, but they are expected to lie between GPRS and W-LAN.

## 15.5 Prototype Evaluation

Since 3D maps are just being introduced as a navigation aid, there are many unanswered questions. One of the most important is to find out what are the advantages of a 3D map compared with a 2D map. In order to learn more about this we organized a pilot study for testing our mobile prototypes and their 3D maps.

### 15.5.1 Settings and objectives

The study was conducted in two phases. The first evaluation phase with initial prototypes took place in August and September 2002 mainly in Tønsberg, Norway. Ten boat tourists participated in usability tests and 30 in focus group discussions. The main purpose of the usability tests was to collect feedback about using mobile 3D maps in city environment, and to compare their usage with a paper map (Laakso 2002). In focus groups we concentrated on the respondents' feelings towards the applications in general and the services they provide.

In September 2003 the second evaluation phase with revised prototypes took place in Turku, Finland with a group of 37 pedestrians. During this evaluation the final prototype from Nokia included a GPS connection, and the iPAQ prototype was also evaluated. The objectives of the second phase were similar to the first one: we wanted to know more about the usability of 3D maps.

### 15.5.2 Results

Users' first impressions of TellMaris' idea and the prototypes were positive in both evaluation phases. Digital maps were found to have many advantages when compared to paper maps. Users liked the idea of having access to different maps and tourist information with one single device. However, 3D maps were not found so critical. Users said that they are so used to 2D maps that they do not really need a 3D map for navigating. Some of them believed that there might be a change in attitudes with next generation.

The amount and quality of the available tourist information was found really important for the users, weather information being the most important information type. All the tourist information in the application should be up-to-date and easily searchable. It should also be organized as layers in order to avoid the small screen being cluttered. Users were also interested to use the application for dynamic services, e.g. booking hotel rooms or tickets for different events.

In the first evaluation phase, when we conducted usability tests comparing the 3D map in the prototype (with no GPS support available) with a paper map, the results indicated that 2D paper maps are faster to use both in orientation and route finding. When considering errors in orientation or lengths of the routes, performances with 2D and 3D maps were practically equal.

A partial reason for slow orientation times with the 3D map was the sunlight. Bright sunlight prevented the users from seeing the display properly and this affected especially the easiness of the initial orientation. The paper map was easy to see even in the sun. Fastness of route finding with the 3D map was affected by the absence of the GPS: users had to interact with the model all the time in order to keep the view in the screen up-to-date. When navigating with the 2D paper map, the whole area is visible every time the user views the map and continuous interacting is not needed; thus also the walking speed is typically higher.

The most common navigation strategy was to recognize buildings from the 3D map, start walking on the direction pointed by the 3D arrow, and check if the current location marked on the 2D map was approaching the target dot. Building recognition was found to be the most positive thing that valued 3D maps over the 2D maps. It was also found quite easy, although non-textured houses were sometimes hard to recognize and to distinguish from each other. Flying mode was found to be much easier than walking mode for navigational purposes.

Similar results were acquired from the second evaluation phase. After using our prototypes for a while, users tended to consider 2D maps a little bit easier (62% vs. 26%) and a lot faster (81% vs. 13%) to use than 3D maps. However, most users (66%) thought that 3D maps are more enjoyable to use, even though it is unclear how much the novelty factor affected on this.

Regarding the 2D and 3D map characteristics, users desired the 3D map to have better graphics with more textured houses. Target buildings should be highlighted in the 3D map and there should be a zooming function available for the 2D map. The most important 3D map characteristics were found to be street names and numbers, easily recognizable landmarks, and building names.

The visibility of the device screen in the sunlight was problematic in both evaluation phases. This problem can be reduced e.g. by enhancing the contrast of the 3D model, but full solution emerges only with new and better display technologies.

The first evaluation phase showed us that having a GPS to take care of moving and turning the model would be crucial for the service to be useful. However, the accuracy and usability of a GPS in a city environment is not very good, as we found out in the second phase. It's a known problem that the number of satellite signals decreases dramatically when walking in narrow lanes. Also in relatively open areas the used receivers do not allow very high accuracies. Better receivers with differential correction are too cumbersome for our purposes. A solution might be a combination of GPS signals and a street network, like in car navigation systems.

Despite of the fact that most users preferred 2D maps to 3D maps, the results were promising. Users were able to recognize real world objects from the 3D model and use these landmarks as navigational aids. It should also be noted that people in general, and especially the members of our target group, are used to navigating with 2D maps. 3D maps are new for them and learning to use them efficiently takes some time, probably more than we could give them in the tests.

Another issue is that in addition of being experienced with 2D maps, majority of our users, especially in the first evaluation phase, were males. There has been some evidence that navigation strategies vary between males and females (Hunt and Waller 1999, Cutmore et al. 2000) and it may well be that females, who might also be less accustomed to using maps, would have found 3D maps with landmarks more useful.

