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Mobile Cartography – Adaptive Visualisation of Geographic Information on Mobile Devices

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Abstract

The progresses in the fields of mobile Internet and positioning methods have lead to a plethora of new possibilities for cartography in mobile usage environments. However, principles of web mapping cannot simply be transferred to the mobile environment. Likewise the availability of *Location Based Services* (LBS) has made it possible to develop mobile map services, yet LBS themselves are mainly driven by technology and only concerned with location-related issues, thus have rather limited meaning for the usability study. This work has introduced a new and comprehensive conceptual framework of mobile cartography, thus established an instrument for the design of useful and usable geovisualisation services. The research enriches and extends cartographic theory and methods in the field of geographic information communication in mobile environments and adaptive methods for cartographic visualisation. It established new concepts for mobile cartography and showed the differences, but also the similarities towards traditional cartography and web cartography. The main focus is on the elaboration of adaptive methods for visualisation of geographic information for mobile usage, i.e. on mobile devices. Adaptation takes place in the components such as the mobile user, his/her activities with associated goals, as well as the situation they are placed in. The usage scenarios described were helpful for the implementation of a rudimentary, prototypical adaptive geovisualisation service for mobile users. The service for the example of point symbol maps was implemented based on open-standard formats and served as a proof of concept. It basically demonstrates how a mobile client can send as *Simple Object Access Protocol* (SOAP) encoded context parameters to a web service. The service handles the user demand by sending a request for the required geospatial data and maybe additional filters to a *Web Feature Server*. The result, a *Geography Markup Language* (GML) document is transformed through an *Extensible Stylesheet Language Transformation* (XSLT) into a *Scalable Vector Graphics* (SVG) document. Further adaptations of the SVG document can be effected by manipulating the *Document Object Model* (DOM). Finally, the web service returns the result as a SVG map back to the client. A few examples generated with this geovisualisation service demonstrate the potential of map adaptation to mobile user activities.

Zusammenfassung

Entwicklungen im Bereich des mobilen Internets und der Positionierungsmethoden führen zu neuen Möglichkeiten für die Kartographie im mobilen Nutzungsumfeld. Allerdings sind die herkömmlichen Ansätze der Internetkartographie nicht ohne weiteres übertragbar. Ebenso bilden *Location Based Services* zwar eine gute Grundlage für die Entwicklung von mobilen Kartendiensten, aber die Techniklastigkeit und Einschränkung auf die Ortsinformation schränken die Brauchbarkeit ein. Mit der Einführung eines umfassenden neuen Forschungsrahmen für die mobile Kartographie, dessen wesentlicher Punkt der Kontext der Nutzung und die Anpassung der Geovisualisierung an diesen Nutzungskontext ist, wird ein Instrument für die Entwicklung von brauchbaren mobilen Geovisualisierungsdiensten geschaffen. Der Forschungsrahmen vereint dabei Geoinformation, Visualisierung, Kontext und Adaption in geeigneter Weise, sodass aufgrund der Kontextinformation die Visualisierung von Geoinformation auf mobilen Geräten adaptiert werden kann. Kontext wird dabei umfassender verstanden und beinhaltet neben der Ortsinformation die Zeit, den Nutzer, die mobilen Nutzeraktivitäten, die Geoinformation, die technischen Gegebenheiten, sowie die Beziehungen zwischen diesen Elementen. Die Modellierung des Kontexts der mobilen Geoinformationsnutzung schafft die Grundlage für die Übertragung des Adaptionskonzeptes aus dem Bereich der Benutzerschnittstellen und Hypermedien in die Kartographie. Die Analyse der wesentlichen Adaptionsdimensionen der Kartographie ermöglicht die Vorschläge von Methoden zur Adaption der Geoinformation in mobilen Geovisualisierungsdiensten. Als Nachweis der Machbarkeit wird anhand von Punktsymbolkarten ein rudimentärer, prototypischer adaptiver Geovisualisierungsdienst auf Basis von offenen Standards implementiert. Im Wesentlichen wird dabei gezeigt, wie ein mobiler Client als *Simple Object Access Protocol* (SOAP) kodierte Anfragen an einen Web Service schickt, die die erforderlichen Kontetxtinformationen beinhalten. Der Service behandelt die Nutzeranfrage indem er die Anfrage der entsprechenden Geodaten, eventuell mit zusätzlichen Filtern versehen, an einen *Web Feature Server* schickt und das Resultat, ein *Geography Markup Language* (GML) Dokument, weiterbehandelt. Dazu gehört die Transformation mittels *Extensible Stylesheet Language Transformation* (XSLT) in ein *Scalable Vector Graphics* (SVG) Dokument sowie weitere Adaptionen des SVG Dokuments über das *Document Object Model* (DOM). Zuletzt sendet der Web Service das Ergebnis in Form einer SVG Karte an den Client zurück. Einige mittels dieses Geovisualisierungsdienstes erzeugte Beispiele verdeutlichen insbesondere die Möglichkeiten der Anpassung der Karten an die Aktivitäten des mobilen Nutzers.

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Chapter 1

Introduction

> *"But is thought continuous, inescapable, or is it as somebody said against Descartes, sometimes I think and sometimes I just am ..."*
> *– David Lodge, 'Thinks …'*

1.1 Motivation

One of the characteristic features of our society is the constantly growing mobility, lately also combined with an increasing desire for mobile usage of computing and communication tools. This trend can be observed in the rapid spread of laptops, mobile phones and other mobile devices. Another trend is the 'democratisation' of computer usage. For years geographic information systems (GIS) have for example been a tool for experts, running only on expensive machines requiring professional skills. In the early nineties easy-to-use desktop GISs were introduced. With the widespread Internet and web mapping a further 'democratisation' of geographic information use took place. And now, after the tremendous success of the Internet and the cellular telephone over the last decade, the next technological wave seems to be the convergence of the two: the mobile Internet **(Andersson and Svensson 1999)**. This brings web GIS and web mapping a step further, since the dissemination of digital geospatial data is no longer bound to the desktop platform. And finally we are on our way to an ***information society***. The availability of current and relevant information is of great importance for our daily life **(Negroponte 1995)**. The impact of the Internet is enormous. The technological progresses 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 people travel and move in areas unfamiliar to them. The global village metaphor also holds for the wish to differentiate oneself from the average mass leading to a growing

(Andersson and Svensson, 1999)
Andersson, C. and Svensson, P. (1999): Mobile Internet - An industry-wide paradigm shift?, *Ericsson Review*(4): 206-213

(Negroponte, 1995)
Negroponte, N. (1995): *Being digital*, London: Hodder & Stoughton

trend towards individualisation (or personalisation). 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, but are forced to manage their individual lives and their mobile everyday activities, which gets more and more complicated. 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.

The emergence of mobile computing along with wireless devices has brought about a whole palette of new possibilities for cartography. New mobile devices such as Personal Digital Assistants (PDA), Smartphones and the like, have inherent advantages concerning personal assistance in mobile environments: they can present up-to-date geospatial information in an individual, dynamic, and flexible way to mobile users, i.e. unbound to space.

Other important trends in information technology that have increasingly gained attention in the field of cartography are user focus, personalisation, and context awareness. The incorporation of these trends could result in more adaptive systems. The challenge for modern cartography lies in supporting as many people as possible with mobile usage of geographic information. A mobile assistance system would incorporate analytical functions, be aware of the user's context and characteristics to assist the user in a mobile environment. 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 order to achieve this, a substantial amount of adaptation is indispensable. There are three reasons for this. First, the increasing quantity of information and the danger of overstimulation 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.

A possible solution to these challenges is an adaptation in the sense of providing the user more relevant, detailed, accurate and thus adequate information meeting his/her needs better. Cartography should provide new and enhanced services that could be combined with existing services, thus bring added value to users. In this sense, cartography should become a more service-oriented business. These new services ought to close the gap between the benefits of web mapping or online GIS and the freedom of mobility. Today some people use highly sophisticated web-based applications to extract geographic information only to print out the results (e.g. a city map or a route description) for having them at hand when they will move around later on. This deviation and degrading of an information delivering process makes little sense. After all, even if this proceeding is considered a valuable approach, due to its static nature it is not able to support many requirements of human life, such as spontaneous decisions and serendipities.

Furthermore there are three critical elements requiring an instant information access during mobility: time, location, and physical conditions. On the one hand there are many situations where there is no time to look up some information later at a stationary, wired PC or an Internet appliance. The information has to be timely, the access immediate. On the other hand many situations are imaginable where time is not a critical factor, but we are at a certain place and need some information related to this place. It would be rather inefficient and inconvenient to go away in order to gather the required information and later come back to the same place to actually use the information. Sometimes this approach is even impossible (e.g. if one is at a place only once in a lifetime). Finally, special physical conditions could require instant information access (e.g. natural hazards such as a storm or fire). Naturally, this factor is tightly coupled with time and location. One needs the information, because one is right here, right now.

Although the technological progress in the field of mobile computing is significant and more and more research is directed to mobile usage of geographic information, several problems are yet unsolved and many gaps are to be bridged when it comes to developing solutions for the mobile context:

- Geovisualisation for the small displays of mobile devices is restricted by several technical limitations, such as the small display size and resolution, the lack of processing power and memory, and most critical the battery lifetime. Furthermore, the mobile network bandwidth is considerably smaller than that in fixed networks.
- The usability of mobile geovisualisation solutions is hindered by inadequate geovisualisation. The causes are either the use of scanned paper maps designed for a medium with different characteristics or the production of illegible and cluttered maps that fit a large screen, but not the small mobile device screen with lower resolution.

Geovisualisation that is not adapted to the usage context, supporting functionality that is not tailored to the users' mobile activities, and poorly designed user interfaces not taking into account the different input modes and conditions of mobile interactivity cause further usability problems.

- The geovisualisation on small displays is dominated by the constraint of the small display. This poses an immense generalisation pressure. However, generalisation alone cannot assure the fitness for use required in mobile geographic information usage situations. The lack of map space also implies that there is no room for auxiliary elements such as a map legend, which makes the map reading process difficult. Furthermore the overview function of maps is missing.
- The mobility of the user has many consequences: the usage of geographic information is very different from a stationary case and is affected by changing modes of movement, different and changing activities beside the usage, a potential of distractions, different and fast changing contexts, and harder usage conditions, e.g. a limited time budget.

1.2 Thesis objectives

The overall objective of this thesis is to establish a conceptual framework for mobile cartography and adaptive visualisation of geographic information on mobile devices by transferring the adaptation approach to the domain of cartography in mobile environments. This research work claims to open and define a new research field in cartography. In addition, the dissertation aims at demonstrating the value of a top-down approach for developing cartographic solutions in a mobile environment.

The focus is on non-explorative, communicative mobile usage of geographic information in urban environments. The main goal is to communicate geographic information in a supportive way rather than learning or exploring. Emphasis is put on the support of everyday activities of mobile users by offering fast and non-intrusive information presentations for quick decisions.

The following list describes the general objectives of this thesis:

- Providing a framework for mobile cartography and adaptive geovisualisation

- Identifying the links and interfaces to related disciplines and methods

The more specific objectives include:

- Developing adaptation methods for geovisualisation
- Demonstrating the potential of Scalable Vector Graphics for mobile cartography and adaptive geovisualisation
- Implementing a prototype mobile geovisualisation service for mobile users serving as a proof of concept for the mobile cartography framework

1.3 Thesis structure

The remainder of the thesis is structured as follows (see Fig. 1):

This chapter introduced the problems and challenges of visualisations for mobile devices and outlined the goals and contributions of this thesis.

Chapter 2 presents the scope of this research work and develops the theoretical and technical background. First, the theories central to mobile cartography are reviewed independently followed by a contemplation of their relationships to cartography. Second, the basic technologies relevant to mobile cartography are described.

Chapter 3 reviews existing approaches and solutions for geographic information visualisation on mobile devices. An evaluation of these approaches reveals the gaps and deficiencies and confirms the need for a fresh approach.

Chapter 4 introduces a new and comprehensive conceptual framework for mobile cartography. After a discussion of the rationale, the building blocks, user, activity, context, information, user interface, visualisation, and technology are elaborated in further detail.

Chapter 5 first describes the transfer of the adaptation concept to cartography and the core elements of adaptive visualisation. Thereafter it illustrates methods for geovisualisation adaptation.

Chapter 6 describes the design of a prototype geovisualisation service with adaptation capabilities.

Chapter 7 gives a synopsis of mobile cartography and evaluates the framework, draws the conclusions and identifies further work to be done in this research field.

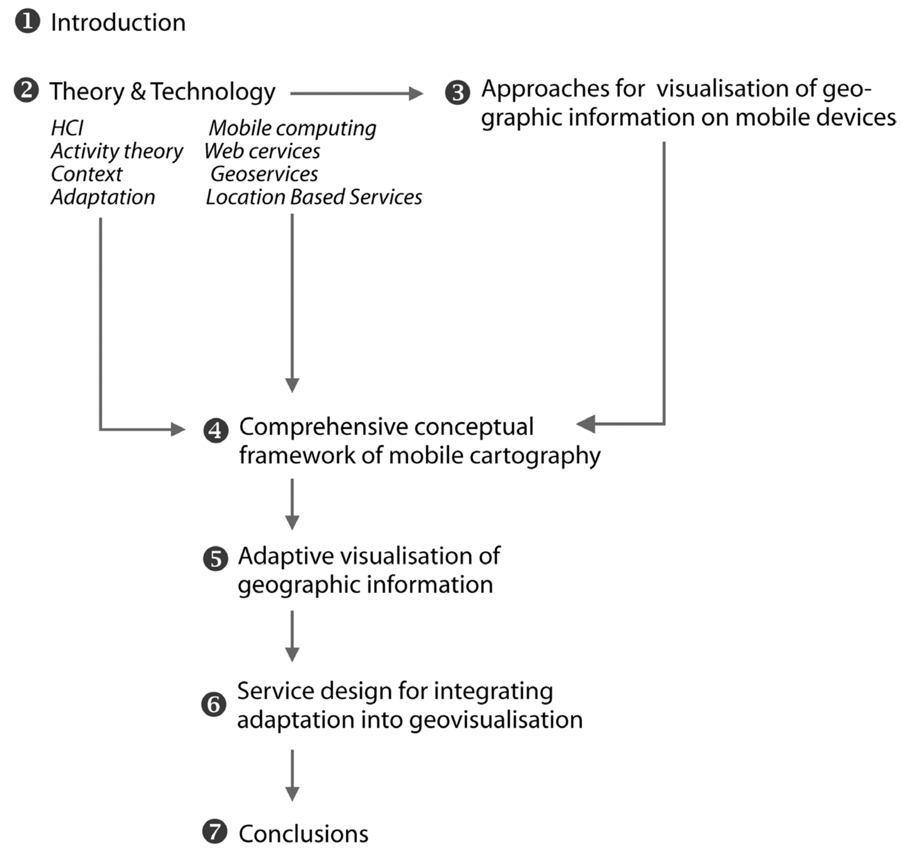


Fig. 1: Thesis structure

Chapter 2

Scope

"The difference between theory and practice is smaller in theory than in practice."
– Anonymous

2.1 Theoretical background

The grounding theory for this work is information and communication theory with respect to cartography. This theory is involved in questions of modelling, structuring and transforming geographic information for mobile usage purposes. In the last thirty years several models of the cartographic communication process and a system of related models have been proposed by cartographers. This cartographic theory which by itself makes vast use of other theories has been discussed by many authors, e.g. **(MacEachren 1995; Buziek 2001; Freitag 2001)**. These contributions mention different theories involved in cartographic visualisation: information and communication theory, model theory, semiotics, system theory, cognitive theory, and activity theory. In recent years the methods and tools of cartography have been extended by some exponents in the discipline towards communication of geographic information through animated and auditory elements. However, in this work the focus is on cartographic visualisation. Therefore methods of visual design and concepts from semiotics are borrowed. **Meng (2003)** argues that not only the cartographic methods and consequently the context of mapmaking have changed, but also the contexts of map use. Despite the shift to context in use and new, non-visual means the visual remains vital for cartography. **Buttenfield and Mackaness (1991, p. 432)** give a comprehensive definition of visualisation:

> *Visualization is the process of representing information synoptically for the purpose of recognizing, communicating and interpreting patterns and structure. Its domain encompasses the computational, cognitive, and mechanical aspects of generating,*

(MacEachren, 1995)
MacEachren, A. M. (1995): *How maps work: representation, visualization, and design*, New York (NY): Guilford Press

(Buziek, 2001)
Buziek, G. (2001): *Eine Konzeption der kartographischen Visualisierung*, Habilitationsschrift, Institut für Kartographie und Geoinformatik, Universität Hannover

(Freitag, 2001)
Freitag, U. (2001): Die Entwicklung der Theorie der Kartographie, *Kartographische Bausteine* Band 19

(Meng, 2003)
Meng, L. (2003): Missing Theories And Methods In Digital Cartography, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

(Buttenfield and Mackaness, 1991)
Buttenfield, B. P. and Mackaness, W. (1991): Visualization, *in* D. J. Maguire, M. F. Goodchild and D. Rhind (Eds.), *Geographical Information Systems: Principles and Applications*, 1, New York (NY): John Wiley & Sons

organizing, manipulating and comprehending such representations. Representations may be rendered symbolically, graphically, or iconically and are most often differentiated from other forms of expression (textual, verbal, or formulaic) by virtue of their synoptic format and with qualities traditionally described by the term ´Gestalt´.

The different kinds of cartographic visualisation are profoundly examined by **MacEachren (1995)**. The two main types of cartographies distinguished are communication oriented and explorative visualisation oriented cartography. For better understanding MacEachren proposed a map cube spawn by the major dimensions of map use: target audience, presentation intentionality, and degree of human-map interaction (see Fig. 2). A similar distinction has been proposed by **DiBiase (1990)**. In his schema the presentation of geographic information in the public realm is named ***visual communication*** in opposition to visual thinking. The present work concentrates on communicating known geographic information (*knowns*) to individual users for *private* use or according to DiBiase the visual communication, however in a more private realm. And the human-computer interaction is compared to desktop environments *low* for reasons to be discussed.

(DiBiase, 1990)
DiBiase, D. (1990): Visualization in the earth sciences, *Bulletin of the College of Earth and Mineral Sciences, Pennsylvania State University* 59(2): 13-18

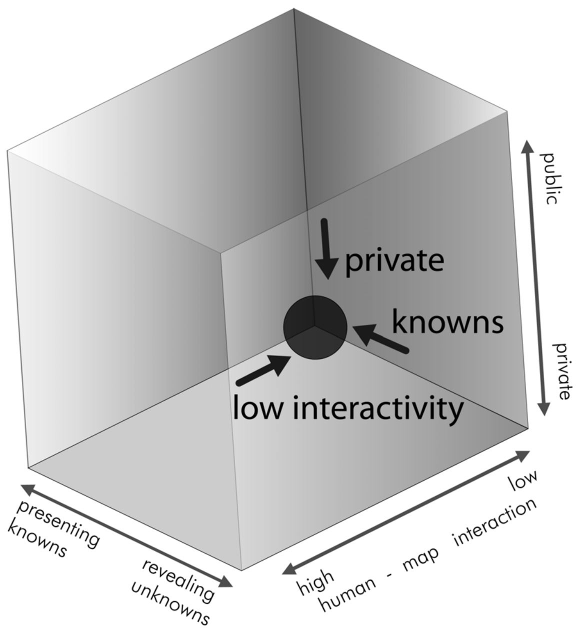


Fig. 2: Focus of thesis related to MacEachren's map cube

For the rest of this dissertation the term ***geovisualisation*** is usually preferred over the term map, because the expression means of visualisations of geographic information in mobile environments can exceed the traditional meaning of a map. Thus the term map is considered too narrow for representations on mobile devices, although the examples in this thesis are not stretching these limits. Geovisualisation is here understood as any kind of visualisation of geographic information (including perspective views, photographs, panoramas, animations, acoustic elements) without a focus on exploratory data analysis, though.

Since this work aims at extending existing cartographic theory towards adaptation and mobile usage of geographic information, it first has to clarify the theoretical foundation and its interrelation with this dissertation. These theories contribute in different ways to the problem of visualising geographic information in mobile environments. Fig. 3 shows an overview of the different theoretic fragments related to this work.

This chapter covers the most relevant theories for communicating spatial information in mobile environments. For identifying and modelling mobile user tasks and usage issues ***activity theory*** is incorporated. Mobile usage per se and adapting visualisation to this mobile usage situation is strongly connected to ***context theory***. Different theories and principles of ***human computer interaction***, e.g. cognitive science theory, interactivity, and usability principles are applied to user focus issues and user task analysis. The basic principles of adaptation prepare the terrain for adapting geographic information in mobile usage situations.

These theories and the ones not yet mentioned here, i.e. information and communication theory and model theory, are discussed in chapter 4 in the context of their usefulness for mobile geovisualisation, where they are combined to build the framework of mobile cartography. The more subsidiary theories like theories about technology adoption and scenario based design are covered in chapter 5.

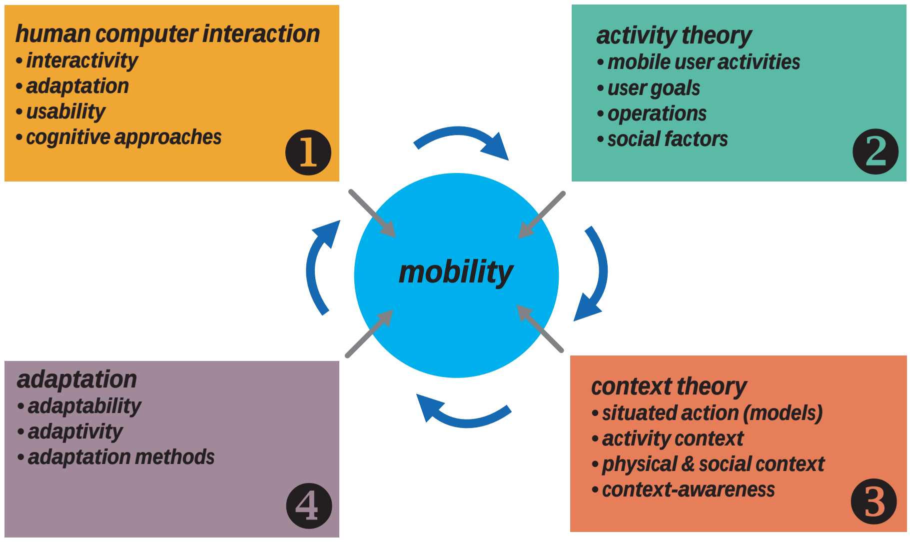


Fig. 3: Theoretical model and applied theories for adaptive geovisualisation

2.1.1 Human computer interaction

mobile HCI
interactivity
usability
mobile usability problems

The mobile environment and the mobile usage situation differ in many respects from a stationary one. The mobile environment has its own characteristics. Mobility and most mobile activities limit our possibilities and shape the way we do things. A major factor is the overwhelming stream of external stimuli. We cannot cope with all of them simultaneously. The focus of attention is thus not always on the system in use or the user interface respectively. Opposed to stationary usage with virtual environments in the hyperspace, the mobile user is much more engaged with the real environment. This includes the wishes or needs to perform activities in parallel to system usage and hence a too intrusive system would be disturbing or even threatening a successful activity performance. That means that too much direct interaction is not possible in mobile contexts. There generally is no time to manually filter the relevant information needed in a specific usage situation. This fact is precisely described in **(Smailagic and Siewiorek 2002)**:

(Smailagic and Siewiorek, 2002)
Smailagic, A. and Siewiorek, D. (2002): Application Design for Wearable and Context-Aware Computers, *pervasive computing* (October-December): 20-29

> *Distractions pose even more of a problem in mobile environments than in desktop environments because mobile users often must continue walking, driving, or taking part in other real-world interactions. A ubiquitous computing environment that minimizes distraction should therefore include a context-aware system able to ´read´ its user's state and surroundings and modify its behaviour on the basis of this information. The system can also act as a proactive assistant by linking information such as location and schedule derived from many contexts, making decisions, and anticipating user needs. Mobile computers that*

can exploit contextual information will significantly reduce demands on human attention.

This statement makes it clear that interacting with computers in mobile environments is quite different from interacting with stationary computers. Though there certainly always is and needs to be some kind of interaction between the system and the user, the degree of interactivity must be minimised, i.e. interactive functions should be sparingly used and the kind of interactions should be wisely chosen in mobile usage contexts respectively. Interactivity has to be adapted to the mobile usage environment to enable the user to achieve his/her information needs with a maximum of relevance for a minimum of interactive input. To clarify this statement interactivity is first defined in general and later re-considered in a mobile context.

Interactivity

The term ***interactive*** became popular in information technology in the late 1970ies with the introduction of the first graphical user interface at Xerox Palo Alto Research Centre later incorporated in the first Apple Macintosh. There are different notions and definitions of the term interactive. A useful definition provides **Steuer (1994)** stating that interactivity is "the extent to which users can participate in modifying the form and content of a mediated environment in real time".

interactive: "of or relating to a program that responds to user activity" (The American Dictionary of the English Language, 4th Ed.),
"of or relating to a two-way electronic or communications system in which response is direct and continual" (dictionary.com),
"reciprocally active; (of a computer or other electronic device) allowing a two-way flow of information between it and a user, responding to the user's input" (*The Concise Oxford Dictionary, 8th ed.*)

interactivity: "In computers, interactivity is the dialog that occurs between a human being (or possibly another live creature) and a computer program." (whatis.com)

From the literature review **(Heeter 1989; Haack 1995)** a few constituting elements can be identified:

- active role of user
- degrees of freedom in choices of content and functions
- selection, appearance, and order of information items changeable by the user
- possibility of customisation through the user

It is important to separate the physical or technical interactions from symbolic interactions, i.e. the surface and deep structure of interaction. Hitting a button or moving the mouse is a surface, physical or explicit interaction, while a symbolic or implicit interaction is for instance the selection of a menu option.