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# 16 Designing electronic maps: an ethnographic approach

Barry BROWN[1], Eric LAURIER[2]

[1] Department of Computer Science, University of Glasgow
[2] Department of Geography, University of Glasgow

**Abstract.** While ethnographic methods are an established tool for requirements analysis in Human Computer Interaction (HCI) and Computer Supported Collaborative Work (CSCW), they have seldom been used for the design of electronic map systems. This chapter presents an ethnographic study of city tourists' practices that draws out a number of implications for designing map technologies. We describe how tourists work together in groups, collaborate around maps and guidebooks, and both 'pre-' and 'post-visit' places. These findings have been used in the design of the 'george square' system which allows tourists to collaborate around an electronic map at a distance.

## 16.1 Introduction

Electronic maps and additional services appear to have a fairly straightforward application. Maps, after all, are one of the oldest of paper technologies – their utility cannot be doubted. In this chapter, however, we argue that we still know very little about how maps are actually used as part of everyday activities. This lack of knowledge implies that the straightforward application of electronic maps will not support real users' actual tasks. We argue that the value of electronic map systems comes when map systems support the complexities around real life map usage. Take, for example, navigation from one point to another. This is the classical wayfinding task that we are all familiar with in our own map use, and a task that has been explored in considerable depth in a range of controlled and experimental settings (*MacEachren* 1995, *Hunt and Waller* 1999). This task has been characterised as involving the goal-directed or planned movement around an environment. Usually the goal discussed is getting to a specific single physical location – an activity that may involve planning, observation and map use. Nearly all electronic map systems support this task through allowing the user to plot a course from where they are to where they want to be.

However, as we discuss in this chapter, if we look at non-staged, non-experimental cases of navigation we find differences between the task 'as it happens' and as classically conceived. Rather than creating a plan and then executing that plan, wayfinding is more ad hoc, involving partial rough plans which are revised throughout a route. Wayfinding also involves dealing with considerable uncertainty – about a navigators' position, as well as the destination. The task itself is also broader than simply getting to a destination – it is often a social activity, finding the route may be shared amongst a group, involving negotiations amongst that group about where to go and how to get there.

Here, we present data from a number of studies where we have analysed the use of maps in uncontrolled 'natural' (e.g. non laboratory, non-staged) settings, data collected using both video and observational techniques over a period of two years. The data we focus on here concerns *tourists* navigating using maps, data we have used to inform the design of map systems for tourists. Since the methods used here differ somewhat from those traditionally used in the design of mapping systems along with our findings we also argue for the greater use of qualitative data in understanding and designing mapping systems. In our own work we have used these findings in the design of the 'George Square' collaborative map system, which we also briefly outline.

## 16.2 Motivation

We are strong advocates of using qualitative, ethnographic data to advise the design of technological systems (Brown et al. 2001). Although few ethnographic studies have been used in the design of map-based systems, in the field of HCI (computer human interaction) and CSCW (computer supported collaborative work) ethnographic, and qualitative methods more generally, are now established techniques for designing computer systems (Anderson 1994). Indeed, work from this tradition has informed wider debates out with the design of technology. Lucy Suchman's book "plans and situated action" caused a major revision in the task-centred notions of cognition which were dominant in cognitive science, as well as HCI, at that time. More recently, Sellen and Harper's work on the use of paper documents demonstrates the many advantages which paper documents have over electronic documents, and how replacing paper systems can harm productivity and effectiveness (Sellen and Harper 2001).

Yet, perhaps surprisingly considering the large body of work which has looked at navigation, there has been little ethnographic or naturalistic work which has looked at map use, and even less which has informed the design of map based computer systems. Malinowski and Gillespie comment that "although spatial ability research conducted in small-scale or laboratory settings has flourished, fewer studies have been done in real-world, large scale settings" (*Malinowski and Gillespie* 2001). Correll and Heth go further and argue that there is an important need for studies of "humans navigating real world routes" (*Cornell and Heth* 2000) since little work has looked at navigation in situ in activities which are not part of experimental task. Exceptions such as (*Malinowski et al.* 2001) or (*Lawton* 1996) have tended to focus on issues such as gender differences. Questions remain about how maps are used in combination with landmarks, how real world way-finding tasks differ from the "navigating from a to b" tasks studied in experiments, and in the social interactions which take place around maps (*Montello* 2003). As Garfinkel puts it: "*maps* are analytic cartography's stepchildren' (*Garfinkel* 2002).