Interactivity is a more intuitive way of working with a computer. This intuitive approach in HCI has the objective to make the use of a computer easier, faster to learn and more transparent to the user. **Dix et al. (1998, p. 104)** state that "the purpose of an interactive system is to aid a user in accomplishing goals from some application domain". Fig. 4 shows the general interaction framework.

(Steuer, 1994)
Steuer, J. (1994): Defining virtual reality: Dimensions determining telepresence, *in* B. F. and M. Levy (Eds.), *Communication in the age of virtual reality*, Hillsdale (NJ): Lawrence Erlbaum Associates. http://cyborganic.com/People/jonathan/Academia/Papers/Web/definingvr1.html

(Heeter, 1989)
Heeter, C. (1989): Implications of New Interactive Technologies for Conceptualizing Communication, *in* S. J. L. and J. Bryant (Eds.), *Media Use in the Information Age: Emerging Patterns of Adoption and Consumer Use,* Hillsdale (NJ): Lawrence Erlbaum Associates

(Haack, 1995)
Haack, J. (1995): Interaktivität als Kennzeichen von Multimedia und Hypermedia, *in* L. J. Issing and P. Klimsa (Eds.), *Information und Lernen mit Multimedia,* Psychologie Verlags Union, 151-166

(Dix et al., 1998)
Dix, A. J., Finlay, J. E., Abowd, G. D. and Beale, R. (1998): *Human-Computer Interaction*, Harlow: Prentice Hall Europe

There are many possible methods for providing the input by the user to articulate his/her task, as well as there are many ways of outputting the system's response, though the visual output on a screen is dominating.

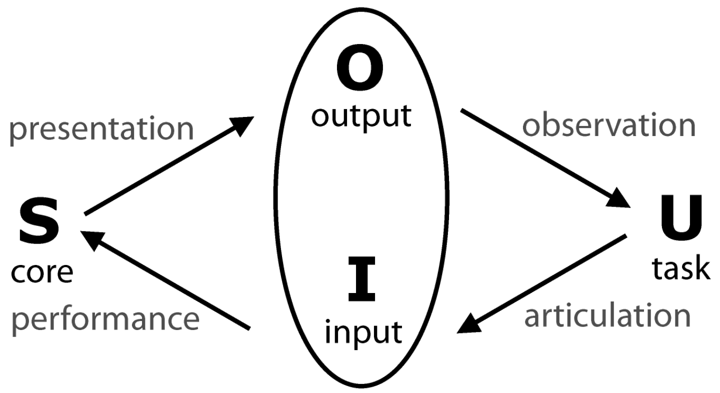


Fig. 4: Interaction framework (Dix et al. 1998, p. 107)

(Holzinger, 2001)
Holzinger, A. (2001): *Basiswissen Multimedia, Band 3*, Würzburg: Vogel Buchverlag

Holzinger (2001, p. 185) distinguishes three different interaction methods:

- descriptive interaction methods, i.e. interaction through linguistic descriptions (symbols, formal and natural languages)
- deictic interaction methods, i.e. interaction through selections by pointing actions (menus, function keys, metaphoric dialogues)
- hybrid interaction methods

(van Mulken, 1999)
van Mulken, S. (1999): *User Modeling for Multimedia Interfaces: Studies in Text and Graphics Understanding*, Wiesbaden: Deutscher Universitäts-Verlag

Apart form the interaction method, the modality of interaction must be differentiated. The term ***modality*** is generally used to refer to the human perceptual channel or senses for information acquisition, i.e. visual, auditory, haptic, olfactory, and gustatory. For HCI the visual and auditory channels are of major importance **(van Mulken 1999)**. If two different modalities are involved in the information perception, the interface or system is called ***bimodal***. If more than two modalities are involved, the system is analogically called ***multimodal***. To exchange information ***codes*** are used. The information to be perceived by a human could be encoded either as text or pictures, i.e. ***monocodal*** or in different coding systems (e.g. sound and text) at the same time, i.e. ***multicodal***. ***Media*** refers to the physical carriers of information.

Interactions in interactive systems can have a ***mode***. This is not to be mixed up with the term modality. The mode of an interaction dialogue affects the interpretation of the actions. An example is the form of the mouse pointer depending on the mode of the interaction in an application.

Today most interactive systems follow a bimodal direct manipulation interaction style which is often referred to as Windows - Icons – Menus - Pointers (WIMP). The initiative and control of this interaction style is clearly on the user side who has several options and often numerous applications simultaneously available **(Dix et al. 1998, p. 136)**. There are definitely many advantages of such an approach. Interactivity means participation of the user, an active part in using the system. Important factors of interactivity are its motivation function that has an impact on the learning effect, i.e. the establishment of an internal mental model and memorability, and its function of individualisation **(Haack 1995)**.

(Dix et al., 1998)
Dix, A. J., Finlay, J. E., Abowd, G. D. and Beale, R. (1998): *Human-Computer Interaction*, Harlow: Prentice Hall Europe

(Haack, 1995)
Haack, J. (1995): Interaktivität als Kennzeichen von Multimedia und Hypermedia, *in* L. J. Issing and P. Klimsa (Eds.), *Information und Lernen mit Multimedia,* Weinheim: Psychologie Verlags Union, 151-166

(Crampton, 2002)
Crampton, J. W. (2002): Interactivity Types in Geographic Visualization, *Cartography and Geographic Information Science* 29(2): 85-98.

Despite the definitions mentioned above, interactivity is a loose and poorly defined concept. Interactivity certainly has pushed HCI a great leap forward and interactive systems are state of the art in many domains, also in cartography. **Crampton (2002)** describes a taxonomy of interactive functions in geovisualisation and argues that a highly interactive map provides many of theses functions, whereas a non-interactive map (e.g. a scanned raster map) does not offer any interaction possibilities. Certainly, interactivity is a powerful means for engaging the user. This is especially the case for explorative analysis and learning where interaction is surely important and desired. However, interactivity per se is not necessarily a quality feature and not always more efficient. It might take too much time to learn or to achieve a goal by interactive steps. For mobile systems, a certain adaptation seems to be more adequate, since the environment is changing very dynamically. This fact does not allow for too much exploration, since time is usually a critical factor. Interaction in HCI is generally seen as control, as power, though interactivity in a mobile context could rather be regarded as a disadvantage, requiring a lot of user attention and also a lot of additional knowledge about the system handling. Therefore the goal is to reduce the need of continuous control actions by the user without taking from the user the overall power over the system. Another critical issue on the interactive approach for mobile devices is related to its usage. Interactivity is mostly used to compensate for the small displays and not for enhancing the user experience.

Further reading:

(Shneiderman 1987)
Shneiderman, B. (1987): *Designing the User Interface*, Reading: Addison-Wesley

(Rodden et al. 1998)
Rodden, T., Cheverst, K., Davies, N. and Dix, A. (1998): Exploiting Context in HCI Design for Mobile Systems, *Proceedings First Workshop on Human Computer Interaction with Mobile Devices*, Department of Computing Science, University of Glasgow, May 21-23, 1998. http://www.dcs.gla.ac.uk/~johnson/papers/mobile/HCIMD1.html

(Olsson and Svanteson, 2001)
Olsson, A. and Svanteson, S. (2001): *User Intelligence Will Make Mobile Solutions Fly*, Whitepaper, Stockholm. http://www.hci.uu.se/~jg/UCD2001/Olsson.pdf

The interaction styles with mobile devices are somewhat different from stationary PCs. In general input to the system is executed by a pen and touch-sensitive screen. This allows for pointing and dragging. Text input can be effected by handwriting recognition or pointing on a soft keyboard. Both ways are tedious for longer texts. Output by the system is mainly visual and partially auditory. The latter is still not evolved to its full extent. Thus, the most promising approach seems to be multimodal interactivity. Especially in mobile situations, speech input and output could be helpful.

Usability

Many mobile applications ignore the fact that input in mobile devices is limited and slow. The design of mobile services is still very technology driven. The consequence are applications and services with poor usability: "The mobile industry in Europe and the US is to a large extent governed and developed by engineers who have not paid sufficient attention to the target groups of mobile devices. Mobile phones are not aesthetically pleasing enough, navigation is tricky and services are hard to use" **(Olsson and Svanteson 2001)**. Before further investigating this statement it is worth exploring the principles of ***usability*** and why it is so important. In the ISO 9241-11 (Guidance on Usability) standard usability is defined as

> *… the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.*

According to this definition usability can express how well the user's goal is feasible with a product (or service) in a specific context. At this place two links to following theories are worth mentioning: goals are genuinely connected with user activities (see section 2.1.2 on activity theory) and the reference to the context of use is taken up in section 2.1.3 on context. Usability is only one attribute of the overall system acceptability as shown in Fig. 5.

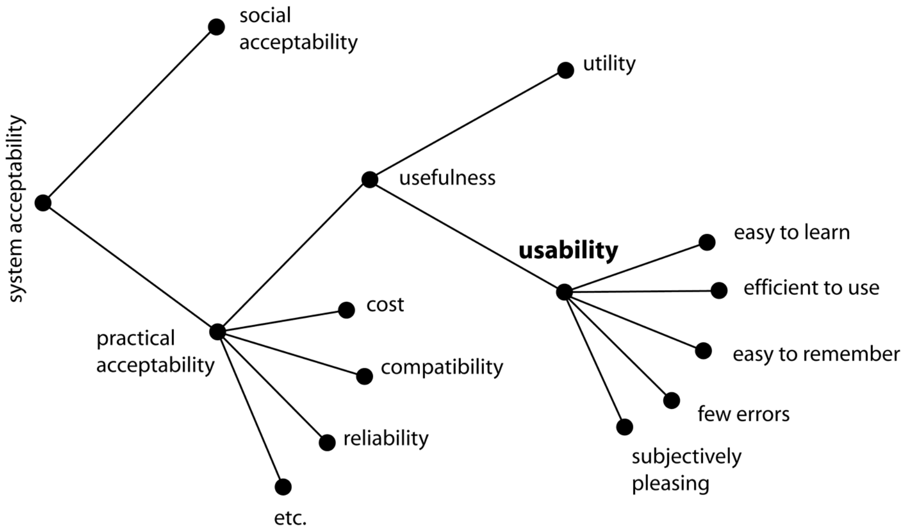


Fig. 5: System acceptability attributes (Nielsen 1993, p. 25)

Nielsen (1993) separates five attributes for usability – depicted in the usability branch in Fig. 5:

(Nielsen, 1993)
Nielsen, J. (1993): *Usability Engineering*, London: Morgan Kaufmann - Academic Press

- ***Learnability***: *The system should be easy to learn so that the user can rapidly start getting some work done with the system.*
- ***Efficiency***: *The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.*
- ***Memorability***: *The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.*
- ***Errors***: *The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.*
- ***Satisfaction***: *The system should be pleasant to use so that users are subjectively satisfied when using it; they like it.*

HCI literature is rich of hints to solve some of the usability related problems by applying specific interaction paradigms or principles. **Dix et al. (1998)** point out three major categories of principles to support usability: learnability, flexibility, and robustness. For each category they identify specific principles. For this work, the category flexibility is the most relevant one. The principles of this category are: substitutivity; multi-modality; representation multiplicity; customizability; adaptivity; adaptability. The last two

(Dix et al., 1998)
Dix, A. J., Finlay, J. E., Abowd, G. D. and Beale, R. (1998): *Human-Computer Interaction*, Harlow: Prentice Hall Europe

principles are of major interest for this research and are discussed in section 2.1.4 and chapter 5.

The need to evaluate quality in use has been addressed by several authors, e.g. **(Nielsen 1993; van Welie et al. 1999; Carroll 2000; Rosson and Carroll 2002)**. Regarding the use of mobile geographic information and the arising usability issues only very recently attention in research has been drawn to that field; e.g. **(Broadbent and Marti 1997; van Welie and de Ridder 2001; Nivala et al. 2003)**. Mobile geographic information usage causes some new usability problems. The major usability problems associated with mobility are:

- diverse user activities
- diverse usage contexts
- changing users
- distracted users
- heterogeneity of devices
- interaction restrictions

While some of these problems are a pure matter of technology, others are related to cognitive abilities. The main reason is that mobility increases the load of cognitive processing. The objective should therefore be to simplify visualisation to such an extent that the user is not forced to think unnecessarily. For Web site design Steve Krug coined the term 'Don't Make Me Think!'. According to **Krug (2000, p. 11)** "It means that as far as is humanly possible, when I look at a Web page it should be self-evident. Obvious. Self-explanatory. I should be able to 'get it' what it is and how to use it without expending any effort thinking about it." In other words, the cognitive effort of the user should be as minimal as possible. Krug's statement is directed to Web site design. If applied to mobile applications or service design it becomes even more important. In mobile usage situations the amount of stimulation is even larger, the problem of focussing the attention even more serious.

It is obvious that a pure interactive based approach will certainly not meet all usability criteria in mobile usage situations. Empirical studies prove the fact that systems requiring too much attention or too many interactions are not used efficiently or not used at all **(The HCI Space)**. One reason is the ´information overload´. The human brain is only capable to pay attention to a number of five to nine things at the same time. This number is called ´maximum cognitive load´. The cognitive load is generally higher in mobile environments. Another argument is the energy and stress balance: though the cognitive abilities of humans are remarkable and

(van Welie et al., 1999)
van Welie, M., van der Veer, G. C. and Eliëns, A. (1999): Breaking Down Usability, *Proceedings Interact 99*, Edinburgh, Scotland, August, 30 - September, 3. http://www.cs.vu.nl/~martijn/gta/docs/Interact99.pdf

(Carroll, 2000)
Carroll, J. M. (2000): *Making use: scenario-based design of human-computer interactions*, Cambridge (MA): MIT Press

(Rosson and Caroll, 2002)
Rosson, M. B. and Carroll, J. M. (2002): *Usability Engineering: Scenario-Based Development of Human-Computer Interaction*: Morgan Kaufmann

(Bradbent and Marti, 1997)
Broadbent, J. and Marti, P. (1997): Location aware mobile interactive guides: usability issues, *Proceedings The Fourth International Conference on Hypermedia and Interactivity in Museums*, Paris, Sept. 1-5, 1997. http://www.ing.unisi.it/lab_tel/hips/hips_pub.htm

(van Welie and de Ridder, 2001)
van Welie, M. and de Ridder, G. (2001): Designing for Mobile Devices: a Context-Oriented Approach, *Proceedings IBC Conference "Usability for Mobile Devices"*, London, UK, May, 9-11

(Nivala et al., 2003)
Nivala, A.-M., Sarjakoski, L. T., Jakobsson, A. and Kaasinen, E. (2003): Usability Evaluation of Topographic Maps in Mobile Devices, *Proc. 21st Int. Cartogr. Conf.*, Durban, S. Africa, Aug. 10-16, 2003

(Krug, 2000)
Krug, S. (2000): *Don't Make Me Think! A Common Sense Approach to Web Usability*, Indianapolis (IN): New Riders Publishing

The HCI Space:
www.tau-web.de/hci/space/i2.html

humans are flexible and adaptive, it has to be emphasized that these adaptation efforts generate stress and need extra energy as well as that the error rate increases, i.e. efficiency decreases **(The HCI Space)**. These empirical findings support the theory that in mobile contexts adaptive approaches could be more appropriate. On the other hand, a pure non-interactive system would not work either. For this research, the author therefore proposes a combined interactive-adaptive approach: both adaptation and interaction are included, but there will be a shift from interaction to more adaptation. A combined system-user cognition approach is favoured. It is closely related to ***shared decision making, shared cognition, augmented cognition,*** and ***amplified cognitive environments***. The aim is to support the human cognition by balancing the cognitive load between human user and the system. This idea has been described by many researchers in the field of cartography and GIS. **Turk (1993)** analyses the ***cognitive responsibility*** between the system and the user. **Weibel (1991)** extends this concept to the amplified intelligence approach in map generalisation.

(Turk, 1993)
Turk, A. (1993): The Relevance of Human Factors to Geographical Information Systems, *in* D. Medyckyj-Scott and H. H. M. (Eds.), *Human Factors in Geographical Information Systems,* London: Belhaven Press, 15-31

(Weibel, 1991)
Weibel, R. (1991): Amplified intelligence and rule-based systems, *in* B. P. Buttenfield and R. B. McMaster (Eds.), *Map Generalization - Making Rules for Knowledge Representations,* Harlow: Longman, 172-186

2.1.2 Activity theory

As pointed out in several publications one approach to overcome the limitations of a pure cognitive science approach in HCI is activity theory (AT). The foundation of AT has been laid by the Russian psychologist Leontjew **(Leontjew 1978)**. The central focus of AT are human activities. In contrast to behaviour activities are always goal bound. Although activities are conducted through individual actions, the activity is the basic unit of analysis: "a minimum meaningful context for individual actions must be included in the basic unit of analysis. This unit is called activity" **(Kuutti 1996)**. AT can be condensed to five basic principles **(Kaptelinin et al. 1999)**:

- ***Object-Orientedness*:** "An activity is a form of doing directed to an object, and activities are distinguished from each other according to their objects. Transforming the object into an outcome motivates the existence of an activity. An object can be a material thing, but it can also be less tangible (such as a plan) or totally intangible (such as a common idea) as long as it can be shared for manipulation and transformation by the participants of the activity" **(Kuutti 1996, p. 27)**.
- ***Hierarchical Structure of Activity*:** activities follow a structure and hierarchy: "… activities consist of actions or chains of actions, which in turn consist of operations

(Leontjew, 1978)
Leontjew, A. N. (1978): *Activity, consciousness and personality*, Englewood Cliffs (NJ): Prentice Hall

(Kuutti, 1996)
Kuutti, K. (1996): Activity Theory as Potential Framework for Human-Computer Interaction Research, *in* B. A. Nardi (Ed.), *Context and consciousness : activity theory and human-computer interaction,* Cambridge (MA): MIT Press, 17-44

(Kaptelinin et al., 1999)
Kaptelinin, B., Nardi, B. and Maculay, C. (1999): The Activity Checklist: A Tool for Representing the 'Space' of Context, *interactions* 6(4): 27-39

Further reading:
(Werlen 1988)
Werlen, B. (1988): *Gesellschaft, Handlung und Raum: Grundlagen handlungstheoretischer Sozialgeographie*, Wiesbaden: Steiner

…"**(ibid., p. 30)**. Whereas actions and operations are conducted sequentially, activities can be performed in a parallel way. The position in the hierarchy is not static (Fig. 7). An activity can become an action or even an operation and vice-versa.

- ***Internalization and Externalization*****:** AT distinguishes between external and internal activities. External activities are directed to physical objects outside the mind, but can be internalised. This allows for example for interacting (mentally) with reality without manipulating the real objects. This fact helps to choose from different possible actions by simulating their effects first. The opposite is also possible: internal activities can also be externalised.
- ***Mediation*****:** tool mediation is a central issue in AT. After AT tools enfold their power when they are used and when there is the knowledge how to use them (Fig. 6). "An activity always contains various artefacts (e.g. instruments, signs, procedures, machines, methods, laws, forms of work organization)" **(ibid., p. 26)**.
- ***Development*****:** activities cannot be understood at a single point in time, but have to consider the 'history' of the activity.

(Bødker, 1991)
Bødker, S. (1991): *Through the Interface: A Human Activity Approach to User Interface Design*, Hillsdale (NJ): Lawrence Erlbaum Associates

An activity is a sequence of actions conducted by a human being aimed at achieving a certain objective. This objective could be solving a problem or a task. An action has therefore always an intentional character **(Bødker 1991)**.

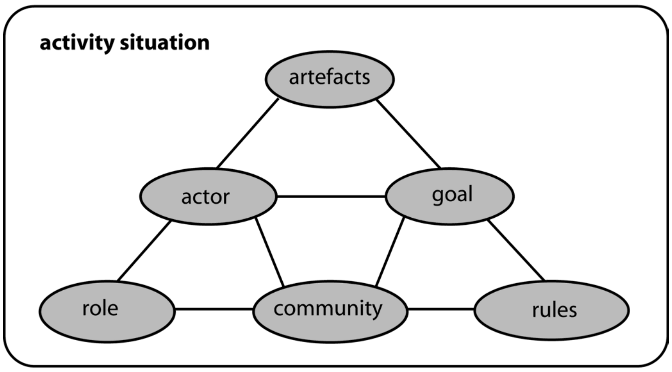


Fig. 6: Elements of activity theory (after Engeström 1987)

(Engeström, 1987)
Engeström, Y. (1987): *Learning by expanding: An activity theoretical approach to developmental research*, Helsinki: Orienta-Konsultit

An action itself is composed of one or several operations conducted unconsciously **(Bødker 1991)**: "Each action that a human being carries out also has operational aspects (how is it done). The operational aspects of actions are implemented through a series of operations. … Actions can be operationalized that is turned into operations. Operations can be conceptualized. Conceptualization means to articulate for oneself what is otherwise self-evident." This different levels and the operationality is shown in Fig. 7.

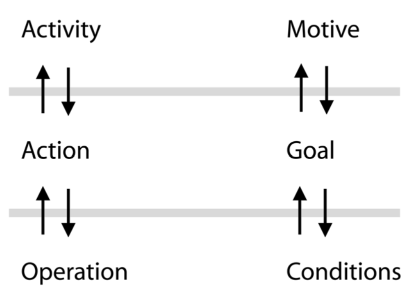


Fig. 7: Levels of activity (Kuutti 1996, p. 30)

Actions are planned by human beings to change a situation or an object to achieve the intended goal. In mobile situations user goals could be orientation, finding persons or objects, finding the way to an object, etc. Another important aspect of human activities is the fact that they are always embedded in a ***context*** and performed in a specific ***role***. An individual can perform the same action in different contexts and roles (see Fig. 6). This context shapes the activities and vice-versa. The activity context constrains the planning of actions before they are executed: "Before an action is performed in the real world, it is typically planned in the consciousness using a model. The better the model, the more successful the action. This phase is called orientation" **(Kuutti 1996, p. 31)**. Fig. 8 shows the activity process model.

To summarise the basic concepts of AT, activities are goal bound and object-directed series of actions taking place in a specific context using means (artefacts, tools).

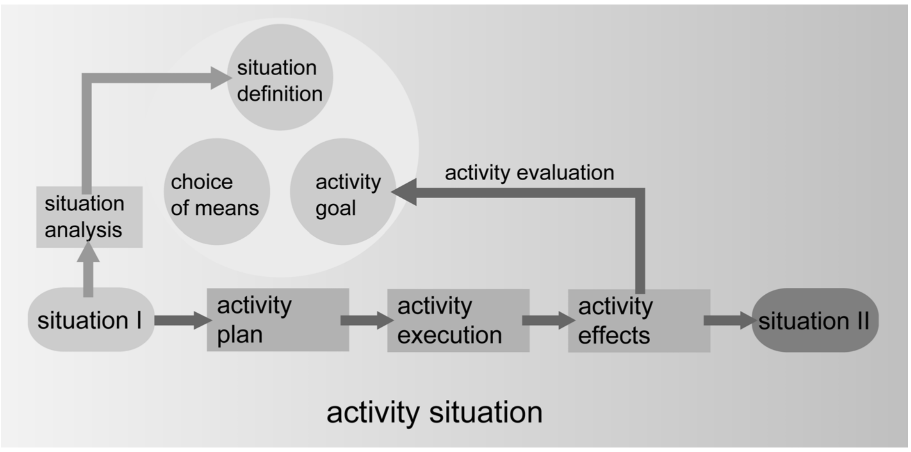


Fig. 8: Process model of activity theory (adapt. from Werlen 1988, p. 13)

2.1.3 Context

In the last section it has been stated that activities are always performed in a context. Thus it is crucial to be aware of the basic concepts of context for understanding user activities. Unfortunately context is a word with many meanings – depending on 'context'.

(Schilit et al., 1995)
Schilit, B., Adams, N. and Want, R. (1995): Context-Aware Computing Applications, *Proceedings Workshop on Mobile Computing Systems and Applications*, Santa Cruz (CA), December 8-9, 1994, IEEE Computer Society Press

(Ryan et al., 1997)
Ryan, N., Pascoe, J. and Morse, D. (1997): Enhanced Reality Fieldwork: the Context-Aware Archaeological Assistant, *in* S. Exxon (Ed.), *Computer Applications in Archaeology*

(Dey and Abowd, 1999)
Dey, A. K. and Abowd, G. D. (1999): *Towards a Better Understanding of Context and Context- Awareness*, Technical Report, GIT-GVU-99-22, Georgia Institute of Technology, Atlanta (GA)

Schilit et al. (1995) define context as about where you are, who you are with, and what resources are nearby. In **(Ryan et al. 1997)** context is defined as the user's location, environment, identity and time. One of the most adopted definitions of context in the field of ***context-awareness*** is the one 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.*

The authors further distinguish between ***primary context*** and ***secondary context*** elements. Primary context elements are ***place***, ***time***, ***identity***, and ***activity***. The primary context elements can work as indices to secondary elements (e.g. appointments, weather conditions). Place as manifested in the term location based service is of utmost importance as a context parameter for geographic information. Place is the more general term widely used in cartography. Location refers to a placement of the mathematical definition relative to natural and artificial features **(Krakiwsky et al. 1990)**; location is a reference to a position obtained by ***geolocation*** under the usage of a location fixing scheme. Positioning technologies are covered in section 2.2.1.