Our motivations, then, were to use ethnographic methods to understand map use, generating recommendations for the design of map based systems. In designing our system, and to an extent in our studies, we choose to focus on *tourists*, looking at their use of maps and other documents. With mobile phones and other portable devices becoming more advanced, tourism is an obvious application area for map based systems. However, commercial technologies in this area have had only limited success, especially when compared to the print-runs of paper based guidebooks, although tourism has been a popular area for research systems, in particular the Lancaster GUIDE system (*Cheverst et al.* 2000), other PDA based systems (Abowd et al. 1997; *Fesenmaier et al.* 2000; *Woodruff et al.* 2001), and our own work with museum based systems (*Brown et al.* 2003)

## 16.3 Methods

For this study we combined video with conventional ethnographic observational work. There is a long tradition of qualitative research in sociology, particularly with the use of ethnography as a research technique (*Loftland* 1971). Ethnography is based around prolonged in-depth study in the site of interest, collecting observations of 'what is going on' (*Hammersley and Atkinson* 1995). Within the CHI and CSCW research fields both ethnographic and video observation techniques have become popular, often in combination (*Luff et al.* 2001).

For this study we used small cameras to videotape activities in which we were participants and observers. We collected four main pieces of qualitative data. Five days were spent studying tourists in Edinburgh and Glasgow, combining observation with videoing their activities. A focus of this work was the documents that tourists used, such as maps, guidebooks, train timetables and so on. Our observations were conducted around major tourist areas: the main train stations, hostels, luxury hotels, Glasgow's main city square, and an historic street in Edinburgh called the Royal Mile. We combined these with five 'video diaries', made by accompanying tourists while sightseeing on a day in the city. We recruited groups of visitors to the city from friends and family of our university's staff. We then followed these visitors around for a day, videoing them as they chose what to do, arranged their visit and navigated their way around the city. We supplemented these observations with twelve interviews with tourists, which were tape recorded and later transcribed. Lastly, we conducted a five day ethnography in the Glasgow tourist information centre, collecting data from the activities of both staff and tourists asking for information[8].

The data collected was diverse, but it allowed us to think about and explore what tourists did in a number of different ways, while remaining close to what tourists do. In analysing this diverse range of data we aimed to produce an ethnographic understanding of tourism and the use of maps by tourists; that is to say one that reflected the pressures, viewpoints and feelings of tourists as much as cataloguing their activities.

[8] One additional source of data was our own experiences as tourists during the time we conducted the study. While we did not collect this data as systematically as the other sources, field notes were taken during four tourist trips by the authors.

## 16.4 Using Maps

Obviously, tourists are heavy users of maps. Indeed, one of the key problems which tourists face when visiting a new place is working out where things are. In visiting a city many of the attractions are distributed around the city non-contiguously. There is therefore a need to minimise the times spent traveling between places, understand what one might see and do along the way, and to find attractions which are closeby or grouped together. In doing so tourists will walk between places, walk around places, navigate public transport, catch taxis, or drive on unfamiliar road systems often with limited information,. To do this, tourists make extensive use of maps.

### 16.4.1 Maps as collaborative artifacts

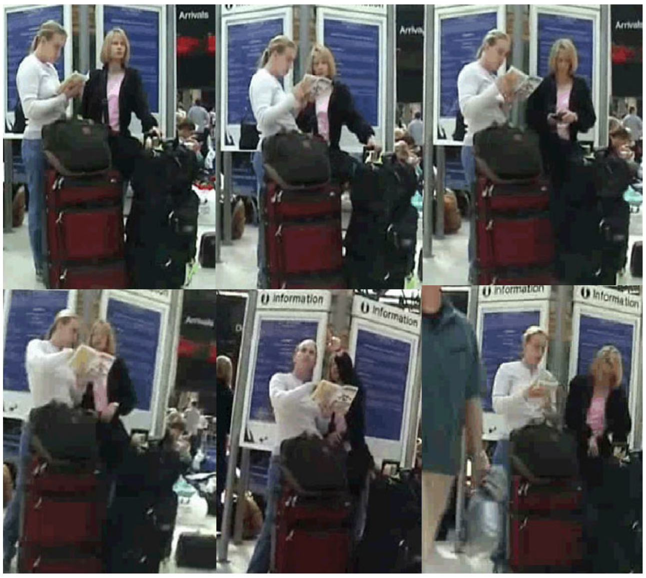

**Fig. 16.1.** Tourists at a train station

However it is important to underline that maps are seldom used in isolation – they are used in combination with other sorts of information – be that signs in the environment, advice given by locals or information from guidebooks. They are used in combination with other sorts of persons and groups – tourists travel with other tourists, e.g. as part of a coach party, stag party, friends or family , and tourists meet locals, e.g. tourist information staff, guides, hotel staff and persons in the street (see later). Statistics from the US show that 79% of leisure visits involve groups of two or more (USDTI 1999). Since leisure travel is predominantly group-based, there is considerable intra-group interaction and collaboration around maps.