(Krakiwsky, 2002)
Krakiwsky, E. J., Lachapelle, G. and Schwarz, K. P. (1990): *Assessment of Emerging Technologies for Future Navigation Systems in the Canadian Transportation Sector*, Contract Report TP 10155-E, Research and Development Directorate, Transport Canada, Ottawa. Publ. 60007, Department of Surveying Engineering, The University of Calgary, Calgary

(van Welie and de Ridder, 2001)
van Welie, M. and de Ridder, G. (2001): Designing for Mobile Devices: a Context-Oriented Approach, *Proceedings IBC Conference "Usability for Mobile Devices"*, London, UK, May, 9-11

A similar context concept is proposed by **van Welie and de Ridder (2001)**. Three elements are more or less identical with the elements from Dey and Abowd: identity, place, and time. The fourth element is ***device***. This element describes the technical characteristics of mobile devices that can be important for information delivery and presentation. Since context is the central issue in mobile geovisualisation services, it is further examined in section 4.2.3.

2.1.4 Adaptation

Systems without interaction possibilities are commonly called batch systems or non-interactive systems. Systems that can be changed by the user are flexible or malleable systems. The latter rely on adaptation of the system. The term adaptation is widely used in science and technology. In biology ***adaptation*** refers to changes in relation to environmental conditions. Not all things can be adapted or are able to adapt themselves. Hence, ***adaptable*** refers to the fact that adaptation is in principle possible. An adaptable system provides the user tools that make it possible for him/her to change the system characteristics **(Oppermann 1994)**. The quality of being adaptable is called ***adaptability***. ***Adaptation*** in a computer system is the adjustment of parameters *through* users, whereas ***adaptivity*** is the automatic adaptation of the system *to* users or a self-adaptation. An adaptive system is capable of changing its own characteristics automatically according to the user's needs **(Oppermann 1994)**. An adaptable system can be changed by the user in an interactive way, i.e. by explicit interference. In an adaptive system the interference is implicit.

adaptation: *"(1) the act or process of adapting or being adapted or the state of being adapted; adjustment (2) something that is produced or created by adapting something else (3) something that is changed or modified to suit new conditions or needs" (Collins English Dictionary, 3rd Edition)*

"The act of adaptation, adapting, means to fit, adjust, make suitable for a purpose, alter or modify | to change (something or yourself) to suit different conditions or uses" (dictionary.cambridge.org)

"To make suitable to or fit for a specific use or situation" (www.dictionary.com)

adaptable: *"(1) able to adapt oneself to new conditions; (2) that can be adapted" (The Concise Oxford Dictionary, 8th ed.)*

(Oppermann, 1994)
Oppermann, R., (Ed.) (1994): *Adaptive User Support: Ergonomic Design of Manually and Automatically Adaptable Software*, Computers, Cognition, And Work, Hillsdale (NJ): Lawrence Erlbaum Associates

Apart from these more general notions of adaptation there are a few special cases of adaptation:

- ***Personalisation:*** is basically the adaptation of something to a user, or "whenever something is modified in its configuration or behaviour by information about the user, this is personalisation" **(Searby 2003, p. 13)**.
- ***Individualisation:*** is often used as a synonym of personalisation, though individualisation is more general, i.e. individualisation could be related to a group (of persons).
- ***Localisation:*** is the adaptation of a software, i.e. in general the user interface, to a specific region, i.e. mostly to a language area and character setting.
- ***Customization:*** is the adaptation of a product or service to a customer or user.

(Searby, 2003)
Searby, S. (2003): Personalisation - an overview of its use and potential, *BT Technology Journal* 21(1): 13-19

Personalisation and customisation are terms often used in marketing, whereas localisation is vocabulary of software engineering.

For an overview of adaptation research refer to **(Browne et al. 1990; Schneider-Hufschmidt et al. 1993; Oppermann 1994; Blank 1996)**. For this work three main threads of adaptation research are of importance: ***adaptive systems***, ***adaptive user interfaces***, and ***adaptive hypermedia***. Most of the following theoretical concepts are related to adaptive user interfaces.

(Browne et al., 1990)
Browne, D., Totterdell, P. and Norman, M., (Eds.) (1990): *Adaptive User Interfaces*, Computers and People Series, London: Academic Press

(Schneider-Hufschmidt et al., 1993)
Schneider-Hufschmidt, M., Kühme, T. and Malinowski, U., (Eds.) (1993): *Adaptive User Interfaces: Principles and Practice*, Human Factors in Information Technology, Amsterdam: North-Holland

(Blank, 1996)
Blank, K. (1996): *Benutzermodellierung für adaptive interaktive Systeme: Architektur, Methoden, Werkzeuge und Anwendungen*, Sankt Augustin: Infix

Structure of adaptive systems

The basic structure of any adaptive system is based on an adaptive object that is adapted to an adaptation target through an adaptation method (Fig. 9). The adaptation method will need information about the adaptation target.

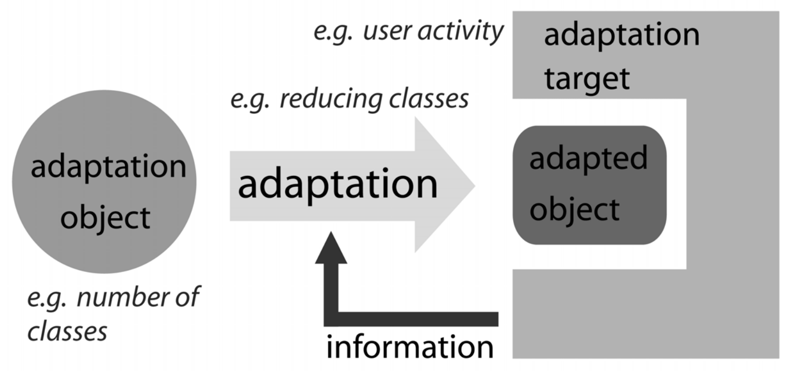


Fig. 9: Basic principle of adaptation systems

Oppermann (1994, p. 6f.) distinguishes three major elements of adaptive systems:

- ***afferential*** component of adaptivity: this component is responsible for gathering information about user interaction and system responses and finding patterns on different levels of interaction
- ***inferential*** component of adaptivity: in this component decisions about if and how system modifications, i.e. adaptations, are made based on analysing captured user information
- ***efferential*** component of adaptivity: this component effects the system's behaviour modifications

Along with the discussion of the structure of an adaptive system the question arises when exactly a system should be called adaptive. This question relates to the degree of adaptivity (Fig. 10).

Fig. 10: Adaptation spectrum

Considering Fig. 10 one could argue that an adaptive system must be completely adaptive, i.e. a system on the left edge of the adaptation spectrum. For this work an adaptive system is a system including some adaptive functions and behaviour, i.e. laying left from the middle of the spectrum.

According to **Holzinger (2001, p. 206)** ***adaptive methods*** (which can be extended to adaptation in general) can be analysed in the following four different dimensions: adaptation ***means,*** adaptation ***information***, adaptation ***process***, and adaptation ***goal***. Table 1 shows other terminologies for adaptation dimensions. The term 'adaptive methods' is to some extent ambiguous. Although in the sense of Holzinger it means methods related to adaptive behaviour, it could also mean methods that are themselves adaptive. For the purpose of this work, the term is used in the sense of a ***method for adaptation***.

Holzinger, 2001)
Holzinger, A. (2001): *Basiswissen Multimedia, Band 3*, Würzburg: Vogel Buchverlag

(Dietrich et al., 1993)
Dietrich, H., Malinowski, U., Kühme, T. and Schneider-Hufschmidt, M. (1993): State of the Art in Adaptive User Interfaces, *in* M. Schneider-Hufschmidt, T. Kühme and U. Malinowski (Eds.), *Adaptive User Interfaces,* Amsterdam: North-Holland

(Karagiannidis, 1995)
Karagiannidis, C., Koumpis, A. and Stephanidis, C. (1995): Supporting Adaptivity in Intelligent User Interfaces: The case of Media and Modalities Allocation, *Proceedings ERCIM Working Group on User Interfaces for All Workshop "Towards User Interfaces for All: Current Efforts and Future Trends"*, Heraklion, Greece, October 30-31

(Brusilovsky, 1996)
Brusilovsky, P. (1996): Methods and techniques of adaptive hypermedia, *User Modeling and User-Adapted Interaction* 6(2-3): 87-129

(Thévenin and Coutaz, 1999)
Thévenin, D. and Coutaz, J. (1999): Adaptation and Plasticity of User Interfaces, *Proc. i3-spring99Workshop on Adaptive Design of Interactive Multimedia Presentations for Mobile Users*, Barcelona.
http://research.nii.ac.jp/~thevenin/papers/I3Workshop1999/I3Workshop99.pdf

Alatalo and Peräaho, 2001)
Alatalo, T. and Peräaho, J. (2001): A Modelling Method for Designing Adaptive Hypermedia, *Proceedings Eight International Conference on User Modeling (UM2001) - Third Workshop on Adaptive Hypertext and Hypermedia*, Sonthofen, Germany, July 13-17, 2001

(Holzinger 2001)	(Dietrich et al. 1993)	(Karagianni-dis et al. 1995)	(Brusilovsky 1996)	(Thévenin and Coutaz 1999)	(Alatalo and Peräaho 2001)
Adaptive Hypermedia	Adaptive user interfaces	Adaptive user interfaces	Adaptive Hypermedia	Adaptive user interfaces	Adaptive Hypermedia
adaptation means	adaptivity constituents	adaptivity constituents	what to adapt?	means	transformants
information	information to be considered	determinants	to what to adapt?	target	adaptors
process	strategies	rules	how to adapt?		heuristics
goal	goals	goals	why to adapt?		

Table 1: Terminology of adaptation dimensions

As Table 1 reveals, there are some semantic differences in the terminology, but consensus can be observed regarding the main structural components. Depending on the system, different objects are adapted, for instance the user interface, hypermedia content or the link structure. The target of the adaptation can also vary. In a learning system it is primarily the user, in a mobile system it could be the context of usage.

Taxonomy of adaptive systems

In literature many attempts of conceptualising adaptation can be found. Some of these attempts resulted in taxonomies of adaptive systems. A basic distinction can be made between adaptive and adaptable systems. Table 2 summarises the major distinguishable elements proposed by **Fischer (2001, p. 11)**.

(Fischer, 2001)
Fischer, G. (2001): User Modeling in Human-Computer Interaction, *User Modeling and User-Adapted Interaction (UMUAI)* 11(2): 65-86

	Adaptive	Adaptable
Definition	dynamic adaptation by the system itself to current task and current user	user changes (with substantial system support) the functionality of the system
Knowledge	contained in the system; projected in different ways	knowledge is extended
Strengths	little (or no) effort by the user; no special knowledge of the user is required	user is in control; user knows her/his task best; system knowledge will fit better; success model exists
Weaknesses	user has difficulty developing a coherent model of the system; loss of control; few (if any) success models exist (except humans)	systems become incompatible; user must do substantial work; complexity is increased (user needs to learn the adaptation component)
Mechanisms required	models of users, tasks, and dialogs; knowledge base of goals and plans; powerful matching capabilities; incremental update of models	layered architecture; domain models and domain-orientation; 'back-talk' from the system; design rationale
Application Domains	active help systems, critiquing systems, differential descriptions, user interface customization, information retrieval	information retrieval, end-user modifiability, tailorability, filtering, design in use

Table 2: Adaptable and adaptive systems (Fischer 2001)

On the premise that the functions and its parameters available in an interactive system are of a finite number, no principal difference in the outcome of a user adapting the system and of the system adapting itself can be implied. The degrees of freedom stay the same for both the user and the system, since the user only uses the system's functionality to achieve his/her goals. The problem for an adaptive system is rather capturing information for adaptation and deferring the user's intentions. This knowledge is available to the user, but not a priori to the system.

(Totterdell and Rautenbach, 1990)
Totterdell, P. and Rautenbach, P. (1990): Adaptation as a problem of design, *in* D. Browne, P. Totterdell and M. Norman (Eds.), *Adaptive User Interfaces,* London: Academic Press, 59-84

The distinction between ***adaptable*** and ***adaptive*** systems or interfaces certainly is the most predominant one, but there are many more grades of flexible systems. **Totterdell and Rautenbach (1990, p. 74)** suggested the following taxonomy of adaptive systems:

- adaptable/ tailorable
- adaptive
- self-regulating
- self-mediating
- self-modifying

Dietrich et al. (1993, p. 15) discern four stages in the adaptation process: initiative, proposal, decision, and execution. Furthermore they distinguish between the two possible agents in these four stages: the user and the system. Both can be the active part in any of the four stages. In the example portrayed in Fig. 11 the system initiates, proposes, and executes an adaptation after it has been accepted by the user.

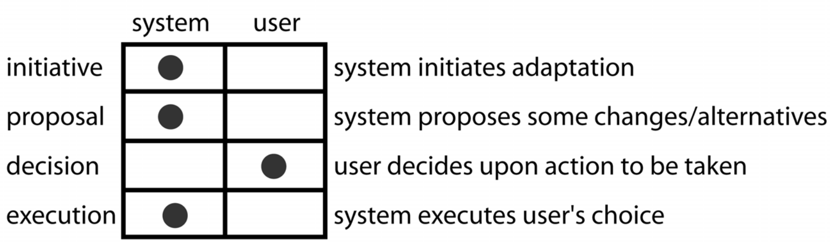


Fig. 11: Agents involved and stages in the adaptation process (Dietrich et al. 1993)

Combining all four stages with the two agents, results in $2^4 = 16$ possibilities. Not all of them are really sensible in practice. Fig. 12 depicts the most important adaptation types. The spectrum of possible adaptation types reaches from adaptable to (self)adaptive. For this work ***self-adaptation*** and ***user controlled self-adaptation*** are the two types of most interest. The case depicted in the lower left corner of Fig. 12, ***adaptation***, describes an interactive, adaptable system where the user has the full control, but also all responsibility to change the system.

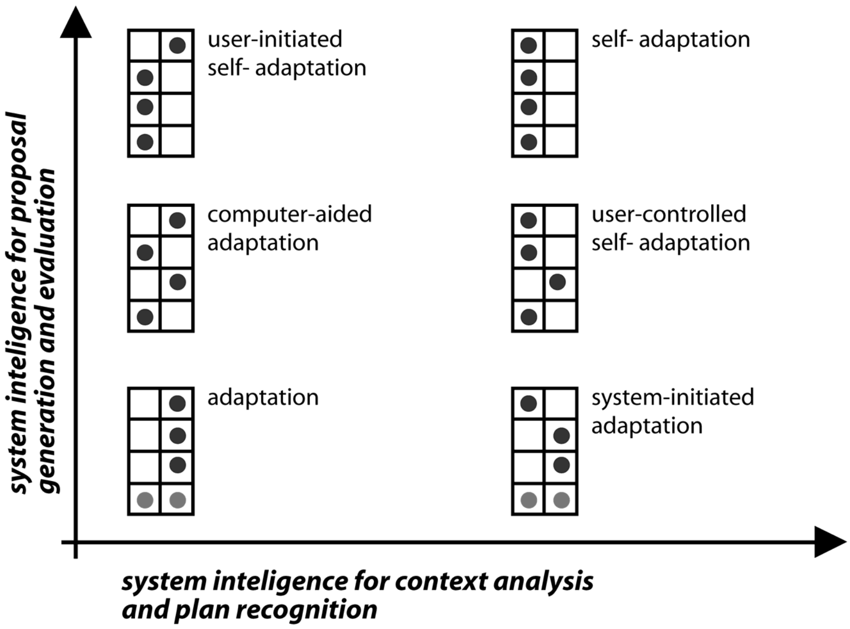


Fig. 12: Different types of adaptation (Dietrich et al. 1993, p. 17)

Motivation for adaptive systems

Before going into the details of adaptation, a justification of this approach and the rationale for adaptive behaviour are presented. In general, an adaptive approach should improve usability, ease our daily life with computer systems, change the role of the computer as a tool for humans rather than humans being slaves of technology: "It is widely believed that 'everyone should be computer literate' and as a consequence vast human and financial resources are being expended internationally on training individuals to adapt to using computers within their lives. The premise … is that computers should be user literate" **(Browne et al. 1990, preface)**. A similar understanding, i.e. a system adapting to the user, can be discovered in **(Oppermann 1994, p. 4)**: "The goal of adaptive systems is to increase the suitability of the system for specific tasks; facilitate handling the system for specific users, and so enhance user productivity; optimize workloads, and increase user satisfaction". Almost the same statement has been made by **Sanderson and Treu (1993, p. 245)**, though they put the focus on the user interface: "That is, depending on the needs of a particular user to whom the interface is to adapt, the adaptation behaviour should be facilitative, such as by enabling the user to complete tasks more quickly or with less knowledge and effort".

(Browne et al., 1990)
Browne, D., Totterdell, P. and Norman, M., (Eds.) (1990): *Adaptive User Interfaces*, Computers and People Series, London: Academic Press

Oppermann, 1994)
Oppermann, R., (Ed.) (1994): *Adaptive User Support: Ergonomic Design of Manually and Automatically Adaptable Software*, Computers, Cognition, And Work, Hillsdale (NJ): Lawrence Erlbaum Associates

(Sandersopn and Treu, 1993)
Sanderson, P. D. and Treu, S. (1993): Adaptive User Interface Design and Its Dependence on Structure, *in* M. Schneider-Hufschmidt, T. Kühme and U. Malinowski (Eds.), *Adaptive User Interfaces: Principles and Practice*, 10, Amsterdam: North-Holland, 241-267

Common to all statements is the focus on usability and a shift from the adaptation responsibility towards the (computer) system.

Timing of adaptivity

The ***timing*** of adaptation is basically related to the question when and how often adaptation will take place. **Dietrich et al. (1993, p. 23f.)** identify three different timings: *before*, *during*, and *between* usage sessions. If adaptation occurs during sessions, they further distinguish between continuous adaptation, adaptation in special situations, and adaptation after or before predefined functions. A similar distinction is made by **Leutner (1995)**. ***Macro adaptation*** designates the occasional adaptation, normally before system usage. On the other hand, ***micro adaptation*** is the adaptivity of a system in very short intervals during usage.

(Dietrich et al., 1993)
Dietrich, H., Malinowski, U., Kühme, T. and Schneider-Hufschmidt, M. (1993): State of the Art in Adaptive User Interfaces, *in* M. Schneider-Hufschmidt, T. Kühme and U. Malinowski (Eds.), *Adaptive User Interfaces,* Amsterdam: North-Holland

(Leutner, 1995)
Leutner, D. (1995): Adaptivität und Adaptierbarkeit multimedialer Lehr- und Informationssysteme, *in* L. J. Issing and P. Klimsa (Eds.), *Information und Lernen mit Multimedia,* Weinheim: Psychologie Verlags Union, 139-149

Related to the question of timing the adaptation is the question of what triggers the adaptation. **Alatalo and Paräaho (2001)** mention two basic types of adaptivity: *adapting to difference* and *adapting to change*, where difference relates to time-independent objects (e.g. different user, different device, different location) and change relates to objects that change over time (e.g. outdoor temperature). Of course this distinction is not always absolutely clear. A user can

Alatalo and Peräaho, 2001)
Alatalo, T. and Peräaho, J. (2001): A Modelling Method for Designing Adaptive Hypermedia, *Proceedings Eight International Conference on User Modeling (UM2001) - Third Workshop on Adaptive Hypertext and Hypermedia*, Sonthofen, Germany, July 13-17, 2001

for instance, though only slowly, change over time. This distinction leads to the two basic triggers: ***difference*** and ***change***. The difference or change can be of a quantitative (e.g. movement speed) or of a qualitative (e.g. activity) dimension. Similarly change can be neutral, an extension or a limitation of possibilities (e.g. limitation through reduced bandwidth). **Sanderson and Treu (1993, p. 246)** differentiate three conditions for adaptation:

- ***locality***: where exactly should changes be made?
- ***granularity***: at what level of generality or specificity within a locality should changes be made?
- ***timing***: the triggering of adaptation can be independent of a particular setting (locality and granularity), but depends on other circumstances

These three conditions can serve as criteria for making adaptation decisions.

(Sandersopn and Treu, 1993)
Sanderson, P. D. and Treu, S. (1993): Adaptive User Interface Design and Its Dependence on Structure, *in* M. Schneider-Hufschmidt, T. Kühme and U. Malinowski (Eds.), *Adaptive User Interfaces: Principles and Practice*, 10, Amsterdam: North-Holland, 241-267

Level of adaptivity

Depending on the domain different objects are available for adaptation. In a hypermedia system, for instance, the content or the link structure can be adapted. In an interactive system, the interaction style or the availability of functions could be adapted. These adaptation objects are not all of the same type and on the same level. Depending on the type of information **Dietrich et al. (1993, p. 27)** distinguish two basic ***levels*** of adaptation:

- logical/invisible/symbol level
- physical/visible/signal level

These levels correspond more or less to the two basic layers (physical and symbolic) of interaction in HCI discussed in section 2.1.1. A further refinement separates goals, tasks, semantic, syntactic, and lexical level. A similar differentiation was proposed by **Stephanidis and Savidis (2001, p. 42)** who distinguish three levels of interaction on which adaptation could be effected:

1) ***semantic*** level of interaction (e.g. by employing different metaphors to convey the functionality and facilities of the underlying system)
2) ***syntactic*** level of interaction (e.g. by deactivating alternative dialogue patterns, such as 'object-function' versus 'function-object' interaction sequencing)
3) ***lexical*** level of interaction (e.g. grouping and spatial arrangement of interactive elements, modification of presentation attributes, alternative input/output devices)

(Stephanidis and Savidis, 2001)
Stephanidis, C. and Savidis, A. (2001): Universal Access in the Information Society: Methods, Tools, and Interaction Technologies, *Universal Access in Information Society* 1: 40-55

Methods of adaptation

(Dietrich et al., 1993)
Dietrich, H., Malinowski, U., Kühme, T. and Schneider-Hufschmidt, M. (1993): State of the Art in Adaptive User Interfaces, *in* M. Schneider-Hufschmidt, T. Kühme and U. Malinowski (Eds.), *Adaptive User Interfaces,* Amsterdam: North-Holland

Basic ***adaptation methods*** (in user interfaces) are: enabling, switching, reconfiguring, and editing **(Cockton 1987)** in **(Dietrich et al. 1993, p. 28)**. Enabling refers to the activation or deactivation of components or features. Switching means the selection of predefined configuration settings. Reconfiguring refers to modification using predefined components. Editing means the adaptation without any restrictions concerning components. An even broader classification distinguishes methods adapting presentation or communication and methods adapting functionality or interaction.

Problems with adaptivity

(Browne et al., 1990)
Browne, D., Totterdell, P. and Norman, M., (Eds.) (1990): *Adaptive User Interfaces*, Computers and People Series, London: Academic Press

General problems of adaptive systems are the ***lack of control*** and ***data protection*** **(Browne et al. 1990, p. 208f.)**. Even if a system adapted itself perfectly and to the user's satisfaction, it could be unacceptable for the user due to psychological reasons. The feeling of being in control, the feeling of power over the machine is very strong and important. This fact is closely related to the second problem: data protection or ***privacy***. If the user does not know and understand which information is stored about him and where it is stored and who will have access to it, even a perfect system based on that knowledge would probably not find any acceptance. A system that adapts in any way to the user, e.g. to preferences, skill, or current location, needs information about the user or related facts. Without this information adaptivity is not possible. Naturally many users feel reluctant to give away personal information. Appropriate means to minimise the chance for misuse have to be developed. They are also needed for other applications like e-commerce. If there are mechanisms to guarantee data privacy and the user is convinced the service provides a substantial utility through the adaptation, the privacy issue can be softened.

(Hilty et al., 2003)
Hilty, L., Behrendt, S., Binswanger, M., Bruinink, A., Erdmann, L., Fröhlich, J., Köhler, A., Kuster, N., Som, C. and Würtenberger, F. (2003): *Das Vorsorgeprinzip in der Informationsgesellschaft: Auswirkungen des Perva-sive Computing auf Gesundheit und Umwelt*, TA 46/2003, TA-Swiss, Zentrum für Technologiefolgen-Abschätzung, Bern. http://www.ta-swiss.ch/www-remain/reports_archive/ publications/ 2003/030904_PvC_bericht.pdf

However, a further problem that might arise in relation to adaptation has to do with utility. Utility is often connected to efficiency, more precisely an increasing of efficiency. In technology use the opposite is often the case, the so called '***rebound effect***'. A rebound effect is the fact that an efficiency improvement was initiated with the intention to reduce the amount of input, but this effect does not happen and instead the output increases **(Hilty et al. 2003, p. 127)**. In a study on the effects of pervasive computing on health and environment the authors state that an efficient navigation in the market of leisure activity choices is of enormous indirect benefit **(ibid., p. 135f.)**. LBS can help in an efficient usage of these leisure options. Many trips will become obsolete. A rebound effect with efficient information and communication adapted to the context results through a possible overkill of intransparent information offers. The gain of time efficiency through more focussed information might be compensated by the increased effort for judging this information (trustworthiness, hidden motivations, etc.).

2.1.5 Inter-relationships of relevant theories and their applications in cartography

In the nineties AT has been discovered for the field of HCI, e.g. **(Bødker 1991; Nardi 1996a)**. It has been recognised that a pure cognitive approach in HCI does not and probably cannot solve all problems of using computer systems, because it is focussed on how the system is actually used. Most cognitive approaches examine a very low level of interaction, for instance the GOMS (Goals, Operations, Methods, and Selection) model. While these methods give certain insight in interaction processes, they lack information about context. AT introduced the notion of the computer as a mediating tool. By understanding the use of computers as actions, the context and intention of use are introduced in the analysis. This helps to understand why computers are used and which goals the user has and can explain some misunderstandings and misconceptions in the design of user interfaces. Since cartography nowadays is computer based and an interface to the map is involved or the map itself is the interface to further information, it is logical that AT has found its way to cartography.

(Bødker, 1991)
Bødker, S. (1991): *Through the Interface: A Human Activity Approach to User Interface Design*, Hillsdale (NJ): Lawrence Erlbaum Associates

(Nardi, 1996a)
Nardi, B. A. (1996a): *Context and consciousness: activity theory and human-computer interaction*, Cambridge (MA): MIT Press

AT is important for cartography when studying the usage of maps. Using a map can be understood as an action and is thus open to AT. There are two major applications of AT to cartography. The first concentrates on the usage of maps for spatially related actions. Such actions could be planning or route finding. To achieve the action goals the usage of maps is necessary. The second is concerned with actions within a cartographic information system, i.e. with actually using maps to solve spatial problems, answer spatial questions or meet information needs. The second understanding is closely related to the relationship of HCI and AT, though there are unique characteristics in the cartographic domain. Parts of AT have been studied in the field of map usage. In this context different ***map functions*** or ***map usage goals*** have been identified **(cf. Witt 1979; Ogrissek 1987)**. ***Map use tasks*** have been described in **(Gluck 1996; van Elzakker 2001)**. A more comprehensive concept strongly following AT has been proposed by **Bollmann (1996)**. A good overview and evaluation of these different activity oriented concepts and approaches in cartography is

(Witt, 1979)
Witt, W. (1979): *Lexikon der Kartographie*, Wien: Deuticke

(Ogrissek, 1987)
Ogrissek, R. (1987): *Theoretische Kartographie*, Gotha: VEB Hermann Haak

(Gluck, 1996)
Gluck, M. (1996): Text, Maps, and User's Tasks, *in* L. C. Smith and M. Gluck (Eds.), *Geographic Information Systems And Libraries: Patrons, Maps, And Spatial Information*, 151-172

(van Elzakker, 2001)
van Elzakker, C. (2001): Map Use Tasks in Regional Exploratory Studies, *Proc. 20th Internat. Cartographic Conference*, Beijing, China, August 6-10, 2001

(Bollmann, 1996)
Bollmann, J. (1996): Kartographische Modellierung - Integrierte Herstellung und Nutzung von Karten-systemen, *Kartographie im Umbruch. Tagungsband zum Kartographenkongress Interlaken 1996*, Interlaken

presented by **Dransch (2001a; 2001b)**. Her research focuses on the activities in HCI and the conception of computer systems as mediating tools. More recent research on exploratory geovisualisation is taking a similar approach **(Fuhrmann and Kuhn 1999; Fabrikant 2001)**. However, for this research the focus is on supporting user activities during mobility in the physical space and more specifically on the activity context itself. Hence, for this research a particular flavour of AT, the activity-context oriented approach is considered as useful.

(Dransch, 2001a)
Dransch, D. (2001a): *Handlungsorientierte Mensch-Computer-Interaktion für die kartographische Informationsverarbeitung in Geo-Informationssystemen*, Habilitationsschrift, Fachbereich Geowissenschaften, Freie Universität Berlin

(Dransch, 2001b)
Dransch, D. (2001b): User-Centred Human-Computer Interaction In Cartographic Information Processing, *Proceedings 20th International Cartographic Conference*, Beijing, China, August, 6 - 10, 2001

(Fabrikant, 2001)
Fabrikant, S. I. (2001): Building Task-Ontologies for GeoVisualization - Position Paper, *Proceedings ICA Commission on Visualization and Virtual Environments Pre-Conference Workshop on Geovisualization on the Web*, Beijing, China, August, 3-4, 2001

(Fuhrmann and Kuhn, 1999)
Fuhrmann, S. and Kuhn, W. (1999): Interface Design Issues For Interactive Animated Maps, *Proceedings 19th Int. Cartographic Conf.*, Ottawa, August 14-21, 1999

(Heidmann, 1999)
Heidmann, F. (1999): *Aufgaben- und nutzerorientierte Unterstützung kartographischer Kommunikationsprozesse durch Arbeitsgraphik: Konzeptionen, Modellbildung und experimentelle Untersuchungen*, Herdecke: GCA-Verlag

Research on ***'cartographic work graphics'*** first introduced by **Bollmann (1996)** and further investigated by **Heidmann (1999)** is strongly connected to AT and to the understanding of adapted geovisualisation proposed in this dissertation. Cartographic work graphics comprises all possible ways of graphic support of electronic map usage and combines model approaches for a task and user oriented modelling of cartographic media. Map use is understood as a goal directed process of visual cognitive operations. The premise of cartographic work graphics is to support these visual cognitive operations adequately to lead to a more effective map usage and thus information gain. Technically cartographic work graphics can be connected to the original map graphic or be superimposed. The cartographic work graphics principally distinguishes three support forms controlling the use of cartographic work graphics according to specific communication goals and communication situations: a) the variation and specific orientating of graphic design means in the map, b) through an addition of particularly motivating or associative perceivable signs or sign patterns, and c) through a change of multimedia information offer **(Heidmann 1999, p. 52f.)**.

Knapp (1995) proposes a general task model for the visualisation of geographic data. At the low level four ***visual operators*** are discerned: *identify*, *locate*, *compare*, and *associate*. A similar approach is taken by **Zhou (1999)** who isolates ***visual tasks*** for the automated generation of visual discourse. Visual tasks are understood as a middleware abstraction between high-level presentation intents and low-level visualisation techniques. These visual tasks are described in further detail in section 4.2.6. Both approaches separate the goals of visualisation (e.g. inform or explore) from the actual tasks of visualising to achieve these goals or to solve the problem.

(Kanpp, 1995)
Knapp, L. (1995): A task analysis approach of the visualization of geographic data, *in* T. L. Nyerges, D. M. Mark, R. Laurini and M. J. Egenhofer (Eds.), *Cognitive aspects of human-computer interaction for geographic information systems*, NATO ASI Series, Serie D: Behavioural and Social Sciences, 83, Dordrecht, 355-371

(Zhou, 1999)
Zhou, M. X. (1999): *Automated Generation of Visual Discourse*, Dissertation, Graduate School of Arts and Sciences, Columbia University

The concern of this research are activities related to the mobile usage of maps in everyday life and thus the focus is more on user activities in geo-space. Solutions need to address immediate user needs within that mobile context and support everyday activities. Since ancient times one of the inherent functions of an everyday map has been to promote mobility. In spite of diversified developments of map types (topographic map, thematic map, atlas information systems) this function remains unchanged. This notion is supported by **Fuhrmann and Kuhn (1998)** who coined the term ***everyday map***:

(Fuhrmann and Kuhn, 1998)
Fuhrmann, S. and Kuhn, W. (1998): The Design of Everyday Maps, *Proceedings Workshop of ICA Commission on Visualization meeting*, Warszaw, Poland, May, 1998

> *We extend the classic notion of a map to 'everyday maps', because we believe 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'. At the same time, the term 'everyday map' derives from Don Norman's discussion of the design of everyday things (Norman 1988), particularly with respect to the notion of affordances.*

A typology of everyday situations grouped in the categories work, home, town, and on the road can be found in **(McCullough 2001, p. 344)**.

(McCullough, 2001)
McCullough, M. (2001): On Typologies of Situated Interaction, *Human-Computer Interaction* 16: 337-349

The definition of everyday maps perfectly fits the idea of maps for mobile environments. The reference to suitability for everyday occasions introduces the importance of the ***relevance*** concept. The importance for a model of information needs based on geographic relevance is emphasized by **Raper et al. (2002, p. 44)**. They name the ***sense-making*** methodology as a potential framework for this purpose (sense-making methodology will be explained in section 4.2.4).

(Raper et al., 2002)
Raper, J., Dykes, J., Wood, J., Mountain, D., Krause, A. and Rhind, D. (2002): A framework for evaluating geographical information, *Journal of information science* 28(2): 39-50

Other valuable theories bringing together context theory, activity theory, and cognitive theory respectively are ***situated action*** **(Suchman 1987; Nardi 1996b)** and ***situated cognition*** **(Clancey 1997)**. Both approaches share the idea that all human cognitive processes and activities are always embedded in a specific situation and that they can only be understood if this situation is known.

Suchman, 1987)
Suchman, L. A. (1987): *Plans and situated actions - The problem of human-machine communication*, Cambridge: Cambridge University Press

(Nardi, 1996b)
Nardi, B. A. (1996b): Studying Context: A comparison of Activity Theory, Situated Action Models, and Distributed Cognition, *in* B. Nardi (Ed.), *Context and consciousness: activity theory and human-computer interaction,* Boston (MA): MIT Press, 69-102

(Clancey, 1997)
Clancey, W. J. (1997): *Situated Cognition*, Cambridge: Cambridge University Press

Since the purpose of this thesis is to establish a framework for mobile cartography and adaptive geovisualisation, the primary focus is on context in the realm of ***context-aware systems***. The objective is to extend the concept of a context-aware system with cognitive theory, AT, and adaptation methods for cartography in mobile environments. This combinational approach is elaborated in chapter 4, where these theories are melted in a new and comprehensive framework for geovisualisation in mobile environments. For this work the term geovisualisation is used rather than map. Geovisualisation has been introduced to extend the concept of mapping from a pure communication-oriented means towards an exploratory instrument and visual thinking. As explained earlier this understanding of the term is not the focus in this research. However, the traditional concept of a map will not satisfy the requirements of presenting geographic information on mobile devices either. Therefore ***geovisualisation*** is used here to cover all forms of presentations of geographic information, i.e. maps, map-like representations, multimedia, even text or audio elements.

2.2 Technical background

The focus of this research is not on technology. Most technological issues are off the field of cartography and are advancing so fast that their coverage in a thesis seems almost worthless. However, it is necessary to set up the basic technology context of this work and the interfaces to related fields. A good overview of the current technologies relevant to visualisation of geographic information is given in **(Buckley et al. 2000)**. In general, the technologies described in the following are assumed available and functioning. The goal of this section is to describe the state of the art in mobile computing and its related fields which govern the thoughts on new methods and to identify the part of technology which seems to be invariant over the next few years and hence directly relevant for this work. Fig. 13 illustrates the relationship between the different technologies and mobile cartography and refers to the section where they are discussed in more detail.

(Buckley et al., 2000)
Buckley, A. R., Gahegan, M. and Clarke, K. (2000): *Geographic visualization as an emerging research theme in GIScience*, Research proposal, University Consortium for Geographic Information Science.
http://www.ucgis.org/priorities/research/research_white/2000%20Papers/emerging/Geographicvisualization-edit.pdf

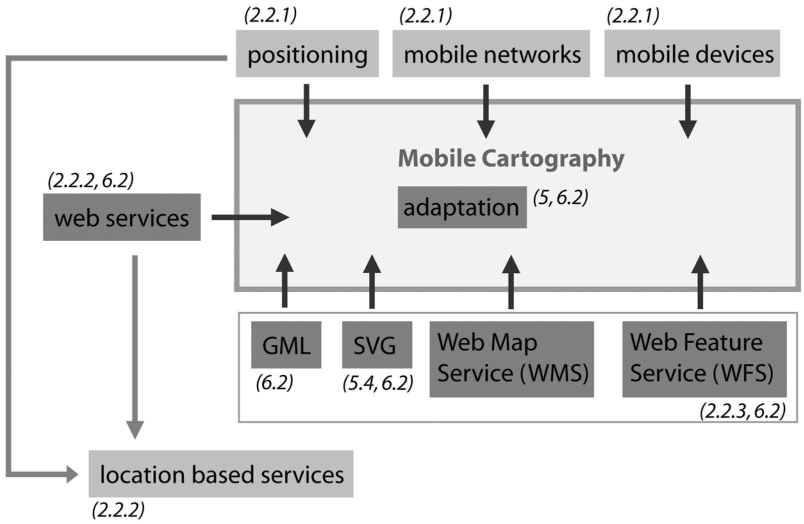


Fig. 13: Relevant technologies for mobile cartography

2.2.1 Mobile computing

A good introduction to the topic of mobile computing and related fields is presented in **(Stanton 2001)**. The pioneer of mobile computing, Mark Weiser, was one of the first to sketch a vision of new kinds of computing after the era of the PC **(Weiser 1991)**. Apart from mobile computing **(Imielinski and Korth 1996; Alatalo et al. 2001)** several partly related concepts can be found in literature: nomadic computing **(Specht and Oppermann 1999)** – ubiquitous computing **(Weiser 1991; Abowd and Mynatt 2000)** – pervasive computing **(Hansmann et al. 2001)** – embedded computing **(Want et al. 2002)** – everyday computing **(Mynatt 1999)** – invisible computing **(Norman 1998)**. Mobile and nomadic computing refer to the possibility of using computing during mobility as opposed to traditional stationary desktop based computing. The other categories go a step further in the sense that computing will be available almost everywhere embedded in any kind of everyday object and moving around computing devices for having access to computing at different places will become obsolete. The ultimate stage is the vision of invisible computing. Strongly connected to the field of mobile computing are the aforementioned context-aware systems.

Mobile devices

The actual computing hardware in the range of this work has to allow mobile information access. **Norman (1998)** calls such devices ***information appliances***. Yet, this term also refers to ubiquitous information access, i.e. embedded technology. For the scope of this work mainly Personal Digital Assistants (PDA) and Smartphones are of interest. The term ***PDA*** has been created by John Sculley in 1992 when he was with Apple. In 1993 Apple launched the first

Mobile computing:
(Stanton, 2001)
Stanton, N. A. (2001): Introduction: Ubiquitous Computing: Anytime, Anyplace, Anywhere?, *Human-Computer Interaction* 13(2): 107-111
(Imielinski and Korth, 1996)
Imielinski, T. and Korth, H. F. (1996): *Mobile computing*, Boston (MA): Kluwer Academic Publishers
(Alatalo et al., 2001)
Alatalo, T., Heikkinen, T., Kallinen, H. and Pihlajamaa, P. (2001): *Mobile information systems*, Seminar Thesis, Department of Information Processing Sciences, University of Oulu (Finland)
Nomadic computing:
(Specht and Oppermann, 1999)
Specht, M. and Oppermann, R. (1999): User Modeling and Adaptivity in Nomadic Information Systems, *Proc. i3 Annual Conference: Community of the Future*, Siena, Italy, October 20 - 22, 1999
Ubiquitous computing:
(Weiser, 1991)
Weiser, M. (1991): The Computer for the Twenty-First Century, *Scient. American* 265(3): 94-104. http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html
(Abowd and Mynatt, 2000)
Abowd, G. D. and Mynatt, E. D. (2000): Charting Past, Present, and Future Research in Ubiquitous Computing, *ACM Transactions on Computer-Human Interaction* 7(1): 29-58
Pervasive computing:
(Hansmann et al., 2001)
Hansmann, U., Merk, L., Nicklous, M. S. and Stober, T. (2001): *Pervasive Computing Handbook*, Berlin; Heidelberg; New York: Springer-Verlag
Everyday computing:
(Mynatt, 1999)
Mynatt, E. D. (1999): *Everyday Computing*, Whitepaper, Georgia Institute of Technology, Atlanta (GA). www.cc.gatech.edu/fce/ecl/projects/mynatt/EC/ec-white-paper.pdf
Invisible computing:
(Norman, 1998)
Norman, D. A. (1998): *The Invisible Computer*, Cambridge, MA: MIT Press
Embedded computing:
(Want et al., 2002)
Want, R., Pering, T., Borriello, G. and Farkas, K. I. (2002): Disappearing Hardware, *pervasive computing*(January - March): 36-47

PDA, called ***Newton***. Sculley had a vision of PDAs as ubiquitous tools. Newton, however, has not been commercially successful. In 1996 Palm Inc. shipped its first ***Palm Pilot*** running under Palm OS. Today, due to an enormous market shift, the Microsoft PocketPC OS (formerly WinCE) powered devices might give these devices its name: ***PocketPC***.

The strength of PDA is within the field of Personal Information Management (PIM), whereas Smartphones put a stronger emphasis on the communication functions. State of the art PDAs have 5" displays with 240x320 Pixel and 65000 colours. Most PDAs synchronise information with a stationary computer over a serial connection, e.g. USB. Other connection means are infrared, ***Bluetooth*** or ***Wireless LAN*** (WLAN). Infrared or Bluetooth are primarily intended for the communication between devices (e.g. PDA to Printer; Mobile Phone to Headset; Digital Camera to PDA; etc.) and for the coupling with a mobile phone's modem providing a connection to the Internet. Wireless LAN (WLAN) works after a similar principle as mobile radio. The reached bandwidths are between 22 and 40 Mbit/s. The coverage, however, is only partial and additional hardware is required. With such a WLAN card the PDA can directly connect to an access point and hence to the Internet. The functionality of PDAs is extendable by plugging external hardware into card slots. Common cards are Secure Digital (SD) and Compact Flash (CF). These cards could simply be memory extensions, but smarter cards host hardware such as GPS, digital cameras, connectivity, etc. The two most used operating systems are Palm OS from Palm Computing and Microsoft's PocketPC 2002. Apart from portable devices like PDAs other kinds of mobile devices exist which are mounted on mobile or moving objects. Such devices are for instance car, ship, and aircraft navigation systems. However, for this work the considered devices will be portable, personal devices.

Important technical improvements for PDAs promise the developments of new display techniques like Organic Light Emitting Diodes (OLED) or electronic paper **(Blankenbach 1999; Myers 2002)**. In addition, initiatives like the Open Systems Graphics (OpenSG) provide fast, real-time capable and portable display systems for virtual and augmented reality systems. These developments will also favour the displays for PDAs. Although there will be improvements in display technologies, physical and economical limits are in the way of significant advances over the next years. The major problem of mobile devices - and limiting factor

(Blankenbach, 1999)
Blankenbach, K. (1999): Multimedia-Displays - von der Physik zur Technik, *Physikalische Blätter* 55(5): 33-38

(Myers, 2002)
Myers, R. L. (2002): *Display Interfaces - Fundamentals and Standards*, Chichester (NY): John Wiley & Sons

for all other parts – is battery power. The further development of fuel cells could improve the life time of mobile batteries substantially.

Mobile networks

Mobile radio networks are composed of several cells (cellular network). In each cell a base transceiver station (BTS) is situated. These BTSs are basically antennas sending and receiving radio signals in well defined frequency bands. Furthermore each cell has a unique cell global identity (CGI). To date the implemented standard in Europe is GSM, which was designed for voice communication. Data transfer is possible with a data rate of 9.6 kbit/s. Since this data rate is much too small for bigger data transfers, new third generation (3G) networks will be established in the near future. One example of a 3G network is the new standard Universal Mobile Telecommunications System (UMTS). UMTS is designed for the mobile Internet with theoretical data rates up to 2 Mbit/s. It is circuit switched and packet switched, this means the device is always-on **(Siemens 2000)**. Until UMTS will be fully operational two other technologies with higher data transfer rates are introduced: High Speed Circuit Switched Data (HSCSD) and General Packet Radio Service (GPRS). What UMTS and GPRS have in common is that the user pays per data transferred to and from the device instead of connection time.

(Siemens, 2000)
Siemens (2000): *UMTS Whitepaper*, Siemens AG
http://www.siemens.ie/mobile/umts/UMTS%20Whitepaper.pdf

Positioning technologies

For positioning of mobile devices two major approaches can be distinguished **(Swedberg 1999; Hein et al. 2000; Mountain and Raper 2000)**. Network-based positioning works on the basis of cellular mobile networks. The easiest but most inaccurate way to determine the position is using the cell global identity, an inherent structure of a mobile radio network. Using signal run time from device to BTS or vice versa the position can be calculated more accurately with different methods. The second approach is called device-based positioning. In this case the device has any kind of sensor integrated which allows for location determination. In most cases this would be a GPS sensor. A hybrid approach is the combination of both approaches. An example is assisted GPS (A-GPS). In this case even very small fragments of GPS signals can be used, since ephemerid and almanac data is sent over the mobile network to the devices. For many applications, though the orientation is as important as the position itself. Kinematic GPS provides directions, but often an orientation is also needed at stops. Using electronic compasses is tempting, yet it must be doubted if they will be built

(Swedberg, 1999)
Swedberg, G. (1999): Ericsson's mobile location solution, *Ericsson Review*(4): 214-221

(Hein et al., 2000)
Hein, G. W., Eissfeller, B., Oehler, V. and Winkel, J. Ó. (2000): Synergies Between Satellite Navigation and Location Services of Terrestrial Mobile Communication, *Proceedings ION GPS 2000*, Salt Lake City (UT)

(Mountain and Raper, 2000)
Mountain, D. and Raper, J. (2000): Designing geolocation services for next generation mobile phones systems, *Proceedings AGI GIS2000*, London

(Hightower and Borriello, 2001)
Hightower, J. and Borriello, G. (2001): Location Systems for Ubiquitous Computing, *IEEE Computer*(August): 57-66

(Wunderlich, 2001)
Wunderlich, T. (2001): Ortsbezogene Information - jederzeit und überall!, *ZfV*(3): 117-122

Duckham et al., 2003)
Duckham, M., Kulik, L. and Worboys, M. (2003): Imprecise Navigation, *GeoInformatica* 7(2): 79-94

in general purpose PDAs. In addition, a compass would count for another energy consuming element. A discussion of location systems in general can be found in **(Hightower and Borriello 2001)** and a good overview of positioning technologies and their use for LBS is given by **Wunderlich (2001)**.

The positioning accuracies show a significant range depending on the method and the area (e.g. city vs. countryside). However, there will always be an error in the position caused by the measurement. An example of handling such imprecision is given by **Duckham (2003)**. One must also always consider the purpose of the location information. For certain tasks, rather imprecise positions will do, for others more precise information is essential. Moreover, the further processing and usage of the positions have to be taken into account. There is no sense in measuring positions up to the millimetre, if they are later displayed on a generalised smaller scale map.

Further improvements in positioning technologies can be expected in the next few years. The launch of the European GNNS ***Galileo***, which is interoperable to the GPS, is expected in 2008. This will increase the total number of navigation satellites in the orbit and thus enhance the chances for satellite visibility also in dense urban areas. Galileo will also improve indoor positioning that is so far handled by passive systems, for example infrared sensors.

2.2.2 Web Services, Geoservices, and Location Based Service

(Cerami, 2002)
Cerami, E. (2002): *Web Services Essentials*, Sebastopol (CA): O'Reilly & Associates

(SUN, 2001b)
SUN (2001b): *Open Net Environment (ONE): An Open Architecture for Interoperable, Smart Web Services*, White Paper

Web services seem to be one of the new buzzwords in information technology. The basic concept of web services is a distributed set of software with limited functionality and standard interfaces allowing the inter-communication of different web services **(Cerami 2002)**. **SUN (2001b)** characterizes ***web services*** as “accessible over the Web, providing an interface that can be called from another program, being registered by a Web service registry, communicating using messages over standard web protocols, and supporting loosely coupled connection between systems.” **SUN** goes even a step further and proclaims ***smart web services*** being aware of the user’s identity and used role, preferences and so on. An interesting concept addressed by SUN is the one of shared context. The underlying idea is that services on a low level can be assembled to get composite, higher level services providing value-added solutions to users. Furthermore, services can communicate with users, with applications or other web services. If services have to work together, they will need to know about the user’s context in order to provide satisfactory answers. At this point the concept of shared context fits in.

The infrastructure for smart web services proposed by SUN is called Open Net Environment (ONE), strengthening the important issue of open standards. Microsoft follows a similar, though rather proprietary way, called .NET. Anyhow, many standards and technologies are involved, the most important one being ***XML*** as a basic language for describing services (see Fig. 14). A service provider should describe the capabilities of the service and its interface with ***Web Service Description Language (WSDL)***. To register and later to discover services ***Universal Description, Discovery, and Integration (UDDI)*** is used. To encode messages for communication between the services the ***Simple Object Access Protocol (SOAP)*** is used. Web services are mostly transported over HTTP.

Web services can be differentiated according to their level of functionality. There are basic or low-level services that offer simple functions and complex or high-level services that combine several functions within one service. One way to achieve more complex and enhanced functionality is the bundling of basic services. The web service architecture provides a mechanism called service chaining. The chaining of services means that the response of one service acts as an input for another or 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.