For example, Figure 16.1 shows some frames taken from a video of two tourists who have just arrived at Edinburgh's main train station. The first tourist holds an "A to Z" street guide to Edinburgh, and is looking through it. While the second tourist glances around the railway station, the first tourist finds the correct page of the map. Then the second tourist takes out her glasses to look at the map, glances at the map and points at an exit sign in the train station that names the street to which the exit leads. They give the street guide a last look, pick up their bags and leave the station.

Even in this short excerpt one can see a division of labour around the use of maps. The second tourist looks around the station to find the exit, while the first tourist tries to find the correct page on the map. She holds the map so as to make both the map and her progress in using it available to her companion. Reading the map is done here in such a way that it can be shared with the first tourist's companion. One tourist takes on the job of map reader while the other takes on what we might call the place reader. In Frame 4 when the map reader points out a relevant feature on the map, the place reader, who has been looking around, is able to immediately pick out a corresponding piece of signage in the railway station. The job of following the map is thus shared by the two tourists. As a tourist 'unit' they use the environment to move between the map and the territory as a course of activity.

This clip demonstrates two important aspects of map use. First, that it is a collaborative activity, and as such, involve negotiation as well as coordination. The two tourists are deciding what they are going to do as well as how. Second, that maps are used in tandem with other information such as information in the environment in the form of signs.

### 16.4.2 Using a map *in situ*

Collaboration is also evident in our second example. In this extract the first author comes across a group of tourists on a street corner attempting to find a historic house. As they discuss the different possible buildings they look at a guidebook of the city, using the guidebook as a group to find the historic house.

Again, we can see similar activities to the first extract – negotiation around a map, combined with an attempt to connect the map with the city streets they find themselves in. In this case connecting the map to the local scenic features takes several formulations of place terms. In their search for one of the city's tourist sites the tourists using a series of different descriptions of one place move back and forth between the spatially arranged text on the streetmap, the accompanying descriptions in the guidebook and house numbers and the street placards attached to the corners of the buildings. These searching methods – 'is it to the left of decon brodies', and asking what street the building is on, do not depend so much upon finding the direction of the house in the visual scene but on finding an indicator in the environment – such as a street name, or the building 'next door' which can be used to find the house. Once this method of searching fails to reveal Gladstone's Land as one of the buildings nearby them then they switch to a formulation of the object itself to see if they can see such an object – 'it's a six storey home and look at the year 1620' (line 11).

| | | |
|---|---|---|
| 1 | **Tourist1:** | Maybe it's down there, it could be down there Fran |
| 2 | **Barry:** | Are you looking for a street? |
| 3. | **Tourist1:** | Nooo it's a (.5) a very old house is it Gladstone or Livingstone. (.5) Very old place. I think it's to the left of Deacon Brodie's ehh |
| 4. | **Fran:** | Gladstone's Land? ↑Gladstone's Land?↓(walks over) |
| 5. | **Tourist1:** | Uhh I think |
| 6. | **Fran:** | Gladstone's land is number six. |
| 7. | **Tourist1:** | Where's six? |
| 8. | **Fran:** | Six is (.5) fifteen. Five. Six. Castle hill (1.5) hill street |
| 9. | **Barry:** | Castle hill is [just there] |
| 10. | **Fran:** | [iddsh] well it has a description let's see what it says |
| 11. | **Fran:** | it's a six story home and look at the year 1620 |
| 12. | **Barry:** | it's on the Lawnmar-ket |
| 13. | **Tourist1:** | Yeah |
| 14. | **Fran:** | Where does it say, oh Lawnmarket Oh. He said it was on the High Street |
| 15. | **Tourist1:** | Maybe they've got it .. ok |
| 16. | **Barry:** | Lawnmarket's just here |
| 17. | **Fran:** | ↑Oh↓ ohhh what's this street called? Is this Lawnmarket too? |
| 18. | **Barry:** | This is Lawnmarket. [It becomes High Street] ermm |
| 19. | **Tourist1:** | [This is Lawnmarket] |
| 20. | **Fran:** | Ohhhh |
| 21. | **Tourist1:** | So 477. |
| 22. | **Fran:** | So where does it become High Street (1.0) |
| 23. | **Fran:** | oohhh it's across the street right over there. It's probably the old one inbetween, lets go and look |

**Fig. 16.2.** Tourists using a map in situ

The tourists show some confusion about the name of the street ('Castle Hill', 'Hill Street', 'Lawnmarket' & 'High Street') which the house is on. It takes quite a few turns of talk before the author as a local can really begin to help (since he did not know directly where Gladstone's Land was or would have offered them directions immediately). This is in part because it takes a few exchanges to display confusion. His local knowledge of the city identifies a common cause of the confusion on this particular street As a local he knows that the Royal Mile goes by several different street names along its course confusing locals and tourists in varying measure and so he looks to see what the name is of the section they are currently standing on and how this relates to the street name found on the map and in the guidebook. At this point, the solution to the puzzle becomes apparent: they are not on the wrong street, the same street has several correct names for it. This unconventional naming of what is visibly a continuous street is the cause of their confusion. As they grasp this and its implications (e.g. 'X' becomes 'Y' at a certain junction (lines 19-23)) and that they do not have contradictory information, then they are ready to begin walking again. After pointing out a house which is on the part of the street next to their original formulation ("next to decon brodies" – a pub on the corner here) they head over to check the candidate house.

The "problem" of location formulation which the tourists face is this:

"For any location to which reference is made, there is a set of terms each of which, by a correspondence test, is a correct way to refer to it. On any actual occasion of use, however, not any member of the set is "right." How is it that on any particular occasions of use some term from the set is selected and other terms are rejected? … I seek to direct attention to the sorts of considerations that enter into the selection of a particular formulation, considerations which are part of the work a speaker does in using a particular locational formulation, and the work a hearer does in analyzing its use." p81 (*Schegloff* 1972)

The work then that the tourists do here involves matching these different formulations and the streets they find themselves in. Indeed, it is the formulation 'very old house' which finally lets them discover the location of the house in the final line.

### 16.4.3 Getting from a to b

Having looked at two examples of map use *in situ* we now move on to the use of maps as a tool for planning and navigating a route between two different points. In our work we often observed tourists using maps in situations where they did not know exactly where they are going, only having the name of a particular area that they were heading towards. This is due to the areas of the city that are interesting to tourists and provide facilities for them are well known and advertised, such as 'The Royal Mile' in Edinburgh and 'Covent Garden' in Paris, They head towards a recognised touristy region of the city with no specific attraction since part of the pleasure of tourism is in going to the recognised places while still having surprises and making discoveries.

Alternatively, tourists used maps to go towards a specific type of attraction, such as a café, but with no *specific* café in mind—they would head towards a street or square where they thought there would be cafés. When navigating in this way, the exact destination is something that emerges while following the route rather than being predetermined in advance. Indeed, destination choice interacts considerably with route choice.

Even when tourists did have a specific destination in mind, they would often only have a rough idea of where they were, and would use a map to locate or orient themselves so as to head in a 'roughly correct' direction, rather than along a specific route. In this way tourists can get to particular places without having to explicitly plan a route, or consult the map in depth – while not the most efficient strategy in the simplistic sense of distance or time, such 'guided wandering' can minimise the amount of explicit planning in advance that needs to be done. Decisions about the route, and even the final destination, can be left to as late as possible, when the tourist might have a better sense of the area, or their position.

So, in using a map, tourists might not know where they were, might have little idea about their orientation, might not know where they were going, and might even be unsure about what they were looking for. In this way map use is often less about explicit route planning and more about wandering a city in a 'exploring' or sight seeing/collecting' manner. The routes that tourists used were more directional than specific, with tourists frequently stopping en route, using the map to find the direction to walk in, and then setting off again.

In these ways tourists attempt to combine both the characteristics of places with their geography, to simultaneously solve the problems of *where* things are and *what* things there are. A different example of this is the use of 'social zoning' of cities. As any frequent visitor will know, one of the most effective ways to find a restaurant in an unfamiliar city is to simply wander around a central area. Although by no means a perfect way of finding particular amenities, walking around exploits the tendency of certain facilities (such as bars and restaurants) to be clustered in particular area[9]. In this way, one can also judge establishments by their appearance and menu, as one walks past. These 'clusters' are also exploited in tourists' use of maps. When choosing where to go to, it is often safer to pick an area with more than one potential facility. We observed tourists heading towards a 'restaurant zone' of a city, often with one restaurant in mind, but with the flexibility to go elsewhere should that restaurant prove to be busy or unsuitable. By combining maps and guidebooks, tourists can look for 'clusters' of facilities in particular areas and go towards these particular areas rather than (or in addition to) heading towards a specific establishment.

### 16.4.4 Maps for pre-visiting an planing

The last aspect of map use we will discuss concerns how tourists use 'pre-visiting' of places to manage their holiday. While our focus so far has been on the visit, considerable work is done by tourists before they travel in gathering information and planning what to do. Tourists pre-visit a place by reading about it before they go there. Through arranging information, reading and looking at maps before traveling, a tourist can do some of the organising activity for the holiday before the holiday. Pre-visiting is not only practical; it is enjoyable. It extends the excitement of the holiday and builds anticipation as well as giving the visitor some sort of idea of what they are visiting before they get there.