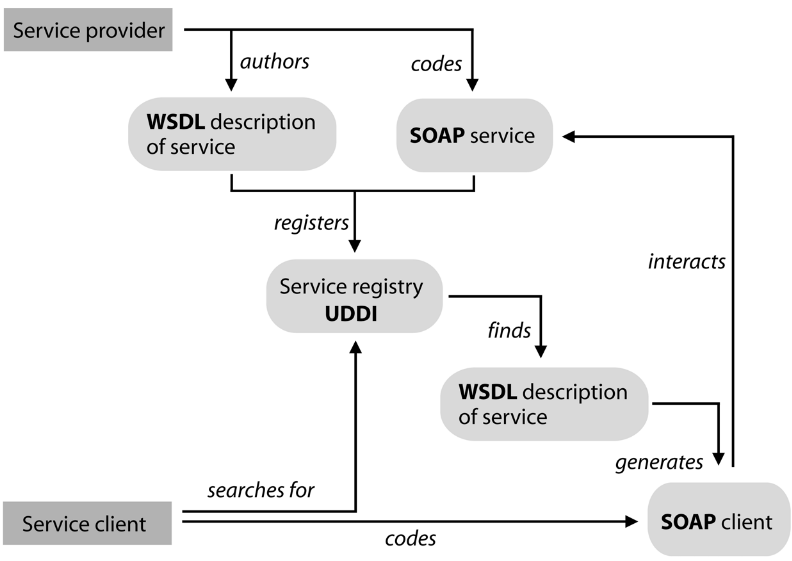


Fig. 14: Web service model (McLaughlin 2001)

(McLaughlin, 2001)
McLaughlin, B. (2001): *Java and XML*, Sebastopol (CA): O'Reilly & Associates

Geoservices

(Meng and Reichenbacher, 2003)
Meng, L. and Reichenbacher, T. (2003): Geodienste für Location Based Services, *Proceedings 8. Münchner Fortbildungsseminar Geoinformationssysteme*, TU München, March 12-14, 2003

The most general notion of geoservices are services that give precise answers to specific spatial questions. However, for this work geoservices are understood as web services that provide, manipulate, analyse, communicate, and visualise any kind of geographic information **(Meng and Reichenbacher 2003)**. There are several types of geoservices, not all aimed at mobile users.

Standards

ISO 19119: www.opengis.org/docs/02-112.pdf

In recent years several standardisation processes have proceeded to specify specifications to guarantee interoperability of geographic information and geoprocessing. The two major organisations involved in these processes are the International Standardisation Organisation (ISO) and the Open GIS Consortium (OGC). At ISO the ISO/TC 211 is concerned with standardising Geographic Information/Geomatics. These ISO specifications are currently harmonised with the Open GIS service architecture. In ISO 19119 a general service framework is specified and a service is defined as "a distinct part of the functionality that is provided by an entity through interfaces". ISO 19101 provides a classification of geographic services with the Extended Open Systems Environment (EOSE) model for geographic information. This model distinguishes six classes of geographic services. Table 3 shows the six classes and example services relevant for this work as well as the corresponding ISO and/or OGC specifications. The model also provides a method for organising services that are meaningful for a specific situation. These so called service organisation folders (SOF) are references to services, either individual services or service chains that are also specified in the framework. SOF could be a means to map relevant services to specific usage contexts.

Geographic human interaction services	Catalogue-centric service that views and browses meta-data about services Spatial-centric service for editing, displaying, querying, and analyzing map data Calculation-centric service allowing viewing and manipulation of geographic data using a spreadsheet format Chain definition editor Geographic symbol editor (ISO 19117 - Portrayal) Feature Generalization editor
Geographic model/ information management services	Feature access service (OGC Simple Feature Access, Web Feature Service; ISO 19125-1 – Simple feature access – Part1: Common architecture) Map access service (OGC Web Map Service; ISO 19128 – Web Map server interface; ISO 19117 - Portrayal) Coverage access service (OGC Coverages; ISO 19123 – Schema for coverage geometry and functions) Gazetteer Service (OGC Gazetteer Service, OGC Geoparser Service, OGC Geocoder Service; ISO 19112 - Geographic referencing by geographic identifiers)

	Geographic metadata catalogue – with discovery, access and management subservices (OGC Web Catalog Service; ISO 19115 - Metadata)
Geographic workflow/ task management services	Chain definition service Subscription service
Geographic processing services Spatial Thematic Temporal Metadata	Coordinate conversion service Subsetting service Feature matching service Feature generalization service Route determination service Positioning service (ISO 19116 – Positioning services Proximity analysis service Feature generalization service Spatial Counting service Geoparsing service Geocoding service Subsetting service Temporal proximity analysis service Geographic annotation service
Geographic communication services	Encoding service (ISO 19118 - Encoding) Transfer service (ISO 19118 - Encoding) Geographic compression service Geographic format conversion service
Geographic system management services	

Table 3: ISO Geographic services

The OGC has proposed a framework for geoservices, named *Open Web Services* (OWS) that fits well in the geoservice model mentioned before. The OGC Open Location Services (OpenLS) specification defines Core Services and Abstract Data Types (ADT). In addition it defines the requirements of a GeoMobility Server (GMS), an open location service offering the core services **(OGC 2003, p. 19)**. A GeoMobility server is a component that offers some basic functionality on which location-based applications can be built. This functionality is comprised by the OpenLS Core Services (Fig. 15): Route, Location Utility, Directory, Presentation, and Gateway. A GMS uses open interfaces to access network location capacity and offers access to its OpenLS Core Services through interfaces. The GMS preferably provides content such as maps, routes, addresses, POIs, traffic, etc. stored according to the OpenLS Information Model, consisting of ADTs. A GMS can also access other content sources via the Internet.

(OGC, 2003)
OGC (2003): *OpenGIS Location Services (OpenLS): Core Services*, OGC Implementation Specification, OGC 03-006r1, Open GIS Consortium

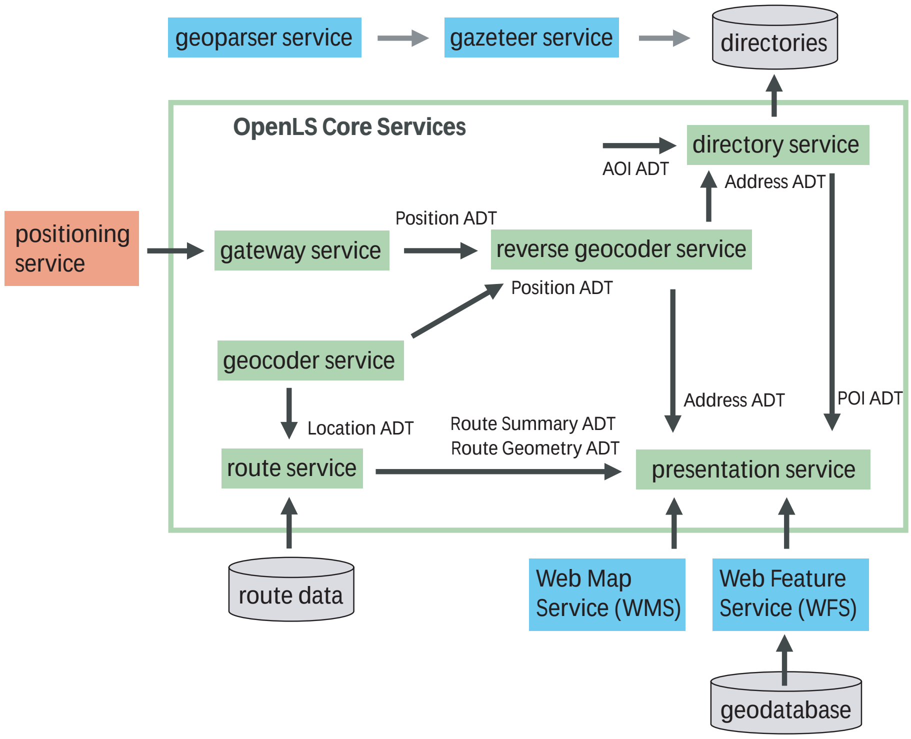


Fig. 15: OpenLS Framework (after OGC 2003)

The OpenLS framework defines a presentation (map portrayal) service as "a network-accessible service that portrays a map made up of a base map derived from any geospatial data and a set of ADT's as overlays" **(OGC 2003, p. 4)**. The OpenLS platform also offers a standard way for encoding request and response messages as well as ADT's with XML, the XML for Location Services (XLS).

Location Based Services

(OGC, 2003)
OGC (2003): *OpenGIS Location Services (OpenLS): Core Services*, OGC Implementation Specification, OGC 03-006r1, Open GIS Consortium

(Ovum, 2000)
Ovum (2000): *Mobile Location Services: Market Strategies*, Ovum Ltd.

One category of geoservices for mobile users are location based services (LBS). LBSs are services accessible with mobile devices through the mobile network and utilizing the ability to make use of the location of the terminals. LBS provide specific, relevant information based on the current location to the user. In **(OGC 2003, p. 4)** LBS is defined as "a wireless-IP service that uses geographic information to serve a mobile user [or] any application service that exploits the position of a mobile terminal." Another definition, emphasizing the importance of the information, is given by **Ovum (2000, p. 5)**: "[LBS are] network-based services that integrate a derived estimate of a mobile device's location or position with other information so as to provide added value to the user." The telecommunication industry has just started to offer LBS to subscribed users. The idea is that a user books such a service and will get information from the network provider which is relevant to his/her current position. For a basic introduction to LBS see for example **(Gasenzer 2001; Koeppel 2000; SUN 2001a)**. The importance of GIS functions for LBS is discussed in **(Virrantaus et al. 2001)**.

The core services of LBS rely on fundamental GIS functions that are also contained in the OpenLS framework (see Fig. 15). The following list describes the services by the LBS company *pocket-it*:

- ***Positioning***: provides the location of the mobile user by connecting to the network operator's positioning system
- ***Geographic search***: searches for any geographic feature
- ***Geocoding service***: determines X and Y coordinates for relevant POIs or addresses
- ***Reverse Geocoding***: converts coordinates into a geographic text format
- ***Proximity search***: find nearest POI or POIs nearby from a position or address, e.g. the nearest bus stop, ATM, drugstore, post office etc.
- ***Routing service***: calculates the shortest or fastest route between two points or a number of points (current position, address, POI) and direction instructions (street names, distances, and turns).
- ***Mapping service***: High quality map display of POI based on a request for a specific location with pan and zoom functionality and optimised for the requesting device

Especially in the case of LBS two different ways of information dissemination are push and pull services. In a pull service the information is desired and expected by the user; the user actively pulls the information. The download and browsing of web pages is an example for a pull service. In a push service the information is pushed to the user without a user request. An example would be an advert of a special offer when passing a shop.

(Gasenzer, 2001)
Gasenzer, R. (2001): Mobile Commerce und Location Based Services: Positionsbasierte Leistungsangebote für den mobilen Handel, *HMD - Praxis der Wirtschaftsinformatik*(8): 37-51

(Koeppel, 2000)
Koeppel, I. (2000): What are Location Services? - From a GIS Perspective, Sun Microsystems. 2001. http://www.jlocationservices.com/company/esri/What%20are%20Location%20Services.html

(SUN, 2001a)
SUN (2001a): *Java Location Services: The new Standard for Location-Enabled E-Business*, White Paper. http://www.jlocationservices.com/company/Sun/JavaLocServBR_R4.pdf

(Virrantaus et al., 2001)
Virrantaus, K., Veijalainen, J., Markkula, J., Katanosov, A., Garmash, A., Tirri, H. and Terziyan, V. (2001): Developing GIS-Supported Location-Based Services, *Proceedings WGIS 2001*, Kyoto, Japan

LBS functionality: www.pocket-it.com

Geovisualisation services

This category of geoservices provides any kind of visualisation of geographic information. For mobile cartography, geovisualisation services are of the utmost interest. A more detailed discussion of geovisualisation services is given in **(Meng and Reichenbacher 2003)**. Geovisualisation service is also called ***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 continue even stronger in the mobile Internet. Table 4 gives a rough, yet incomplete overview of the main differences.

(Meng and Reichenbacher, 2003)
Meng, L. and Reichenbacher, T. (2003): Geodienste für Location Based Services, *Proceedings 8. Münchner Fortbildungsseminar Geoinformationssysteme*, TU München, March 12-14, 2003

	map products	geovisualisation services
information detail	more detailed	less detail
information content	comprehensive	focussed, more relevant
personalisation	one size fits all	can be adapted
usage	more enduring	short-term, instant
design and production	by cartographers	automatically, based on cartographic methods
graphic quality	high	inferior, but enhanced quality in use
link to other information	more difficult, poor interoperability	built-in (service chaining), better interoperability
functionality	greater functionality	limited functionality

Table 4: Comparison of map products and geovisualisation services

The services described so far can be ordered in a hierarchy. Although a geoservice must not necessarily be distributed and web-based, geoservices normally are a subset of web services. A geoservice is the most general category of service related to geographic information. LBSs and geovisualisation services are subsets or implementations of a geoservice. Both, LBSs and geovisualisation services, can be based on lower level services such as web feature services or web map services. Furthermore, they can also incorporate one another, i.e. there are LBS with a geovisualisation component and geovisualisation services based on LBS functionality.

Open standards for geoservices

As a technology web mapping has matured over the last couple of years. Due to its universality the Internet, and hence web mapping as well, demands for a high degree of interoperability. The Open GIS Consortium has established standards in many realms of GI. For web mapping the OGC has defined a standard, the specification for ***Web Map Servers*** (WMS). Together with the ***Web Feature Server*** (WFS) specification and other specifications it offers an open standard for web mapping. Other standardisation efforts have brought up XML based formats for modelling geographic data, the ***Geography Markup Language*** (GML), and presenting geographic data as vectors, the ***Scalable Vector Graphics*** (SVG). SVG is a multi purpose graphic format, but as **Neumann and Winter (2000)** confirm well suited for cartographic purposes. Most recent activities establish a specification of SVG for mobile needs

In academia the need for an open and interoperable platform has also been recognised. **Edwardes et al. (2003a)** describe the requirements of an open research platform for on-demand mapping and generalisation.

(Neumann and Winter, 2000)
Neumann, A. and Winter, A. (2000): *Kartographie im Internet auf Vektorbasis, mit Hilfe von SVG.* http://www.carto.net/papers/svg/index_d.html

(Edwardes et al., 2003a)
Edwardes, A., Burghardt, D., Bobzien, M., Harrie, L., Reichenbacher, T., Sester, M. and Weibel, R. (2003a): Map Generalisation Technology: Addressing the Need for a Common Research Platform, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

Chapter 3

Approaches for visualisation of geographic information on mobile devices

If you have been far, there is always someone who's been further than your far, at last you're straight and you make a new start
– The Beautiful South: 'Hooligans don't fall in love'.

3.1 Related work

Only little work has been done on how to visualise geographic information, especially map data, on very small displays. It is surprising that even for screen display in general hardly any studies have been conducted. Exceptions are a few studies of the issues and problems in screen design for cartographic visualisation and proposals of new minimal dimensions; see for example **(Spiess 1994; Malic 1998; Wilfert 1998; Arleth 1999; Thissen 2000; Brunner 2000; Brunner 2001; Neudeck 2001)**. Moving on to even smaller displays, used in PDA for instance, these problems intensify. Reading map graphics becomes very difficult. Important map functions, e.g. providing spatial context and overview, are very hard to keep on small displays. **Brunner (2001)** describes different effects resulting from the raster technology of screens. Several graphical primitives (e.g. circles) that are widely used for map symbols and map fonts are highly sensitive for graphical distortions.

Some research has been done on using graphics on small displays. But maps are often more complex than simple graphics. Moreover, the smaller the displays are, the more important graphical issues like minimal dimensions become. **Neudeck (2001)** studied different proposals of minimal dimensions for screen maps and offers a new set of threshold values based on tests. These minimal dimensions have to be much larger to ensure legibility on

(Spiess, 1994)
Spiess, E. (1994): Some Problems with the Use of Electronic Atlases, *LIBER Quarterly*. http://www.konbib.nl/infolev/liber/articles/1spiess.htm

(Malic, 1998)
Malic, B. (1998): *Physiologische und technische Aspekte kartographischer Bildschirmvisualisierung*, Dissertation, Inst. für Kartographie und Topographie, Universität Bonn

(Wilfert, 1998)
Wilfert, I. (1998): Internet und Kartographie, *in* M. Buchroithner, W. G. Koch and I. Wilfert (Eds.), Kartographische Bausteine, Band 14, Dresden: Technische Universität Dresden, Institut für Kartographie.

(Arleth, 1999)
Arleth, M. (1999): Problems in screen map design, *Proc. 19th International Cartographic Conference (ICA 1999)*, Ottawa, August 14-21, 1999

(Thissen, 2000)
Thissen, F. (2000): *Screen-Design-Handbuch: Effektiv informieren und kommunizieren mit Multimedia*, Berlin; Heidelberg: Springer-Verlag

(Brunner, 2000)
Brunner, K. (2000): Limitierungen bei der elektronischen Bildschirmanzeige von Karten, *in* B. Schmidt and C. Uhlenküken (Eds.), *Visualisierung raumbezogener Daten: Methoden und Anwendungen, Bd. II: Beiträge zum 3. GeoViSC-Workshop*Münster: Institut für Geoinformatik, Westfälische Wilhelms-Universität Münster

small screens. Neudeck also presents first practical guidelines for screen map graphics that can be embedded in the design of mobile maps.

(Brunner, 2001)
Brunner, K. (2001): Kartengestaltung für elektronische Bildanzeigen, *in*, *Kartographische Bausteine*, Band 19, Dresden: Technische Universität Dresden, Institut für Kartographie

(Neudeck, 2001)
Neudeck, S.: Zur Gestaltung topografischer Karten für die Bildschirmvisualisierung. Disserta-tion, Inst. für Photogrammetrie und Kartographie. Studiengang Geodäsie und Geoinforma-tion, Univ. der Bundeswehr München, 2001

3.1.1 Research approaches

Most of the research related to this work is in the field of context-aware mobile computing or geographic information services for tourists.

One of the earliest context-aware systems has been developed at Xerox PARC in Palo Alto among others by the pioneer of ubiquitous computing Mark Weiser. ***ParcTab*** is a prototype demonstrating applications like information access, communication, computer supported cooperative work (CSCW), remote control and local data processing in office environments **(Want et al. 1995)**. The device positioning is based on infrared technology and can display different information dependent on its position.

(Want et al., 1995)
Want, R., Schilit, B., Adams, A., Gold, R., Petersen, K., Goldberg, D., Ellis, J. and Weiser, M. (1995): *The ParcTab Ubiquitous Computing Experiment*, Technical Report CSL-95-1, Xerox Palo Alto Research Center, Palo Alto (CA)

In the mid 1990ies at Georgia Institute of Technology the ***Cyberguide*** Project was initiated **(Long et al. 1996)**. It is a series of prototypes of portable tour guides. They are all based on the Apple message pad (Newton). Indoor positioning is done by infrared technology, outdoor positioning applies GPS. Cyberguide is built on three modules: a map module, a communication module, and a positioning module. The maps are displayed as bitmaps. Information which is sent to the message pads is centrally stored on a stand-alone computer. Dynamic changes of information are not easy to propagate. Another drawback is the fact that an increase in the information amount could crack the capacity of a stand-alone system.

(Long et al., 1996)
Long, S., Aust, D., Abowd, G. and Atkenson, C. (1996): Cyberguide: Prototyping Context-Aware Mobile Applications, *Proceedings ACM CHI 96 Conference on Human Factors in Computing Systems*. http://www.acm.org/sigchi/chi96/proceedings/shortpap/Abowd/gda1txt.htm

At Rutgers University the research project ***DATAMAN*** was conducted **(Acharya et al. 1994)**. The goal was to enable data handling in a mobile environment. DATAMAN is map centred, i.e. the user interface is based on a map.

(Acharya et al., 1994)
Acharya, A., Imielinski, T. and Badrinath, B. R. (1994): *DATAMAN Project: Towards a Mosaic-like Location Dependant Information Service for Mobile Clients*, TR-320, Rutgers University. ftp://www.cs.rutgers.edu/pub/technical-reports/dcs-tr-320.ps.Z

From mid 1997 to mid 1999 the Distributed Multimedia Research Group of Lancaster University and Lancaster City Council conducted a joint research project named ***GUIDE*** **(Cheverst et al. 2000)**. The group established a prototype of a context-sensitive, mobile multimedia, computer supported tool for visitors of Lancaster. While walking around the town, visitors can constantly view information about sightseeing objects displayed on a mobile device.

(Cheverst et al., 2000)
Cheverst, K., Davies, N., Mitchell, K., Friday, A. and Efstratiou, C. (2000): Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences, *Proceedings CHI 2000*, The Hague, Netherlands, April 2000. http://www.guide.lancs.ac.uk/CHIpaper.pdf

Another early research project linked to LBS was ***Hyper-Interaction within Physical Space*** (HIPS). The objective of this EU project was to develop a service for museum visitors that allowed them to access attribute information connected to physical objects in real-time. HIPS predominantly dealt with the adaptation of hypermedia with respect to interactive tour guides **(Broadbent and Marti 1997)**.

(Broadbent and Marti, 1997)
Broadbent, J. and Marti, P. (1997): Location aware mobile interactive guides: usability issues, *Proceedings The Fourth International Conference on Hypermedia and Interactivity in Museums (ICHIM '97)*, Paris, September 1-5, 1997. http://www.ing.unisi.it/lab_tel/hips/hips_pub.htm

Several feasibility studies have been carried out in the ***OnTheMove*** project **(Kreller et al. 1998)** initiated by Ericsson Eurolab to demonstrate the potential of 3G telecommunication systems – UMTS – for mobile broadband multimedia applications. The mobile-aware city guide application aimed at building prototypes on the basis of the Mobile Application Support Environment for 3G systems (MASE). Two prototypes, a Java applet and a Java stand-alone application, have been developed. The location manager module of the prototypes is based on GPS. Map data is displayed as scanned raster city maps offering panning functionality. The user can also display his/her position and select and deselect single layers.

(Kreller et al., 1998)
Kreller, B., Carrega, D., Shankar, J. P., Salmon, P., Böttger, S. and Kassing, T. (1998): A Mobile-Aware City Guide Application, *Proceedings ACTS Mobile Summit 1998*, Rhodos, Greece

The Fraunhofer Computer Graphics Center in Rostock ran the ***Mobile Visualisation*** (***MoVI***) project **(Kirste et al. 1995)**. The project is based on the concept of Mobile Data Terminals (MDT). Some new ideas concerning level of detail and detail of demand are very interesting. Although only raster data is considered, new techniques for displaying map data on small displays are presented. In another project several Institutes of Fraunhofer Gesellschaft investigate mobile user support. The ***SAiMotion*** project aims at providing adaptive and situation-aware solutions for nomadic users **(Heidmann and Hermann 2003, p. 126)**.

(Kirste et al., 1995)
Kirste, T., Heuer, A., Kehrer, B., Schumann, H. and Urban, B. (1995): Concepts for Mobile Information Visualization - The MoVi-Project, *Proceedings Sixth Eurographics Workshop on Visualization in Scientific Computing*, Chia, Italy, May 3-5, 1995

(Heidmann and Hermann, 2003)
Heidmann, F. and Hermann, F. (2003a): Visualisierung raumbezogener Informationen für ultraportable mobile Systeme, *in*, *Visualisierung und Erschließung von Geodaten - Seminar GEOVIS 2003, 26. bis 27. Februar 2003, Universität Hannover*, Kartographische Schriften, Band 7, Bonn: Kirschbaum Verlag, 121-131

Strongly connected with the basic idea, but with a commercial background is the ***MOGID*** (Mobile Geo-depended Information on Demand) project **(Balsiger et al. 2000)**. The location technology used is an enhanced UL-TOA (uplink time of arrival), which is software based and therefore applicable to almost any mobile device. The solution is implemented as a Java applet that can be accessed via AT commands from the GSM module. The information is stored in a standard relational DBMS. Since it is a commercial service, only information which is interesting enough according to the provider and worthy in the sense that people might pay for will be stored in the locational database.

(Balsiger et al., 2000)
Balsiger, P., Sun, D., Gomez, M., Pellandini, F., Aeschlimann, M., Dworzak, C., Hubmann, M. and Sollberger, A. (2000): MOGID: Mobile Geo-depended Information on Demand, *Proceedings Workshop on Position Dependent Information Services - Joint W3C-WAP Forum Workshop*, Sophia Antipolis, Nice, February 2-3, 2000. http://www.w3.org/Mobile/posdep/wap-v2.htm

(Malakka, 2000)
Malakka, R. (2000): Deep Map: The Multilingual Tourist Guide. http://www.eml.villa-bosch.de/english/research/deepmap/deepmap.html

In the project ***Deep Map*** an interdisciplinary research group at the European Media Lab (EML) developed a prototype of a digital personal mobile tourist guide for the city of Heidelberg **(Malakka 2000)**. Deep Map integrates research from various areas of computer science, such as geo-information systems, data bases, natural language processing, intelligent user interfaces and knowledge representation. The goal of the project was to develop information technologies that can handle huge heterogeneous data collections, complex functionality and a variety of technologies, but are still accessible for untrained users. The core of the guide is a GIS. However, the GIS will be extended to the fourth dimension by integrating temporal information (e.g. city history). Tour planning, virtual tours, and localisation of users per GPS are interfaces to this project. There is also the interesting sub-project ***Talking Map*** that investigates speech recognition, natural language input/output interfaces, verbal directions, and spatial reasoning. Especially the speech output could be of interest as an alternative means to deliver spatial data to the user.

(Poslad et al., 2001)
Poslad, S., Laamanen, H., Malaka, R., Nick, A., Phil, B. and Zipf, A. (2001): CRUMPET: Creation of User-friendly Mobile Services Personalised for Tourism, *Proceedings 3G 2001*, London, March, 26-28 2001

The follow-up project ***CRUMPET*** aimed at designing usable mobile services for tourists and investigated service adaptation techniques **(Poslad et al. 2001)**.

(Volz et al., 2002)
Volz, S., Haala, N. and Klinec, D. (2002): NEXUS - An Open Global Infrastructure For Spatially Aware Applications, *Geoinformatics*(July/August): 24-26.

NEXUS is a project dealing with a platform for mobile services **(Volz et al. 2002)**. The basic concept is based on Virtual Information Towers that hold information about the area they service. The main focus is on modelling geographic information adequately for mobile service provision and offering an open platform for other service providers to build their location services on top of it.