Indeed, the 'pre-visiting' we observed with maps pointed us towards a much–neglected aspect of using maps: their educational function. A major aim of using a map is to learn about a place sufficiently that one can get around without using a map, learning about a place by looking at where the streets go, the names of the streets and potential landmarks. We observed one tourist who spent over twenty minutes at a Glasgow train station reading a map of a popular mountain walk. In looking at the map, this tourist was learning about the arrangement of geographical features his walk would take him through. While not finding his way while located in the map's territory, he was learning about things that would help him when on the walk, such as the distances between places, the sequential order he would encounter them, what difficulties he might face (e.g. rive crossings, rock scrambles) and what landmarks and

[9] Although this is a tendency of smaller or denser cities: Manhattan rather than Los Angeles.

sights there are around the area. That these routes are learned in the use of maps is obviously not a new observation (e.g. (*Cornell et al.* 2000)) but rather we emphasise that tourists do this as a specific activity. Also, when we use maps in situ as part of the process of traveling around, we are also learning about sites and streets in such a way that if we return we will have more idea of our location and how to get around. If, technologically, we just support wayfinding then we will neglect this crucial function. Maps provide an overview and allow us to fit our observations and our traveling together.

Pre-visiting as an activity also happens while on the holiday itself, with tourists gathering information about places and *planning* what they are going to do using maps. One important aspect of tourist planning is that it is 'satisficing' (*Simon* 1955), in that plans are 'good enough' rather than detailed plans of activity. Indeed, tourists' plans are often deliberately ambiguous so that they can take into account future contingencies. As Suchman argues, plans can never determine behavior but rather are, amongst other things, used flexibly in deciding what to do (*Suchman* 1987). Her approach acknowledges that decisions are often easier to make when one is actually in a particular place. For example, when planning a route, planning the complete route in advance using a map is to put it bluntly, impossible. Approaches will involved to plan in more or less detail in advance, and then inescapably picking out features once the trip is underway (e.g. specific roads by using road signs when one is driving).

Tourist plans are often deliberately designed to be only as specific as is appropriate to the knowledge of the tourist, their desire to see specific sites and perhaps their style of exactitude (some can be vague others love detail). A number of the tourists we interviewed talked about allocating days to particular places before they traveled. This method of temporal allocation of a general place leaves a lot unspecified: when each day is, and what activities are done in each place, for example. Yet this sort of planning while still allocating bounded and slots to each place with estimable amounts of things that can be done in those slots, acknowledges that certain sorts of details are better kept flexible until closer to the time, as they will be dependent on local transport details, and can be adjusted in the face of other local contingencies, such as changing weather. Indeed, a stereotypical bad holiday is one that is excessively planned, in that changing circumstances are not be taken into account. Planning with maps is therefore less a job of outlining exact routes but one of learning about a place in advance – its configuration and such – working out rough and flexible itineraries and plans which are expected to change as you visit that place.

What appears to provide a more closely scripted version of tourist navigation is when they follow or copy plans provided by various tourist institutions. A popular example of this is the package holiday, but even on package holidays not all of one's time is structured: many activities (such as choosing a restaurant) still involve some planning during the visit. For the tourists we followed, bus tours were frequently used to help structure the visit in this way. One group we followed took the tour bus on the first day they visited the city, so as to obtain an 'overview' of the city that they used more improvisational on later days to organise the rest of their visit.

Returning to what is actually done with maps, while on the bus, one passenger used a pen to draw a line on his map as the bus traveled around the city. This annotation letting him adapt the map to record where he had been for later recollection, and helping him to link the different sights together. In this way these bus tours had a role as a way of helping tourists follow a 'good' route along their maps., They ran the tourists through the territory laying out sites indexically as above and below, left and rights, close and far apart etc., providing information about the key streets and attractions and allowing one to visit these again at leisure. The bus tour thus provided an experience of the map in motion, a series of now recognisable urban features (high street, shops, castles etc.) and various other information about the city,. Bus tours then, were as much aids for later adventures with the map, as being a strict plans or activity to follow in themselves.

## 16.5 Designing map technologies

Now we have discussed our observations concerning the use of maps we move onto discussing what implications can be drawn for mapping systems. Designing mapping systems presents a number of challenges for designers. Even if we focus only on tourists' electronic maps, need to be sufficiently mobile and to fit the tasks which tourists undertake. However, tourists have already adopted many new technologies, e.g. the web, mobile phones and digital cameras. This suggests that there are many opportunities for mapping systems which fit tourist practice better than existing systems.