(Gartner and Uhlirz, 2001)
Gartner, G. and Uhlirz, S. (2001): Cartographic Concepts for Realizing a Location Based UMTS Service: Vienna City Guide "Lol@", *Proceedings 20th International Cartographic Conference*, Beijing, China, August 6 - 10, 2001

Different projects propose solutions for displaying geographic information on small displays. The ***LoL@*** project developed a prototype tourist guide for 3G networks and handsets **(Gartner and Uhlirz 2001)**. The goal of the project was to build a demonstrator for an UMTS based map service for the city of Vienna. The map graphics has been optimised for the display size of a Smartphone. The map has a slight skew that, together with the silhouette of important sightseeing spots, gives a more perspective spatial impression (Fig. 16, left).

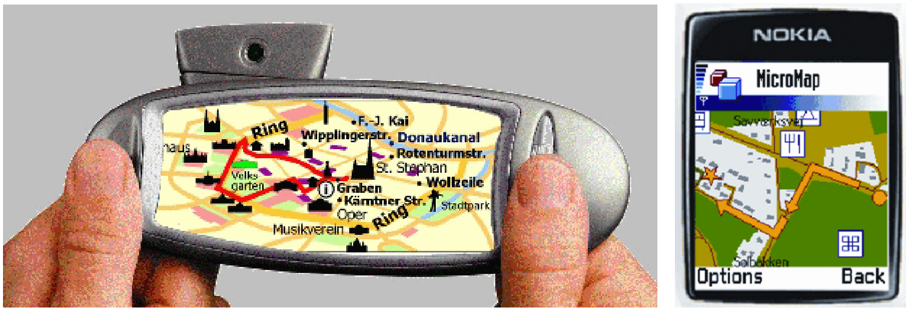


Fig. 16: LoL@ prototype (Gartner and Uhlirz, 2001) and GiMoDig design proposal for navigation map (Nissen et al., 2003)

A few EU projects deal or dealt with mobile geographic information visualisation: A similar goal as in the CRUMPET project was pursued in the ***HYPERGEO*** project **(Mountain and Raper 2000)**. In the ***VATGI*** project standards for the exchange of thematic geographic information (e.g. POI) have been developed **(VATGI-Consortium 2001)**. Two recent EU projects are very closely related to this research.

(Mountain and Raper, 2000)
Mountain, D. and Raper, J. (2000): Designing geolocation services for next generation mobile phones systems, *Proceedings AGI GIS2000*, London

(VATGI-Consortium, 2001)
VATGI-Consortium (2001): *VATGI Project INFO 2000 - PUB 1199 VATGI FINAL REPORT*, Public Report, VATGI Consortium. http://www.VATGI.org

GiMoDig (Geospatial info-mobility service by real-time data-integration and generalisation) is a project of several National Mapping Agencies aiming at developing spatial data delivery from national primary geo-databases for mobile use and the necessary real-time data integration and generalisation methods. In a work package on small-display cartography, possible map designs are examined and guidelines elaborated **(Nissen et al. 2003)**. Fig. 16 (right) shows a prototype of a navigation map for a Smartphone.

GiMoDig
Project Homepage:
gimodig.fgi.fi/index.php

(Nissen et al., 2003)
Nissen, F., Hvas, A., Münster-Swendsen, J. and Brodersen, L. (2003): *Small - Display Cartography*, GiMoDig D3.1.1 (Public Deliverable), KMS: National Survey and Cadastre - Denmark. http://gimodig.fgi.fi/pub_deliverables/D3_1_1.pdf

The goal of the ***WebPark*** project is to develop personalised value-added LBSs for mobile users in national parks **(Krug et al. 2003)**. National parks in coastal and alpine areas are used as test fields. First approaches for visualising species information for visitors of the Swiss national park are proposed by **Edwardes et al. (2003b)**. This concept foresees an activity based semantic filtering of information and investigates the architecture of a generalisation service.

(Krug et al., 2003)
Krug, K., Mountain, D. and Phan, D. (2003): WebPark: Location-Based Services for mobile users in protected areas, *Geoinformatics*(March). http://www.soi.city.ac.uk/~dmm/research/pubs/WParticle_by_Consortium_GeoInformatics_nr2_March_2003.pdf

(Edwardes et al., 2003b)
Edwardes, A., Burghardt, D. and Weibel, R. (2003b): WebPark - Location Based Services for Species Search in Recreation Area, *Proceedings 21st Int.l Cartographic Conference*, Durban, South Africa, August 10-16, 2003

An approach similar to this research is taken by **Urquhart et al. (2003)**. The goal is to ensure the usability of LBS by developing appropriate representations for mobile devices by applying a user-centred approach to LBS development and the design of optimised cartographic representations for mobile contexts.

(Urquahrt et al. 2003)
Urquhart, K., Cartwright, W., Miller, S., Mitchell, K., Quirion, C. and Benda, P. (2003): Ensuring Useful Cartographic Representations in Location-Based Services, *Proceedings ICC*, Durban, South Africa, August 10-16, 2003

This research work also shares some substantial ideas of the approach of 'situational visualizations', although situational visualisations have a lot in common with virtual environments and augmented reality and are more focussed on exploring the environment. Situational visualisations are based on a mobile 'Virtual

GIS' that takes the user's spatio-temporal location, his/her actions and the situatedness in a environment into account **(Krum et al. 2001)**.

Useful research on ***dynamic maps*** has been conducted by **Arikawa et al. (1994)**. The concept of dynamic maps includes queries of geodatabases and selection of appropriate visualisation methods. Of interest is the idea to adapt the number of displayable features in the retrieval set according to a map saturation.

Some research has been conducted on adaptive graphics. **Krüger et al. (2000)** demonstrate the adaptation of perspective graphics for wayfinding tasks in buildings. **Jung and McKeown (2001)** describe an XML based approach of adapting different kind of graphics, to which they count maps as well. One of their examples deals with quantitative and qualitative changes that can be applied to maps.

Scholz (2002) developed an application closely related to adaptive maps. In a scenario he describes event based screen maps for pedestrians. The rule-based modelling approach includes the detection of situations and offers reactions reflected in the map, such as the user position update, different scales depending on movement speed (walking or bus), displaying the bus network depending on drives or stops of the bus, etc.

Adaptation of maps *sensu strictu* has so far been investigated only by **(Heidmann 1999; Chalmers et al. 2001; Zipf 2002; Zipf and Richter 2002)**. **Heidmann (1999, p. 253)** explicitly speaks of *adaptive* work graphics that automatically adapts itself to the user characteristics and the current task context. He identifies the models needed for adaptive behaviour, the user model, the task model, and the situation model and gives examples of parameters for each model. This work has strong influence on the framework of mobile cartography (chapter 4), especially on the user, activity, and context. The research of **Chalmers et al. (2001)** is targeted at adapting maps for different bandwidths, i.e. reducing the file size by adapting the content of the map. Their approach deduces from an original map an adapted map with reduced content for a transmission on a 10kB/s connection. This approach basically seems to generalise maps by applying a selection operator. Although this can be considered as adaptation, it is not as comprehensive as the approach of Zipf and the one developed in this work.

(Krum et al. 2001)
Krum, D. M., Ribarsky, W., Shaw, C. D., Hodges, L. F. and Faust, N. (2001): Situational Visualization, *Proc. ACM Symposium on Virtual Reality Software and Technology*, Banff, Canada, November 15-17, 2001, ACM Press

(Arikawa et al. 1994)
Arikawa, M., Kawakita, H. and Kambayashi, Y. (1994): Dynamic Maps as Composite Views of Varied Geographic Database Servers, *Proceedings First International Conference on Applications of Databases, ADB-94*, Vadstena, Sweden, June 21-23, 1994

(Krüger et al. 2000)
Krüger, A., Baus, J. and Butz, A. (2000): Smart Graphics in Adaptive Way Descriptions for Pedestrians, *Proceedings Advanced Visual Interfaces (AVI '00)*, Palermo, Italy, May 23-26, 2000, ACM Press

(Jung and McKeown, 2001)
Jung, B. and McKeown, J. (2001): Adaptive Graphics, *Proceedings XML2001*, Orlando (FL)

(Scholz, 2002)
Scholz, F. O. (2002): *Ereignisgesteuerte Bildschirm-karten*, Diplomarbeit, Institut für Informatik - Abteilung III, Rheinische Friedrich-Wilhelms-Universität Bonn

(Heidmann, 1999)
Heidmann, F. (1999): *Aufgaben- und nutzerorientierte Unterstützung kartographischer Kommunikationsprozesse durch Arbeitsgraphik: Konzeptionen, Modellbildung und experimentelle Untersuchungen*, Herdecke: GCA-Verlag

(Chalmers et al., 2001)
Chalmers, D., Sloman, M. and Dulay, N. (2001): Map Adaptation for Users of Mobile Systems, *Proceedings WWW10*, Hong Kong, May 2001

(Zipf, 2002)
Zipf, A. (2002): User-Adaptive Maps for Location-Based Services (LBS) for Tourism, *in* K. Woeber, A. Frew and M. Hitz (Eds.), *Proceedings of the 9th International Conference for Information and Communication Technologies in Tourism, ENTER 2002, Innsbruck, Austria, Springer Computer Science*Berlin; Heidelberg: Springer-Verlag. http://www.eml.villa-bosch.de/english/homes/zipf/ENTER2002.pdf

(Zipf and Richter, 2002)
Zipf, A. and Richter, K.-F. (2002): Using Focus Maps to Ease Map Reading: Developing Smart Applications for Mobile Devices, *Künstliche Intelligenz*(4): 35-37

Zipf (2002) studies the potential of adaptive map services for tourists and offers a first overview of the design steps involved in adaptive map generation. He gives a few examples of possible map adaptations: culture specific map colouring, map generalisation, user oriented-maps, and focus maps. ***Focus maps*** are of special interest on small displays **(Zipf and Richter 2002)**. The basic idea is to apply focus-context techniques to map design, i.e. moving the most relevant spatial information in focus and showing it with full detail (exaggerating or emphasizing) while displaying the other, contextual information with less detail and graphically not that prominently. For this purpose regions of interest have to be modelled. The methods used to emphasize the region of interest are generalisation and colour use. The region of interest is compared to the rest of the map either generalised less or symbolised with brighter colours. The former approach is similar to the variable-scales solution discussed in the next section.

(Zipf, 2002)
Zipf, A. (2002): User-Adaptive Maps for Location-Based Services (LBS) for Tourism, *in* K. Woeber, A. Frew and M. Hitz (Eds.), *Proceedings of the 9th International Conference for Information and Communication Technologies in Tourism, ENTER 2002, Innsbruck, Austria, Springer Computer Science*Berlin; Heidelberg: Springer-Verlag. http://www.eml.villa-bosch.de/english/homes/zipf/ENTER2002.pdf

(Zipf and Richter, 2002)
Zipf, A. and Richter, K.-F. (2002): Using Focus Maps to Ease Map Reading: Developing Smart Applications for Mobile Devices, *Künstliche Intelligenz*(4): 35-37

The projects and approaches presented differ in their extent of covering cartographic design issues. With the advent of mobile computing and context sensing technologies, the first projects mainly examined the technical aspects of context-awareness, e.g. *ParcTab*, *CyberGuide*, and *DATAMAN*. In the second half of the 1990ies, more and more projects took up the idea of LBS. Some of them were intended as demonstrators of possibilities of 3G mobile networks (UMTS) such as *OnTheMove* and *Lol@*. Interestingly most projects target tourists (e.g. GUIDE, DeepMap, CRUMPET, Lol@) and pedestrian navigation (*NAVIO*, *GiMoDig*). A trend to more personalised, user adaptive map based services can be observed from the beginning of this millennium with projects like *DeepMap*, *CRUMPET*, *GiMoDig*, and *WebPark*. Whereas these projects all have an influence on the research presented here, not all of them provide solutions applicable to the problem area described in chapter 1. The next section will therefore describe the solutions developed that can be used for displaying geographic information on small displays.

3.1.2 Existing solutions

Besides research projects, industry solutions offer a view on the commercial state of the art in mobile geographic information visualisation. These solutions are strongly influenced by solutions of car navigation systems. After an overview of city map guides, navigation systems, and LBS, a brief outlook on newer solutions for handling the small screen problem round off the contemplation of related work.

City map guides

City map guides
Falk City Guide: www.falk.de

The basic functionality of solutions for mobile geographic information visualisation is provided by city maps with searchable POIs like the Falk City Guide. These map guides include a GPS positioning and tracking function. The map function is in general also the basic component for all other systems and services.

Navigation systems

Navigation Systems
TomTom Navigator 2: www.tomtom.com
Destinator 3.0: www.destiator.de
MobileNavigator: www.navigon.de
MobilePilot: www.tele-info.de
map&guide travelbook:
www.map&guide.de

Long before the success of the PDA small displays were used in car navigation systems. The first systems have been installed in luxury class cars. Today these fixed mounted systems are almost standard in middle class cars. Recently solutions based on PDA have entered the market. The map graphics is simplified and designed for the special purpose of navigating on road networks. Fig. 17 (left) illustrates a perspective route display of TomTom Navigator, a navigation system for PocketPCs. These navigation systems can also be used off-board.

Location based services

Location Based Services
Handy-Finder: www.o2-online.de
PinPoint:www.o2.co.uk/business/productsservices/locationservices/pinpoint/0,,142,00.html

(Kölmel and Wirsing, 2002)
Kölmel, B. and Wirsing, M. (2002): Nutzererwartungen an Location Based Servcies - Ergebnisse einer empirischen Analyse, *in* A. Zipf and J. Strobl (Eds.), *Geoinformation mobil*, Heidelberg: Wichmann Hüthig Verlag, 85-97

LBS with visualisation components are increasingly provided by telecommunication companies. These services cover simple city maps, routings, business finder, ATM finder etc. The example in Fig. 17 (right) shows a map related service for PDAs provided by the telecommunication company O_2. Different studies have proved that a visual communication of geographic information in the form of maps is high on the users' wish list of LBS **(Kölmel and Wirsing 2002)**.

Fig. 17: Examples of car navigation system map displays and LBS

Solutions to displaying geospatial information on small displays

(Rauschenbach, 2000)
Rauschenbach, U. (2000): *Bedarfsgesteuerte Bildübertragung mit Regions of Interest und Levels of Detail für mobile Umgebungen*, Dissertation, Fakultät für Ingenieurwissenschaften, Universität Rostock. http://wwwicg. informatik.uni-rostock.de/Projekte/MoVi/ Publications/ dissRauschenbach/diss.pdf

One solution to handle the limited map space is to drop the principle of uniform scale normally used in maps. In the MoVi project fisheye views of city maps were examined **(Rauschenbach 2000)**. The city map has a regular scale in the focus area (generally in the middle of the map) and is distorted in the other parts of the map, represented at smaller scales.

A similar approach is taken in the GiMoDig project. The use of variable-scales allows for a better exploitation of the limited resource 'map space'. **Harrie et al. (2002)** demonstrate a procedure for generating variable-scale maps with SVG. Fig. 18 (left) shows an example of a variable-scale map developed in the GiMoDig project.

(Harrie et al., 2002)
Harrie, L., Sarjakoski, L. T. and Lehto, L. (2002): A variable-scale map for small-display cartography, Proceedings ISPRS Symposium on geospatial theory, processing, and applications, Ottawa, Canada

Fig. 18: Variable-scale map for small displays (Harrie et al., 2002) and radial generalisation in variable-scale maps (Rappo, 2003)

(Rappo, 2003)
Rappo, A. (2003): Fischaugenprojektionen mit distanzabhängiger Informationsdichte für die kartographische Visualisierung auf kleinen Bildschirmen, Diplomarbeit, Geographisches Institut, Universität Zürich

The variable-scale approach can help to solve the problem of lacking map space, i.e. a larger geographic area can be displayed on the same display area. However, it does not necessarily make the map more legible. The map graphics is still cluttered towards the edge of the display. For that reason a new kind of generalisation, radial generalisation, is required. Radial generalisation will radially simplify the map from the centre, i.e. the focus of the map and the user's position, towards the edges. Such an approach has been taken in the work of **Rappo (2003)**. Fig. 18 (right) illustrates the decreasing level of detail towards the edges of the map display.

The schematisation of topology is a solution for maps showing primarily topological information, for instance traffic network maps **(e.g. Barkowsky et al. 2000; Avelar 2002)**. The result of such a graph schematisation is shown in the schematic map in Fig. 19 (left). Schematic maps are "obtained by relaxing spatial and other constraints from more detailed maps … [and] are seen as conceptual representations of the environment" **(Casakin et al. 2000)**. Sometimes these kinds of maps are also called ***topograms***. Fig. 19 (right) depicts an example of such a topogram **(Brunner 2001)**. The simple graphics is well suited for small displays, but this sort of

(Barkowsky et al., 2000)
Barkowsky, T., Latecki, L. J. and Richter, K.-F. (2000): Schematizing Maps: Simplification of Geographic Shape by Discrete Curve Evolution, *in* C. Freksa, W. Brauer, C. Hbel and K. F. Wender (Eds.), *Spatial Cognition II, LNAI 1849,* Berlin; Heidelberg: Springer-Verlag, 41-53

(Avelar, 2002)
Avelar, S. (2002): *Schematic Maps On Demand: Design, Modeling and Visualization*, Dissertation, Institut für Kartographie, Eidgenösische Technische Hochschule Zürich

(Casakin et al., 2000)
Casakin, H., Barkowsky, T., Klippel, A. and Freksa, C. (2000): Schematic Maps as Wayfinding Aids, *in* C. Freksa, W. Brauer, C. Hbel and K. F. Wender (Eds.), *Spatial Cognition II, LNAI 1849,* Berlin; Heidelberg: Springer-Verlag, 54-71

(Brunner, 2001)
Brunner, K. (2001): Kartengestaltung für elektronische Bildanzeigen, *in*, *Kartographische Bausteine*, Band 19, Dresden: Technische Universität Dresden, Institut für Kartographie

visualisation method cannot be used for all kinds of geographic information.

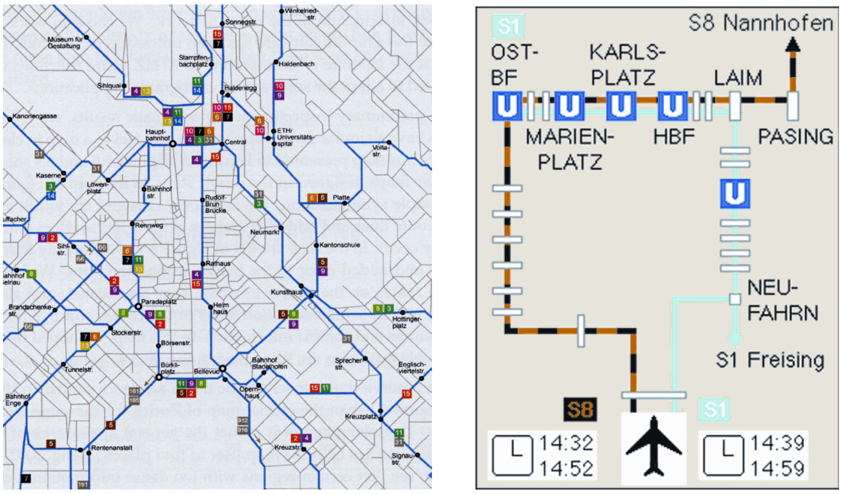


Fig. 19: Schematic map (Avelar, 2002) and topogram (Brunner, 2001)

The use of different LoDs and adaptive or smooth zooming techniques does not completely solve the problems arising from small displays, but offer helpful tools. Adaptive zooming is a technique for adapting content and LoD of a map automatically during zooming **(Brühlmeier 2000)**. **Cecconi (2003)** proposes a conceptual framework for on-demand mapping. It is based on the use of different LoDs in a ***multi resolution database*** (MRDB) in combination with real-time generalisation algorithms. **Hampe and Sester (2002)** developed strategies for real-time generalisation for mobile applications based on the MRDB approach. In continuing work related to the GiMoDig project they demonstrate how MRDBs can effectively be used to solve generalisation problems in mobile map services **(Hampe et al. 2003)**.

(Brühlmeier, 2000)
Brühlmeier, T. (2000): *Interaktive Karten - adaptives Zoomen mit Scalable Vector Graphics*, Diplomarbeit, Geographisches Institut, Universität Zürich

(Cecconi, 2003)
Cecconi, A. (2003): *Integration of Cartographic Generalization and Multi-Scale Databases for Enhanced Web Mapping*, Dissertation, Geographisches Institut, Universität Zürich

(Hampe and Sester, 2002)
Hampe, M. and Sester, M. (2002): Real-time integration and generalization of spatial data for mobile applications, *in*, *Geowissenschaftliche Mitteilungen, Heft Nr.60, Schriftenreihe der Studienrichtung Vermessungswesen und Geoinformation Technische Universität Wien*

(Hampe et al., 2003)
Hampe, M., Anders, K.-H. and Sester, M. (2003): MRDB Applications for Data Revision and Real-Time Generalisation, *Proc. 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

3.2 Evaluation of approaches and solutions

The projects and solutions described in the last section show some promising and partially feasible approaches for the display of geographic information on mobile devices. However, most of them tackle the problem on a too isolated and detailed level. Navigation systems focus primarily on navigation functionality, although in recent times more efforts have been put on better visualisations (see Fig. 17). Work on graph schematisation, MRDB, adaptive zooming, and radial generalisation are important corner stones for the visualisation aspects of mobile information visualisation, but need to be integrated into a coherent framework. What is missing in almost all approaches is a coherent methodological framework for adaptive presentation of geographic information in a mobile context including alternative (not only visual) solutions for visualisation on mobile devices and multimodal presentation. This section detects the weaknesses of the different approaches and points to the respective chapters where some of the problems and inadequacies are tried to overcome.

Most of the projects described above use maps to communicate geographic information on mobile devices. Yet, predominantly the used maps are in raster format. These raster maps are generally scanned paper maps which were designed for the paper medium. The map graphics is far too delicate for the size and resolution of the mobile device displays. It must be doubted, if an efficient usage of such maps on small displays is possible. Especially LBS were shouted as the killer application for 3G are still far away from offering usable map graphics. So far, their focus has been primarily on content and location information management. Nevertheless, the basic functions developed for LBS are crucial for mobile map-based services.

Another observation is that the development of solutions for mobile geographic information usage is technology and market driven and rarely methodologically founded. Most projects and commercial solutions implement what is technically feasible. It is not reflected whether it is sensible, useful or appropriate for the mobile environment. Chapter 4 introduces a new and more comprehensive framework for mobile cartography combining different theories and approaches described so far in isolation and enlightening as a core feature the adaptation concept.

Being technology driven, most services do not focus on graphical quality and clarity. Instead in most services an 'anything goes' approach rules the visualisation of geographic information. Even if vector data is used, the maps are cluttered and difficult to read considering the complicated reading conditions in mobile environments. At least some producers apply design principles for screen maps resulting in more legible maps. However, these maps still do not use the whole potential of adaptation to the usage situation. Thus, new or enhanced methods for appropriate visualisations of geographic information on mobile devices are needed. Section 4.2.6 covers visualisation aspects and section 5.4 puts forward new methods.

The commercial background of LBS solutions is also an impediment for a real individualisation of the information content and does not make use of the full potential and the information wealth in the Internet. The user will only get the information that a service provider has pre-selected and stored on a server. This situation is analogue to editorial of maps or tourist guides. Many approaches are targeted at a special user groups (service technicians, sales manager, etc.) with special needs and are not necessarily universally valid. These services often serve marketing and advertisement purposes not always desired and tolerated by users. Another problem is that these services are not interoperable due to proprietary formats and technology.

In addition to the technology focus, most approaches concentrate too much on location as a context dimension. Although location is an important context parameter, it is not the only context dimension. For effective mobile cartography, other context dimensions must be considered. The broader understanding of context and its value for mobile geovisualisation is examined in section 4.2.3.

With the exception of the positioning function (by use of GPS) in car navigation systems and city guide maps, the solutions do not offer egocentric maps. And even the spatial centring of the map around the user is only the simplest way. The concept of egocentric maps should be addressed in a much broader sense as accomplished by approaches like LBS. It should extend the egocentric map approach to ***egocentric*** design, where the user is put into the centre of the whole information design and presentation. These egocentric presentations reflect the users' demand for information and corresponding maps adapted to their needs. In addition to the label 'egocentric', these maps will be more personal and private. Egocentric maps have to put the user in centre, spatially, temporally, and thematically.

In relation to the egocentric map approach adaptation is of major importance. The possibilities and components of adaptation within the process of visualising geographic information on mobile devices are investigated in chapter 5.

Although the existing solutions for visualisation of geographic information on mobile devices are far away from being satisfactory, the discipline of cartography has not yet taken the challenge to serve the needs of a more and more mobile information society. New information technologies and concepts, such as mobile computing, LBS, and adaptive systems, have not yet found their way into cartographic theory. Though there are concepts proposed for multimedia cartography and interactive cartographic visualisation systems, new aspects have been neglected so far. These aspects are user mobility (movement; speed), usage contexts, activities, and events. Concerning the problem of the small displays most approaches developed in cartography, i.e. solutions known from desktop and web mapping, seem to fail in a mobile context under the severe restrictions mentioned above. Unfortunately there exist only rudimentary solutions for accessing and displaying geographic information on mobile devices and a theory for screen design targeted at mobile devices is missing up to now. It is the author's conviction that for progressing in mobile geographic information visualisation a broader understanding and a comprehensive framework of mobile cartography embracing all involved theories and concepts is crucial. The next chapter introduces this framework and explains the links between its building blocks. This serves as the base for the transfer of the adaptation concept to cartography for mobile users.

Chapter 4

A new and comprehensive conceptual framework of mobile cartography

It is the framework which changes with each new technology and not just the picture within the frame.
– Marshall McLuhan

4.1 Rationale for a mobile cartography

Cartography as many other disciplines has seen dramatic changes over the last dozen years. The advances in technology had and still have an enormous impact on the discipline. With the 'digital revolution' the branch of digital cartography has appeared. The Internet has offered new possibilities of map distribution. More recently, as the preceding chapters witnessed, new technologies like telecommunication and mobile computing are ready to be used. However, these technologies are only the prerequisites for mobility oriented cartography. The salient element of a ***mobile cartography*** is its potential for adapting the way information is visualised. In the next section, the details of mobile maps and a comprehensive framework of mobile cartography will be elaborated.

Using these new technologies, maps can be transferred to and displayed on mobile devices. To start with, the author elaborates the characteristics of cartographic visualisations on mobile devices and tries to deduce the most relevant and specific attributes of ***mobile maps***. A mobile map is here defined as a map or a map-like visualisation designed for the display on a mobile device. Many attributes of mobile maps can be found in other maps as well. An analysis of the characteristics of maps can be found in **(Goodchild 2000, p. 4f.)**: maps are visual, flat, exhaustive, uniform in level of detail, static, generic, precise, and slow. Another list of

(Goodchild, 2000)
Goodchild, M. F. (2000): Cartographic Futures On A Digital Earth (Keynote Address,19th International Cartographic Conference 1999, Ottawa), *cartographic perspectives* 36(Spring)

(Heidmann, 1999)
Heidmann, F. (1999): *Aufgaben- und nutzerorientierte Unterstützung kartographischer Kommunikationsprozesse durch Arbeitsgraphik: Konzeptionen, Modellbildung und experimentelle Untersuchungen*, Herdecke: GCA-Verlag

characteristics of cartographic screen media is given by **Heidmann (1999, p. 35)**: dynamism, interactivity, individuality, multifunctionality, multimodality, multicoding, adaptivity, linkage, and ubiquity.

Table 5 shows the comparison of different map groups regarding the set of characteristics of mobile maps. It is evident that mobile maps primarily profit from a combination of known maps attributes. ***Printed maps*** – whether produced manually or digitally– are hardly changeable in their form. Yet, they are highly mobile. ***Internet maps*** or ***web maps*** allow a certain personalisation and adaptation, their distribution is easy and fast, they are up to date, and can incorporate multimedia and interactivity. However, Internet cartography is a priori not mobile. This also means that the potential for adaptation of web maps is rather limited.

Mobility of maps is not a new feature. For centuries maps have been mobile in the sense of being transportable or movable. The new opportunities digital technology and especially the Internet brought to cartography implied also the loss of mobility.

	(digital) mobile maps	analogically or digitally produced printed maps	digital maps - offline (CD-ROM)	digital maps - online (Web)
medium				
mobile	✓	✓	-	-
positionable	✓	-	-	(✓)
dateable	✓	-	-	✓
content				
dynamic	✓	-	✓	✓
multimedia	✓	-	✓	✓
adaptable	✓	-	✓	✓
adaptive	✓	-	✓	✓
interactive	✓	-	✓	✓
location-dependently designable	✓	-	(✓)	(✓)
time-dependently designable	✓	-	(✓)	✓
usage				
mobile	✓	✓	-	-
synchronised	✓	-	-	✓
location independent	✓	✓	-	-
time independent	✓	✓	✓	(✓)
usage situation quickly	✓	✓	-	-
resources limited	✓	-	-	-

Table 5: Characteristics of different map groups

A major advantage of mobile computing is therefore the combination of all assets of digital technology with mobility. The real new momentum and at the same time the biggest challenge for cartography, however, is the ability to directly respond to the user's mobility and provide new services for mobile users. The mobile computing paradigm and also the mobility of geographic information usage are characterised by the slogan "*anything, anytime, anywhere*". This slogan shows a paradox: on the one hand thanks to ***mobile computing*** any information (anything) can indeed be accessed (almost) ***independently*** of location and time (anywhere und anytime), on the other hand it is not about ***any*** information, but it is about the selection and presentation of information ***dependent*** on location and time (and other factors). "The challenge in an information-rich world (in which human attention is the most valuable and scarcest commodity) is not only to make information available to people at any time, at any place and in any form, but to reduce information overload by making information relevant to the task-at-hand and to the assumed background knowledge of the users" **(Fischer 2001, p.65)**. 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 relevant to his/her current context and interests, knowledge and skill level, presented in a way he/she is used to. In contrast to traditional cartography this means the location of the user can be determined by methods described in section 2.2.1. This offers the chance to tailor geovisualisation to this location and other parameters (e.g. time) defining the user's context as to be discussed in section 2.1.3. The use of such a system must not be complicated. It would be usable at hand, and being self-explanatory. The complex functionality is hidden from the user and as many tasks as possible are automatically performed, though interaction is always possible when needed. Mobile users having to perform spatial tasks or having spatial questions of all sorts will be given assistance through mobile cartography. This understanding easily fits the concept proposed by **Aronoff (1991)** where three categories are distinguished: the questions category, the function category, and the answers category. It also fits the web service concept discussed in section 2.2.2. Hence, the challenging momentum of this vision for cartography consists in an adequate adaptation of geovisualisation to mobile usage situations with the overall goal to guarantee usability.

(Fischer, 2001)
Fischer, G. (2001): User Modeling in Human-Computer Interaction, *User Modeling and User-Adapted Interaction (UMUAI)* 11(2): 65-86

(Aronoff, 1991)
Aronoff, S. (1991): *Geographic Information Systems: A management perspective*, Ottawa: WDL Publications

In spite of the great potential and chances of the vision described above, these new possibilities have not yet been fully addressed in cartography. Although different concepts of information technology, GIS and web mapping introduced some substantial innovative issues to cartography, none of them fully covers the scope of cartography in a mobile context. These fields have all their own accentuation (market, technical issues). A comprehension of the concept of ***mobile cartography*** and its scope is still missing. It is therefore time to bring these divergent views into one coherent and convergent concept of mobile cartography, which can be defined as theories, methods, and technologies of dynamic and adaptive cartographic visualisation of geographic information and its interactive use on mobile devices where visualisation is adapted to either one or all components of the actual usage context (location, time, user, activities, information, and system).

As in all new and developing fields, the terminology is not so clear and fixed yet. Beside mobile cartography a couple of other terms are in use. Some of them stress other characteristics of maps on mobile devices, some come from other disciplines. ***Tele-Cartography*** means the exchange and transmission of spatial information through cartographic products that are transmitted by telecommunication technologies and are accessible by mobile query and display devices **(Gartner 2000)**. The original sense of ***telos*** referring to *remote*, *dislocated* is valid as well for Internet cartography. TeleCartography focuses primarily on technical aspects, mainly transmission technology, i.e. *tele*communication techniques. The use of mobile devices implicitly indicates a mobile usage situation. However, there is no reference to adaptation in the definition. The same critique is true for terms like *wireless mapping*, where transmission technology is emphasized. Another well established concept are ***Location Based Services***. Mobile maps can and definitely will be used for LBS, but one can easily think of LBS without any cartographic visualisation.

(Gartner, 2000)
Gartner, G. (2000): TeleKartographie, *GeoBIT*(4): 21-24

On the one hand this work uses the term ***mobile***, since it reflects the user's mobility in three different dimensions: the *mobile media*, the *mobile usage*, and the *mobile content*. Attributes like wireless are too narrow and put the emphasis rather on technology. On the other hand the thesis uses the term ***cartography*** to resolutely distinguish the concept from *mobile mapping* or *mobile GIS* where the focus is on real-time graphic rendering, analysis or data capturing on site without appropriately considering graphical design. However, it must be stressed that in the background several more or less complex GIS analytical functions (e.g. routing) must be available to serve the visualisation front-end. In addition, it is not necessary to call the concept *mobile digital cartography,* since it would not work in an analogue mode and also, because there has never been a *mobile 'analogue' cartography* – neither as a term nor as a method to be distinguished from. This also seems to be another indicator that such an independent research field has never existed in cartography so far. Thinking of the rather static nature of traditional cartographic products for mobile users this is not surprising.

The core element of the mobile cartography concept is adaptation. An adaptive geovisualisation service is capable of adapting to a specific user, his/her activities, the system in use, and the current information demand. The first who mentioned this basic understanding was **(Bollmann 1996, p. 35)**. He stated that a map is representing communication sequences in the context of activities attributing to the map the role of a dynamic system. A map in such a sense is an immediately available medium adapting itself to the user's goals and activities.

(Bollmann, 1996)
Bollmann, J. (1996): Kartographische Modellierung - Integrierte Herstellung und Nutzung von Karten-systemen, *Kartographie im Umbruch. Tagungsband zum Kartographenkongress Interlaken 1996*, Interlaken

For an extended discussion of issues covered in this chapter and those to be covered in the next chapters see **(Reichenbacher et al. 2002; Reichenbacher and Meng 2003)**.

(Reichenbacher et al., 2002)
Reichenbacher, T., Angsüsser, S. and Meng, L. (2002): Mobile Kartographie - eine offene Diskussion, *Kartographische Nachrichten*(5)

(Reichenbacher and Meng, 2003)
Reichenbacher, T. and Meng, L. (2003): Themenheft 'Mobile Kartographie', *Kartographische Nachrichten* (1&2)

4.2 A framework of mobile cartography

To capture the basic ideas of the vision sketched above, the author introduced a first conceptual framework of mobile cartography in **(Reichenbacher 2001)**. This framework showed the major building blocks of mobile cartography in focus. This chapter has elaborated so far the core of mobile cartography: adaptation of geographic information visualisation to the mobile usage situation. The framework of mobile cartography proposed here accounts for that fact. Fig. 20 shows the refined conceptual framework. The key components are context, information, user interface, and visualisation. The original framework also included technology. As discussed earlier, technology is regarded as the basic enabling system working in the background. It can be attributed to the context. The components shown in Fig. 20 can be arranged according to the widely used design pattern of **M**odel – **V**iew – **C**ontrol. The basic idea is to separate the data from presentation and the logic that controls how the data is displayed. These three axes are aligned horizontally in Fig. 20. A second grouping can be achieved by using the primary adaptation dimensions: adaptation objects (the elements to be adapted), adaptation target (the elements which the adaptation objects are adapted to), and the adaptors (the

(Reichenbacher, 2001)
Reichenbacher, T. (2001): The World In Your Pocket - Towards A Mobile Cartography, *Proceedings The 20th International Cartographic Conference*, Beijing, China, August, 6 - 10, 2001

methods that actually perform the adaptation). These dimensions are aligned vertically in Fig. 20. The figure also shows that the user performing any activities is set in a context. The same applies for the information demand and the geographic information usage in the form of perceiving visual representations of the information.

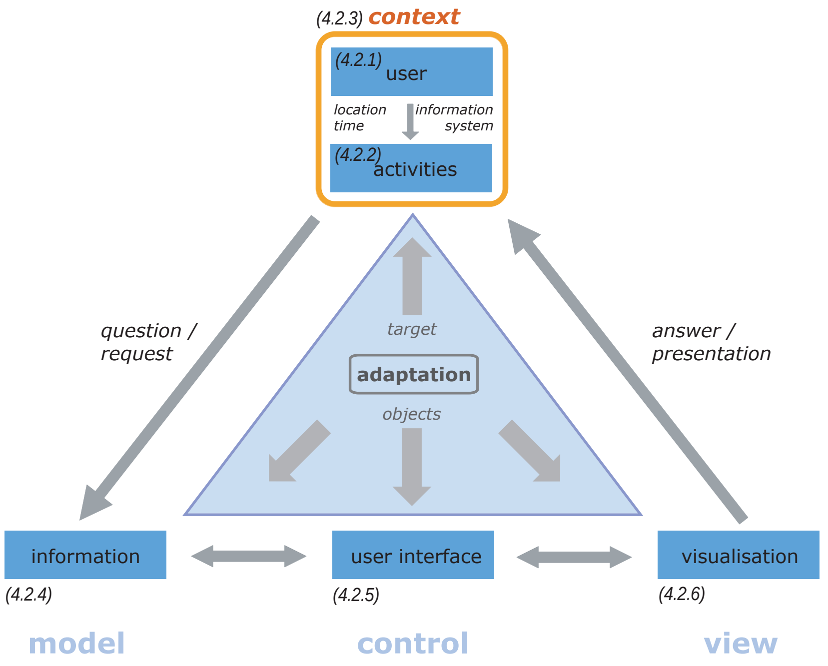


Fig. 20: Conceptual framework of mobile cartography

The main goal of the mobile cartography approach is to offer visualisations of geographic information with the greatest possible ***relevance*** to the mobile user. Relevant is defined in the Collins English Dictionary as "having direct bearing on the matter in hand". This definition already embodies the importance of the user. It is the user (the 'hand') that is the object of relevancy. The information and its visualisation have to be relevant to the user. In that sense it has also to be relevant to the context the user belongs to and its dimensions (location, time, activity, information, system, etc.). In the remainder of this chapter the major components of mobile cartography and their relationships as outlined in the framework are explained in more detail. Firstly, the role of the user in mobile cartography with a special focus on the influence of mobility is clarified, followed by an attempt to capture the basic activities of mobile users. Secondly, the importance of context for mobile cartography is enlightened and the different dimensions of usage context and their possible modelling are described. The section on information looks on issues of information structure, quality, demands and relevance. An analysis of implications of visualisation is preceded by a section investigating the role of the user interface in mobile cartography. The role of adaptation in the mobile cartography framework is to maximise the relevancy by modifying the visualisation in respect and is extensively examined in chapter 5. At the end of this chapter the relationships of the framework components are summarised.

4.2.1 Mobile users

The user plays the central role in mobile cartography. The whole effort of mobile cartography – and cartography in general – is directed towards the user. The following analysis covers three different user related topics: information demand, mobility, and individualisation.

It is not questioned that a mobile user will sooner or later have a spatial ***information demand***. This information can be expressed in different types of questions as depicted in Fig. 21 **(**map from **Neudeck 2001)**. The information demand of mobile users is studied in more detail in the section on information. For the scope of this research the information demand arises in a mobile environment, i.e. the information required is related to the user's mobility.

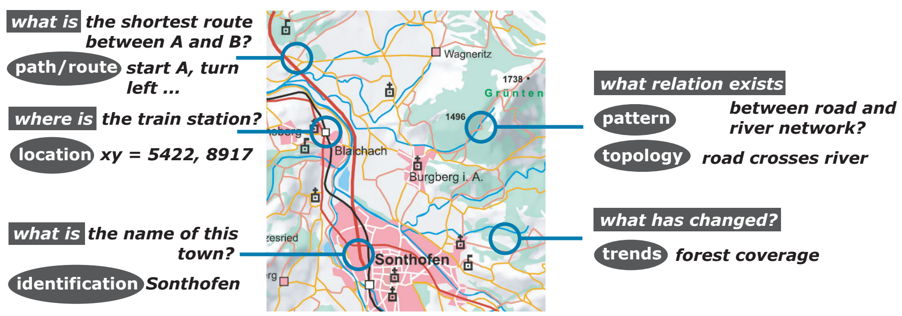


Fig. 21: Typical spatial questions (adapted from Kraak and Ormeling 1996)

(Kraak and Ormeling, 1996)
Kraak, M. J. and Ormeling, F. J. (1996): *Cartography: visualization of spatial data*, Harlow: Longman

When speaking of users and mobile cartography it is worth discussing some issues of ***user mobility***. The meanings of mobility range from just being in motion, changing locations or travelling to social mobility like changing roles or social classes. This is also reflected by different meanings of *mobile* (Merriam-Webster's Collegiate Dictionary): capable of moving or being moved: movable; changeable in appearance, mood or purpose: adaptable, versatile; moving habitually or occasionally from one region or climate to another: migratory; characterized by the mixing of social groups. As touched on in section 4.1 it has to be discerned what/who is mobile? Is it solely the user, the device (medium) or both? In mobile telecommunications the corresponding ***mobility types*** are called ***personal*** and ***terminal*** mobility. In the same manner ***discrete*** mobility is distinguished from ***continuous*** mobility. In the former case a service is only available at certain places (e.g. access points like office or home). In the latter case the service is continuously available during movement. Portability is a special form of discrete mobility where the user can take his/her device from one access point to another **(Van Thanh 2002)**.

(van Tanh, 2002)
Van Thanh, D. (2002): Introduction to Mobility.
http://www.item.ntnu.no/~thanhvan/doc/MobilityForelesning.PDF

To study the influences of user mobility on mobile cartography it is necessary to take a more systematic approach to movement as proposed for example by **Coffey (1981, p. 153ff.)**: ***Structure*** and ***movement*** are of ***dualistic*** nature. Movement effects structure and structure constrains movement. Mobility is also a matter of ***scale***. At a large scale pure body movement can be considered as mobility, whereas at a very small scale, i.e. from a large distance, the same could be observed as static. A further typification of movement is related to ***medium*** and ***mode***. The medium represents the base for the movement, i.e. asphalt, water or steel. Every medium possesses a certain friction influencing the movement. The mode affects this influence of the medium on the movement. The ***structure*** of movement can be analysed in terms of ***geometry***, i.e. the distance and orientation of the movement, the shape generated by the movement, the arising patterns, absolute and relative locations of start, middle, and end points of movements. Moreover, ***topology*** plays an important role. Additionally, several movements can build a ***movement hierarchy*** that again is the dualism of a structure hierarchy. Finally, the ***intrinsic characteristics*** of movement per se can be isolated: ***directionality***, ***continuity***, and ***permanence***. Movement can be uni-directional (e.g. A->B or B->A), one-way (e.g. only A->B, but not B->A) or bi-directional (A->B and B->A). The characteristic continuity has been described in the paragraph above. A discreet movement involves stops. Permanence reflects the temporal aspect of movement. It can only be a temporary or a permanent matter (which is rather the case for natural movements than for moving human beings). ***Models*** of movement can be deterministic or stochastic. For research on modelling movement patterns and deferring user activities see **(Mountain and Raper 2002)**.

(Coffey, 1981)
Coffey, W. J. (1981): *Geography - Towards a General Spatial Systems Approach*, London: Methuen & Co

(Mountain and Raper, 2002)
Mountain, D. and Raper, J. (2002): Modelling human spatio-temporal behaviour: A challenge for location-based services, *Proceedings AGI 2002*, London

The spatial scope of mobility is another factor that influences for example the choice of mobility medium and mode. Local mobility could pragmatically be defined as mobility within walking distance.

One consequence of mobility, or more precisely the possibility of mobile geographic information usage during mobility, is an increasing demand for ***individualisation***. What has been introduced by the concept of ***on-demand mapping*** goes a step further. 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. Here, any adaptation or generation of a map requested or triggered by a single user is understood as an individualisation.

Further reading:

(Beck and Beck-Gernsheim 2002)
Beck, U. and Beck-Gernsheim, E. (2002): *Individualization: Institutionalized Individualism and its Social and Political Consequences*, London: SAGE Publications

(Searby 2003)
Searby, S. (2003): Personalisation - an overview of its use and potential, *BT Technology Journal* 21(1): 13-19

Each human being is unique, an individual. We all differ from each other, though maybe not that much. These individual differences may play an important role in using geographic information, but also in many other aspects of life. These differences can be more general characteristics related to the personality or more specific characteristics that may vary from one system usage or usage situation to another.

The fact that knowledge about the personality and cognitive abilities are of help for designing systems for a special user group has been acknowledged by **Shneiderman (1987)**. **Benyon (1993, p. 6)** points out that the interaction with a system can be seen as a cognitive task and hence individual differences in cognition preferences or abilities are to be expected. Such cognitive preferences and abilities are relatively stable human characteristics which change very slowly over time. However, it seems to be difficult to isolate relevant user attributes which might have an influence on the visualisation and the adaptation of it.

(Shneiderman, 1987)
Shneiderman, B. (1987): *Designing the User Interface*, Reading: Addison-Wesley

(Benyon, 1993)
Benyon, D. (1993): Accommodating Individual Differences through an Adaptive User Interface, *in* M. Schneider-Hufschmidt, T. Kühme and U. Malinowski (Eds.), *Adaptive User Interfaces: Principles and Practice*, Amsterdam: North-Holland, 149- 166

A more promising approach is to isolate a few typical user types, ***stereotypes*** "… to design methods so they can be adjusted to the cognitive characteristics of the individual user" **(Slocum et al. 2001, p. 70)**. One approach to find such stereotypes is the personality theory, a branch of differential psychology. A typology of personalities has first been introduced by the psychologist C.G. Jung in 1921 who distinguished four dichotomies **(Jung 2001)**: extroversion – introversion; thinking – feeling; sensing – intuition; judgement – perception. Based on Jung's typology Isabel Briggs and her mother Kathryn Myers developed the Myers-Briggs Type Indicator (MBTI) that distinguishes 16 types as a combination of the four dichotomies. This type can relatively easily be determined and can act as a rough stereotype, since user characteristics that build a personality are fairly constant and also have an impact on the usage of a system.

(Slocum et al., 2001)
Slocum, T. A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D. R., Fuhrmann, S. and Hedley, S. (2001): Cognitive and usability issues in geovisualization: a research agenda., *Cartography and Geographic Information Science* 28(1): 61-76

(Jung, 2001)
Jung, C. G. (2001): *Typologie*, München: Deutscher Taschenbuch Verlag GmbH & Co. KG

An even more universal stereotype is a ***mobile user stereotype*** that can be formed, because despite all individual differences there are also a few things all mobile users have in common. Mobile users are under time pressure, need to make quick decisions, are more easily distracted, have to process an enormous amount of stimuli, are less predictable, are limited in their interaction with a device, etc.

This stereotype can be taken as a rough model for adapting geovisualisation. It certainly needs to be extended through more fine-grained user models; however, this is beyond the scope of this thesis.

4.2.2 Mobile activities

(Heidmann and Hermann, 2003)
Heidmann, F. and Hermann, F. (2003): Visualisierung raumbezogener Informationen für ultraportable mobile Systeme, *in*, *Visualisierung und Erschließung von Geodaten - Seminar GEOVIS 2003, 26. bis 27. Februar 2003, Universität Hannover,* Kartographische Schriften, Band 7, Bonn: Kirschbaum Verlag, 121-131

(Edwardes et al., 2003b)
Edwardes, A., Burghardt, D. and Weibel, R. (2003b): WebPark - Location Based Services for Species Search in Recreation Area, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

An activity here is defined as a motivated sequence of coherent actions carried out at a specific location for a certain time. For example, dining is an activity carried out at a restaurant. As mentioned above, there are many different activities mobile users conduct and for which appropriate information visualisation techniques have to be developed. Apart from their motivation and inherent structure these activities also have a ***spatial scope***. In two research projects, Fraunhofer SAiMotion **(Heidmann and Hermann 2003)** and WebPark **(Edwardes et al. 2003b)**, the ***range or scope of activities*** and information demand has been analysed. The ranges of activities are related to ***ranges of context***. In Fig. 22 the following three major ranges are distinguished:

- ***immediate surroundings***: information supporting identification of objects
- ***region of activity***: context information relevant for dynamism of user activities
- ***background space***: global, descriptive overview information supporting the planning of activities

Information on global context, i.e. on a macro scale requires small scale maps to provide the necessary overview, whereas for local context, i.e. on a micro scale large scale maps showing objects for direct references to the real environment are more appropriate. The regional context, i.e. on a meso scale, is between the two and sets the main context for activity planning. In addition the scope of each region also depends on the mobility medium. It makes a big difference whether one travels by bike, car or plane. The range of these media differs substantially, thus the size of the different regions.

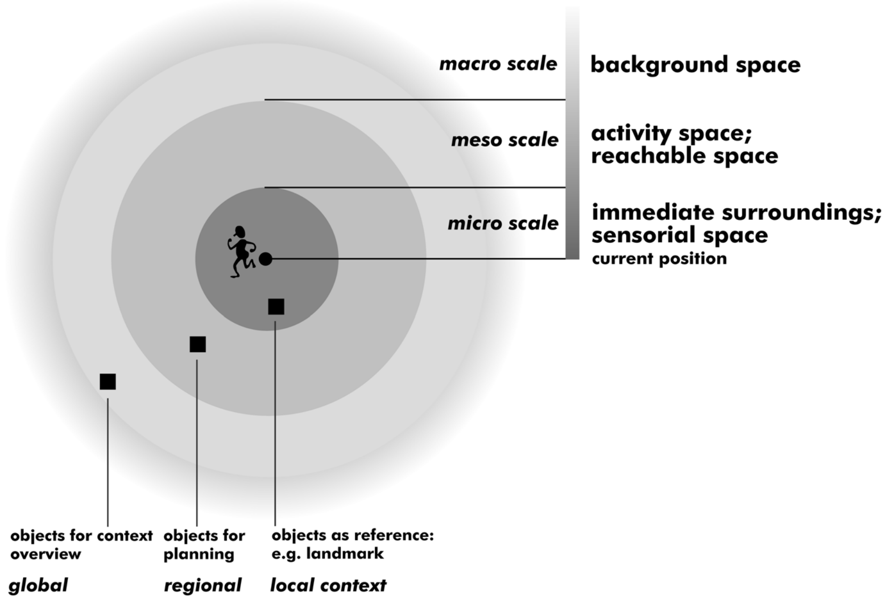


Fig. 22: Spatial scope of activities (adapted from Heidmann and Hermann 2003, p. 126)

Comparing services from different LBS providers brings a certain insight into possible demands of mobile users and the activities they might need support for. Such services, as for instance provided by the company *gate5*, are people finder, vicinity search, content search, category search, routing search, event guide, personal info manager, group activity manager, activity recommender, city guide, tour guide, news magazine.