### 16.5.1 Collaborative map use

As emphasised above, an important part of tourism map use is sharing the use of maps with others. For this reason, maps systems which offer only a small displays, or displays which can only be used by one user at a time, cannot be used as described above. One key requirement of map systems is therefore that they can fit into interaction amongst groups. Luff points this out when he discusses the 'micro-mobility' of technological artifacts (*Luff and Heath* 1998). Many supposedly portable computer systems lack the ability to be shared during interaction, as paper documents can be. This means that they cannot be used as a resource in interaction, where there is a need to gesture at areas of the map and such.

Yet collaboration around the maps also presents opportunities for technological systems. One problem that tourists face is co-ordinating their activities while they are separated — in particular getting groups back together again. One application that would assist this is a handheld– or phone–based system that allowed tourists to communicate their location to each other. So, if a group splits into two, they could choose to 'tie' their locations together so that each subgroup would be able to see where the other was. 'Tying' in this way could support synchronous awareness without running into difficult privacy problems. In addition, technology could support tourists showing the routes they took and things they did when they meet up again. This could allow them to make recommendations to their companions and also to other tourists who they meet.

### 16.5.2 Combining electronic maps and guidebooks

Electronic guidebooks and maps have of course been a popular application area for mobile technology, with existing system generally following a similar format to paper guidebooks, augmented with GPS (for example TomTom CityMaps). Our fieldwork implies a number of limitations with this design. In particular, the rich affordances of paper guidebooks suggests that to be successful, electronic guidebooks must offer compelling advantages over their paper equivalents. Simply copying content into an eBook is unlikely to be successful if that content is much harder to use. In particular, the examples above show the importance of labeling; due to the smaller resolution of electronic maps this could be a considerable disadvantage as they often need to hide labeling so that maps are sufficiently clear.

One innovation that electronic guidebooks could support is in making connections between where attractions are and what they are through their interaction with electronic maps. Electronic guidebooks need to explicitly support the comparison of information, such as location, allowing users to quickly move between related pieces of information. Partly due to the limited screen size, however, mobile systems seldom offer this feature. Pocket internet explorer, for example, only allows the user to load one web page at a time. One solution to this could be to produce paper maps which are designed to be used with an electronic guidebook. This would remove some of the disadvantages of the small screen by allowing users to juxtapose the PDA and the map in their visual field. In addition, by using the cameras increasingly common in devices, users could point out areas of interest on the map in a way that was apparent both to the system and to one's friends, triggering on-screen display of information.

A more general issue our fieldwork uncovered was the problems which tourists experience in connecting maps to the environment they are in. There are opportunities here for experimentation with different representations which would support city navigation better. For example, one variant on the conventional overhead map would be a 3D view of nearby streets which, by tracking which way a PDA is held, could directly 'point out' specific attractions. A user could then point the PDA in a direction and see on their PDA a 3D view of what they see, with attractions of interest highlighted. A PDA with this feature could actually 'show' directly how to get to a particular places. Electronic maps could also use photographs overlaid on maps in different ways to help tourists make the connection between the flat representation of the map and the 3d world that they are exploring.

Mapping systems could also support more of the 'wandering' behavior of tourists; for example, showing at a glance whether a tourist is going in the right direction rather than simply displaying a pre-determined route. Indicators could show close by attractions, cafés, areas or main streets to support surreptitious discovery. These sort of representations move beyond supporting wayfinding to supporting the broader range of tasks which tourists undertake when navigating. So, such a representation would support going between one shopping district and another, while looking for a café. In cases like this it is not the exact route that is important, although walking in the right direction is, but a more general sense of learning about the city as one wanders around.

### 16.5.3 Supporting pre visiting an planning

A number of systems have attempted to augment maps through offering electronic 'tour guides' which offer information about a visitor's current location, and suggestions of where they might want to go next. These systems, such as the Lancaster GUIDE system, and more recently the EU funded "m-toGuide" system (http://www.mtoguide.org/), have generally been based around a 'walk-up pop-up' model where information (voice, and text) is pushed at users based on their current location. Our observations suggest some limitations with this model. We observed that tourists frequently used maps and guides before visiting a place – an activity we called 'pre-visiting'. In this way tourists can plan what they want to do, but also can pass the time while waiting for public transport.

Presenting information to tourists while they are actually at an attraction may have limited utility, since at that point the environment is likely to contain richer sources of information than can be provided by a device. Our fieldwork also showed that tourists often do not follow tours in a straightforward way. Tours instead act as structures through which tourists can learn about the place being visited, and use to build their own, more ad hoc plans. Systems should therefore present tours and attractions to tourists in such a way as to allow them to browse and learn from the tours rather than strictly following them, and to be aware of 'official' tourist attractions without being restricted to them. Viewing tours in advance would allow tourists to 'pre-visit' and judge different places and make their own plans about what to do rather than necessarily following an official tour.

To explicitly support pre-visiting tourist systems could also experiment with different ways of representing information about the city. Most existing systems present the positions of tourist attractions by overlaying icons representing attractions onto maps. Mobile systems could instead support 'occasioned maps' (*Psathas* 1979). These are maps which are drawn for a particular purpose. For example, if a user is going shopping the system could build a shopping map, which highlights the good shopping streets, particularly popular stores, reviews of stores, cafés and so on. Systems which understand something of the structure of places (such as what places are good for shopping, the arts, going out at night etc.) could produce maps which are specifically focused towards particular activities. The important point here is that systems should support potential actions as well as just offering information. Maps could answer questions such as "Where is a good coffee shop around here?" or even "Where are my children?", that is, answering questions tied to the current activity rather than just offering an objectified view of a place. In particular, these maps could endeavor to show something of the 'social zoning' of different places, such as what areas are good for shopping, going out, or eating. This would support something of how tourists navigated cities, described above.

### *The "George Square" system*

We have been using these conclusions in the design of our own map based collaborative tourism system – which we call the "George square" system, after the main city square in Glasgow. This system has been specifically designed to support tourists collaborating together around maps, either in a face to face setting or at a distance from each other. In our system two tablet PCs are connected with audio connections between headphones connected to the tablets. On each tablet a map is displayed along with recommendations listed both on the map, and in a legend at the side. Recommendations feature attractions to visit, web pages and also photographs taken by others in the area. The system also allows users to take photographs, with the photos placed on the map and shared between the map users.

The design of this system meets a number of the implications described above. The system does not just support the presentation of information, but collaboration around that information. The use of tablet PCs supports face to face collaboration around the map better than a smaller PDA would support. By sharing user's locations and photographs users can also share a visit when they are distant from each other. This could take the form of a temporary break in a visit, as suggested above, but also a new type of 'shared' visiting experience where a visit is shared over the internet with those at home.

Rather than focus on a 'walk up pop up' model of information presentation, this system has also been designed to instead support 'pre-visiting'. The system supports viewing a place before actually getting there, seeing what recommendations and information is available about that place before the actual visit. The recommendations which the system produces are generated through a path matching algorithm to suggest what web pages and attractions people with similar previous paths to your own found. In this way the system is always dynamically suggesting future actions to the user, rather than fixed recommendations based on current location. In this way recommendations provide information about what to do next, in a flexible way which supports the 'wandering' behavior described above. As a user walks through a city, different attractions are suggested based on other tourists behavior – such as local cafés, tourist attractions, or even local web pages.


**Fig. 16.3.** The George Square System

The system can be seen in Figure 16.3 – it offers each of a pair of tourists a map, showing places to go, photographs to look at, web pages to read, and tools to take and to see photographs. It supports mutual awareness of locations, map use and photography, and awareness of selected past locations, photographs and web pages via the Recer recommender system. Recommendations for both visitors are shown as map icons and as list items on the right of the map, with the 'other' visitor's recommendations slightly greyed out. We are currently evaluating this system to explore what uses the system is put to, and how well it supports collaborative tourist activity around maps.

## 16.6 Conclusion

In this chapter we have explored some aspects of map use by tourists, presenting an ethnographic study and design implications for these technologies. First, we discussed how maps are used in groups, looking at how the use of a map is inescapably part of collaboration and involves allocating tourism's work. Second, we looked at how maps are used in situ, and the problems which tourists have in connecting a map with the streets they find themselves in. Third, we discussed how maps are used for wayfinding and navigation between different areas. Lastly, we covered pre-visiting and the importance of maps in planning for tourists.

Designing mapping systems for tourists presents a number of specific challenges. Good tourist technologies are not only those that make tourists more efficient, but that also make tourism more enjoyable. Much of what is enjoyable about leisure is that it provides an opportunity to spend time in unusual circumstances with other tourists, making friends, or with friends or family. While we have described the use of maps here in a fairly utility orientated way, we must not lose sight of the pleasurable nature of map use, and how much of map use involves activities that are not goal–oriented. As Wood reminds us (*Wood* 1987) map use can be as much about pleasure as it is about goal directed action. Indeed, with an inherently pleasurable activity such as tourism – hedonic and emotional – we must be careful to hold on to the image of wandering tourists rather than the lone optimizing tourist. Learning how to design for these sorts of group activities is a continuing challenge for designers, as interest extends from worksites to other environments. Interfaces may succeed as much for their playful nature as their usability. Much can be learn here from the interfaces of games, in particular online games (*Dyck et al.* 2003) and games that interact with travellers' changing environments (*Runnberg and Juhlin* 2003). Our focus has to be as much on designing technologies which are pleasurable, as well as fitting to the users task.

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