Location services
www.gate5.de.
http://www.vodafone.de/kundenbetreuung_services/unterwegs/31326.html

This enumeration shows an increasing importance of managing lifestyle activities in space and time. Activity programmes, i.e. lists of activities to be performed in a specific time period, e.g. eating, working, or going in 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)**.

(Wang and Cheng, 2001)
Wang, D. and Cheng, T. (2001): A spatio-temporal data model for activity-based transport demand modelling, *International Journal Geographical Information Science* 15(6): 561-585

Besides regarding these services, an analysis of literature on map usage functions and GIS functionality draws a clearer picture of relevant mobile user activities. Table 6 summarises relevant spatial questions, map usage tasks, GIS operations and examples of mobile services.

[a] *(SUN 2001a)*
SUN (2001a): *Java Location Services: The new Standard for Location-Enabled E-Business*, White Paper. http://www.jlocationservices.com/company/Sun/JavaLocServBR_R4.pdf

[b] *(MAGIC 2000)*
MAGIC (2000): *Introduction to MAGIC Services*, Technical Information White-paper, MAGIC Services Forum. http://www.magicservicesforum.org/tech/ tech_info_whitepaper.doc

[c] *(van Elzakker 2001)*
van Elzakker, C. (2001): Map Use Tasks in Regional Exploratory Studies, *Proceedings 20th International Cartographic Conference*, Beijing, China, August 6-10, 2001

[d] *(Albrecht 1996)*
Albrecht, J. (1996): Universal GIS operations for environmental modeling, *Proceedings 3rd International Conference on Integrating GIS and Environmental Modeling*, Santa Barbara (CA)

[e] *(Niedzwiadek 2000)*
Niedzwiadek, H. (2000): Eye on the Future of Java Location Services, *Proceedings Mapworld 2000*, San Antonio, TX, April 30 - May 3, 2000

[f] *(Oracle 2001)*
Oracle (2001): *Leveraging Location-Based Services for Mobile Applications*, Technical White Paper, Oracle. http://www.jlocationservices.com/company/Oracle/LS_Tech_wp.pdf

Questions / Problems	Tasks / Actions	(GIS) Operations	Services (Solutions/Answers)
locating			
where am I ? [a] where is Mum? [a] where is my car? [a] where is Karstadt? [a] am I near X ? am I left or right of X?	to **locate** [c]	position [a] geocoding [e]	locate person [b] locate objects [b]
navigating			
how do I get there / to … ? what is the fastest way to ..?		route [a] slope [d], aspect [d] viewshed [d] centrality/ connectedness [f]	trip templates [b] suggestions to travellers based on destination and geography [b] weather sensitive planning / guidance [b] travel across areas without roads [b] route commentary [b] navigation with real-time map display [b] navigation with real-time 3D display [b]
searching			
where is the *nearest* … ? what is near of …? [c] what is the distance to …? [c] what is the spatial distribution of …? [c] what is the nearest visible landmark?	to **position** [c] to **define** [c] to **find** order, patterns [c] to **contemplate** spatial context [c]	proximity [d] distance [f] area [f] relationship [f] *distribution* [a] suitability [f] buffer [d] corridor [d] overlay [d] thiessen/voronoi [d] presentation [f]	service discovery [b] location-sensitive pushed information (warnings, information) [b] location-sensitive message delivery [b] location-sensitive appointments [b] group travel support [b] guidance to parking [b]
Identifying			
who is there? what is there? [c] what is that? [b] how much is there? [c]	to recognize [c] to identify [c] To quantify/ estimate [c]	directory [a] *selection* [f] thematic search [d] spatial search [d] measurements [d]	
Checking			
can someone help me to …? what is the state of …? what happens at … ? will I be in time?	search for help to **determine** changes [c] to **establish** trends [c] to **detect** processes [c]	 inventory [f] description [f] pattern [d] trend [f] *frequency* [f] trend [f]	accident/incident support [b] traffic information delivery [b] tracking of progress to an appointment [b]

Table 6: Relationship between spatial user actions and GIS operations

However, there is no consistent taxonomy of mobile spatial actions, but from the analysis of the services mentioned above and the literature review, the following elementary actions to which any more concrete activity could be attributed can be distinguished. The elementary actions listed in Table 7 are ***locating***, ***navigating***, ***searching***, ***identifying***, and ***checking***.

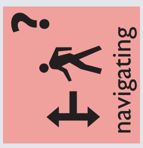
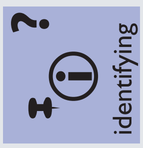
action		questions	objective	operations	service	parameter	support
 locating	**orientation & localisation** locating	where am I? where is {person| object}?	localise people and objects	positioning geocoding geodecoding	deliver position of persons and objects	coordinate object address place name	orientation in space
 navigating	**navigation** navigatingthrough 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

Table 7: Elementary mobile user actions with spatial relation

These basic actions can be assembled in a modular manner to activities (Fig. 23). In general an activity is guided by a motivation. To satisfy the motivation most likely some spatial problems or spatial questions will have to be solved or answered. To do this, the elementary actions with their associated goals are performed in a certain combination. According to activity theory, this process involves several operations. It is important to separate the goals and plans involved in a spatial user action (e.g. navigation: get from here to point A) from the operations needed to achieve them (direction following, translation of position on the display to the real world environment, etc.). Services in general are to help the user to achieve his/her action goals and assist him in the execution of the necessary actions to be taken. A service assisting a mobile user should answer or solve the questions/problems at hand and be capable of adapting itself to these different actions and associated goals. Instead of relying on a user model only, the activities with their associated goals, user roles, and information needs are more likely to be the common ground for adapting to.

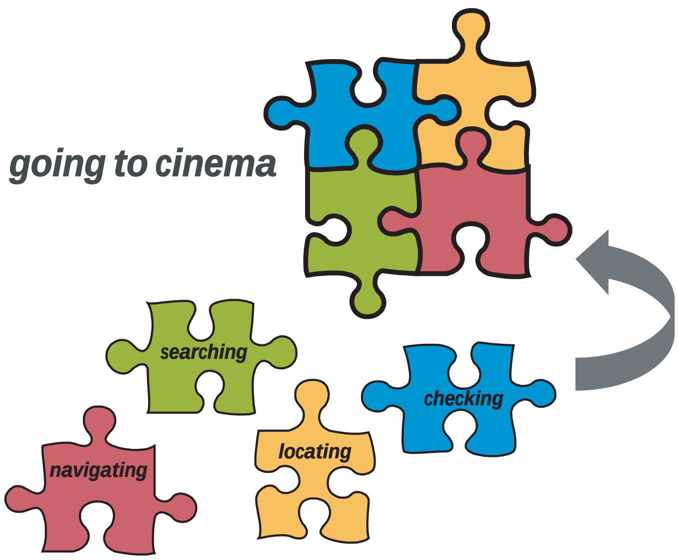


Fig. 23: Modular construction of activities based on single actions

The isolation of elementary, mobile, spatially related actions aims at being able to map these actions with related goals (and spatial questions) to supporting geovisualisation services. This makes it possible to adapt these services later to the specific action. Again, these elementary services can be combined or bundled to higher level services. Since the objective is to simplify the problem space of possible adaptations, the proposed categorisation of actions contains certain overlaps between actions. In addition not all actions are on the same aggregation level. Locating, for example, is far more elementary and specific than searching.

An alternative approach to isolating elementary spatial user actions is the application of patterns. In software design and HCI design patterns are increasingly used to provide developers solutions to recurring standard problems. Transferred to mobile geographic information usage situations, several recurring, typical, spatially related problems could be described in patterns.

The activities a user wants to accomplish when being mobile are highly dependent on context and vice versa. User activities shape the context and specific contexts do not allow certain kinds of activities. Knowing some aspects of the current context helps to reduce the number of possible activities. The next section covers the features of context important for mobile cartography.

The development of a geoservice adapting to the current user activity requires knowledge about this activity. An automatic identification of the user's activity is very difficult. First attempts in detecting mobile user activities have been made by **Mountain and Raper (2002)**. They try to model mobile user activities from observing spatio-temporal behaviour. By finding similar patterns conclusions for activities can be drawn. This already gives a hint that a learning component will be necessary for any progress in that direction.

(Mountain and Raper, 2002)
Mountain, D. and Raper, J. (2002): Modelling human spatio-temporal behaviour: A challenge for location-based services, *Proceedings AGI 2002*, London

In the section on activity theory the fact that individuals perform their actions in a specific ***role*** has been emphasized. The role a user is acting in sets the context and a given context can enable or disable certain roles. To better fit a service to the user's needs, knowledge about the user's role is crucial. Thus a typology of elementary user roles in mobile environments is required. **Kristoffersen and Ljungberg (1999)** distinguish three 'modalities' of mobility which can also be understood as user roles: travelling, visiting, and wandering.

(Kristoffersen and Ljungberg, 1999)
Kristoffersen, S. and Ljungberg, F. (1999): Mobile use of IT, *Proceedings 22nd Information Systems Research Seminar in Scandinavia Conference (IRIS 22)*

As stated earlier, the performance of mobile activities is dependent on information. It will also rely on fast and efficient communication of this information realised as visualisations. Mobile maps should support the user in performing these activities. The section on visualisation will sketch a minimal set of functions and visualisation capabilities a mobile map must provide to achieve this objective.

4.2.3 Mobile context

It is no surprise that the most prominent adapted services for mobile users are LBS, since location is the most important context dimension concerned with mobility. However, there are many more facets of context which can partly be derived from location. Examples of such context parameters are time, weather or medium of transport. There are also technological context aspects, such as network quality, device characteristics and many more. Furthermore several context dimensions can be separated: physical context, system context, semantic context, social context etc.

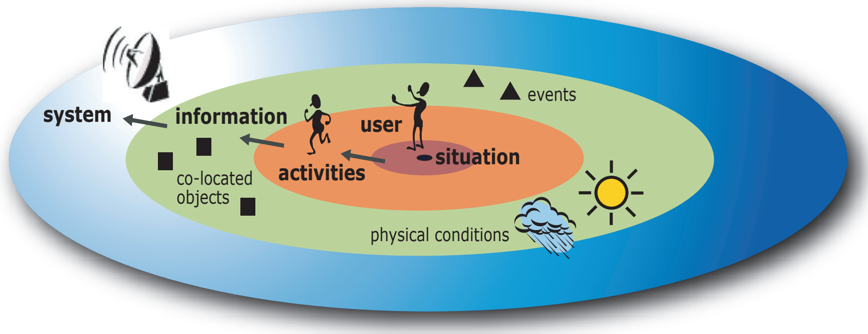


Fig. 24: Dimensions of the geographic information usage context

As pointed out in section 2.1, context is an ample field. For the purpose of mobile cartography ***context*** is understood as the more general concept embracing the more specific dimensions like ***situation***, ***user***, ***activities***, ***information***, and ***system*** (see Fig. 24, Fig. 25, and Table 8). These context dimensions are not independent, but have many and sometimes quite complex interrelationships as illustrated in Fig. 25. 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. **Nivala and Sarjakoski (2003)** list apart from the dimensions mentioned so far purpose of use, social context, cultural context, physical context, orientation context, and navigation history context. Table 8 gives a summary of the main dimensions of context in literature to mobile geographic information usage.

(Nivala and Sarjakoski, 2003)
Nivala, A.-M. and Sarjakoski, L. T. (2003): Need for Context-Aware Topographic Maps in Mobile Devices, *Proceedings 9th Scandinavian Research Conference on Geographic Information Science ScanGIS'2003*, Espoo, Finland

	(Graham and Kjeldskov 2003)	(Dix et al. 2000)	(Nivala and Sarjakoski 2003)	(Reichenbacher 2003)
Where	Position (absolute)	Physical Context	Location	Position
Where	Location (relative)	Physical Context	Orientation	Location
When	Time		Time	Time
What else	Objects present	System Context / Infrastructure Context	System	Information Technology
What task	Activity	Domain Context		Activity
Who	User	Domain Context	Purpose of use User Social	User
What conditions	Physical Environment	Physical Context	Physical surroundings	Information
What culture		Domain Context	Cultural	

Table 8: Dimensions of context in mobile cartography

(Graham and Kjeldskov, 2003)
Graham, C. and Kjeldskov, J. (2003): Indexical Representations for Context-Aware Mobile Devices, *Proceedings IADIS Internat. Conference on e-Society*, Lisbon, Portugal, June 3-6, 2003

(Dix et al., 2000)
Dix, A., Rodden, T., Davies, N., Trevor, J., Friday, A. and Palfreyman, K. (2000): Exploiting Space and Location as a Design Framework for Interactive Mobile Systems, *ACM Transactions on Computer-Human Interaction* 7(3): 285-321

(Nivala and Sarjakoski, 2003)
Nivala, A.-M. and Sarjakoski, L. T. (2003): Need for Context-Aware Topographic Maps in Mobile Devices, *Proceedings 9th Scandinavian Research Conference on Geographic Information Science ScanGIS'2003*, Espoo, Finland

(Reichenbacher, 2003)
Reichenbacher, T. (2003): Adaptive Methods for Mobile Cartography, *Proc. 21st Internat. Cartographic Conference*, Durban, S. Africa, August 10-16, 2003

Situation as the core of context is a function of ***location*** and ***time*** and is understood here in the original sense (Lat. ***situs***) of being situated, i.e. placed in a spatio-temporal reference system which points to the (rest of the) context at hand. It should not be mixed up with the meaning of situation in the definition of **Dey and Abowd (1999, p. 3f.)**. There it denotes the circumstances or environment. Situation, however, is a combination of Dey and Abowd's context types, location and time. The ***situatedness*** of the user provides the context at hand. The reason for distinguishing situation and context is that – in the strict sense of LBS – adapting can be directed only to the situation, i.e. location and time or in a more ample manner to a wider context.

(Dey and Abowd, 1999)
Dey, A. K. and Abowd, G. D. (1999): *Towards a Better Understanding of Context and Context- Awareness*, Technical Report, GIT-GVU-99-22, Georgia Institute of Technology, Atlanta (GA)

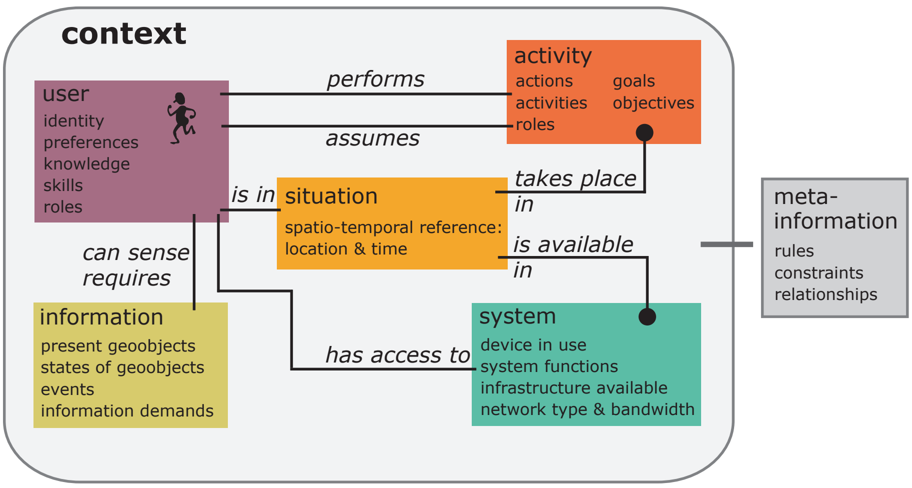


Fig. 25: Generic context model for mobile cartography

Location information is related to a position and denotes different kinds or levels of granularity (e.g. point coordinates, addresses, place names, regions) with distinct ranges of values. The granularity required for specific activities or information demands varies substantially. It is worth mentioning that the majority of services will not need accuracies in the millimetre and centimetre range, but of several meters. Although not always feasible it is assumed that these different forms of location information are convertible by methods like geo-coding, geo-decoding, information overlays etc. An alliance founded in 2000 by Nokia, Ericsson and Motorola, called ***Location Interoperability Forum (LIF)***, established standard location protocols for the exchange of device locations. The LIF is now part of the ***Open Mobile Alliance (OMA)***, an organisation of 100 companies aiming at developing an open framework for LBS. Another player in the location domain is the Open GIS Consortium that offers a standard with the OpenLS framework (sec. 2.2.2). Apart from the location the orientation of the user (bearing) is an important context factor. The device orientation can for instance be determined with an electronic compass or kinematic GPS.

OMA (LIF):
www.locationforum.org/
www.openmobilealliance.org
OGC:
www.opengis.org
MAGIC:
www.magicservicesforum.org

For ***time*** information the same granularity differences as for location can be identified. Time could for instance represent exact system time, day time, season, etc. This temporal granularity affects the way the system or service can react to a user request. Of course, the counterpart geographic information must also be temporally modelled.

The ***user*** and the activities he/she is performing are situated, hence dimensions of the context. Some authors see the modelling of the user in its own right. This user model (UM) approach is mostly taken for web content adaptation. Here it is part of the context model. As for the other dimensions, for the user in particular the question arises which characteristics need to be modelled or, in other words, which attributes are important and relevant for the mobile geographic information usage and the adaptation to it. **Dransch (2003)** offers a useful framework for modelling geographic information users based on activity theory.

(Dransch, 2003)
Dransch, D. (2003): Konzepte zur Modellierung der Nutzer von Geovisualisierungs-Systemen, *in*, *Visualisie-rung und Erschließung von Geodaten - Seminar GEOVIS 2003, 26. bis 27. Februar 2003, Universität Hannover,* Kartographische Schriften, Bonn: Kirschbaum Verlag, 103-110

Activities are *per definitionem* embedded in a context and thus belong to the context. At an initial stage it is reasonable to establish a straightforward mobile activity taxonomy in the manner described in the preceding section. For a given context it is also important to know which activities are possible, allowed, appropriate etc. This refers to the more difficult task of modelling rules and constraints in contexts. Another aspect connected to activities is the social dimension, i.e. the fact whether the activity is performed alone or in a group, if other people are involved or affected. This kind of information could also be modelled in the user dimension.

The ***information*** in mobile cartography cannot only be the source for visualisation, but also a context dimension of its own, describing the context of objects inside the spatial context scope, e.g. building types. This type of contextual information is termed ***co-located*** geospatial objects. In linguistics ***collocation*** refers to the common, meaningful appearance of words. Similarly, in space some objects commonly tend to be present more often than others. For instance, the presence of a church indicates the presence of a churchyard. Discrete geospatial objects can be modelled with the collocation approach, i.e. the presence of a geospatial object could be deferred with a certain probability/likelihood from the observation of another geospatial object. For continuous data, i.e. continuous fields (e.g. temperature), spatial autocorrelation can be applied. Yet, it is often enough to derive a set of co-located geospatial objects through basic GIS overlay functions such as *select_within_distance*. Advanced operations can also include the calculation of visibility (is object X visible from the user's position?). Clearly the attributes and states of these co-located geospatial objects are of utmost interest, since they considerably characterise the context. This information partially overlaps with another type of contextual information, the ***physical parameters*** (e.g. temperature, humidity, noise level, etc.).

The characteristics of the ***system*** in use constitute another important context dimension that must not be underestimated. Device or network characteristics have a substantial influence on the way information should best be transmitted and visualised. One standard for describing device capabilities is the ***Composite Capabilities/Preference Profile (CC/PP)***. CC/PP is an exchange protocol specified by the World Wide Web Consortium and defined within the resource description framework (RDF).

CC/PP: www.w3.org/Mobile/CCPP/

It is at least as important as to identify the relevant context dimensions as it is to model the ***relationships*** between them and to describe the rules or ***constraints*** valid for a context. For instance, the physical context (e.g. the weather) has an influence on possible activities (e.g. ice skating on a lake during summer is not appropriate). Activities also set up a context, e.g. riding a bus or shopping. Thus the elaboration of an ***activity typology*** can help defining a corresponding ***context typology***.

The example code below shows an XML representation of the context parameters described before:


```
<context>
    <location>
        <x>4468503.88</x>
        <y>5332375.59</y>
    </location>
    <time>14:37:52</time>
    <date>20031022</date>
    <user>Tumasch Reichenbacher</user>
    <activity>navigating</activity>
    <information>
        <collection>
            <gml:boundedBy>
                <gml:box>
                    <gml:coord>
                        <gml:X>4283473.363317592</gml:X>
                        <gml:Y>5238410.644518324</gml:Y>
                    </gml:coord>
                    <gml:coord>
                        <gml:X>4635323.458982407</gml:X>
                        <gml:Y>5604895.796881676</gml:Y>
                    </gml:coord>
                </gml:box>
            </gml:boundedBy>
            <gml:featureMember>
                    <gml:Point
srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">

    <gml:coordinates>4468219,5334317</gml:coordinates>
                        </gml:Point>
                    <poi.ID>409</poi.ID>
                    <poi.Name>Stadtgespr</poi.Name>
                    <poi.code>11001</poi.code>
                    <poi.str>Gabelsbergerstr.</poi.str>
                    <poi.Hausnr>38</poi.Hausnr>
                    <poi.Attr>Happy Hour 21:30-22:30</poi.Attr>
                </poi>
            </gml:featureMember>
        </collection>
    </information>
    <system>
        <devicedisplay>
            <height>320</height>
            <width>240</width>
        </devicedisplay>
        <formats>
            <supported>SVG</supported>
            <supported>BMP</supported>
        </formats>
        <connection>wlan</connection>
    </system>
</context>
```


(Schmidt et al., 1998)
Schmidt, A., Beigl, M. and Gellersen, H.-W. (1998): There is more to context than location, *Proc. International Workshop on Interactive Applications of Mobile Computing (IMC98)*, Rostock, Nov., 1998

Context information in mobile computing can partly be derived from different sensor information. **Schmidt et al. (1998)** show in an example of sensor fusion how to derive first symbolic abstractions, termed cues, from physical sensor data and then how to map these cues to contexts. Some context information can be accessed from other sources and has not necessarily to be sensed *in situ*. The Internet and web services which constitute a distributed computing environment allow for the extracting of context information by georeferencing methods. An example is the retrieving of weather conditions for a given location from a meteorological web service.

For any kind of adaptation, i.e. also the adaptation in a geovisualisation service based on the mobile usage context, a formalisation of context is essential. So far, only a few attempts to formalise context have been made, e.g. **(Boy 1991; Hewagamage and Hirakawa 2000; Hirakawa and Hewagamage 2001; Schmidt and Gellersen 2001)**. In the most general form situation and context can be described as functions of a set of parameters. These parameters are of mixed type and level: some parameters can be numerical, others are per definition symbolic, some parameters are atomic, and others are composed of numerous sub-parameters. **Chen and Kotz (2000)** distinguish low-level contexts (e.g. location, time, orientation, light level, temperature) and high-level contexts (e.g. current activity).

(Boy, 1991)
Boy, G. (1991): *Intelligent Assistant Systems*: Academic Press

(Hewagamage and Hirakawa, 2000)
Hewagamage, K. P. and Hirakawa, M. (2000): Situated Computing: A Paradigm to Enhance the Mobile User's Interaction, *in*, *Handbook of Software Engineering and Knowledge Engineering*: World Scientific Publishing Company

(Hirakawa and Hewagamage, 2001)
Hirakawa, M. and Hewagamage, K. P. (2001): Situated Computing: A Paradigm for the Mobile User-Interaction with Multimedia Sources, *Annals of Software Engineering*(12): 213-239

(Schmidt and Gellersen, 2001)
Schmidt, A. and Gellersen, H.-W. (2001): Modell, Architektur und Plattform für Informationssysteme mit Kontextbezug, *Informatik Forschung und Entwicklung*(16): 213-224

(Chen and Kotz, 2000)
Chen, G. and Kotz, D. (2000): *A Survey of Context-Aware Mobile Computing Research*, R2000-381, Department of Computer Science, Dartmouth College

The situation and context functions can be described as follows:

$S = f_1(l,t)$ and $C = f_2(S,U,A,I,T) \mid R$

where: *l* = location (position as coordinate pair, place name, address)
t = time (exact time, time interval, daytime)
U = user (identity: uid or user group: gid)
A = activities {locating, navigating, searching, identifying, checking}
I = information
T = system (device capabilities, network type, network bandwidth)
R = constraints and rules (valid for the context)

The approach of **Hewagamage and Hirakawa (2000)** introduces the ***situation metaphor*** for modelling human-computer interaction. The context space *CS* is a set of past usage contexts C_i, i = 1, …, ∞:

$$CS = \sum_{i=1}^{\infty} C_i = \sum_{i=1}^{\infty} f_2(S_i, U_i, A_i, I_i, T_i)$$

The information that is relevant in a particular context C_i can be expressed as a function to retrieve a subset e_i of information entities E:

$$r(C_i) = \{ e_i \mid e_i \in E \}$$

Let two distinct contexts C_i and C_j such that $C_i, C_j \in CS$ and the following conditions hold:

If $C_i \Delta C_j \in CS$ then $|l_i - l_j| < \varepsilon$

for a given distance threshold $\varepsilon > 0$ and $t_i + t_j$ is a continuous period and where the operator Δ means the concatenation of two contexts.

If $C_i \Delta C_j \in CS$ then C_j is C_{i+1}

If $r(C_i) = \emptyset$ then C_i is a null context.

To access elements in the context space, an exploration function F based on the context dimensions can be defined:

$$F(C_i, P) = \{C_j \mid G(C_i, P) \subset (C_j, P)\}$$

where $P \in \{l, t, U, A, I, T\}$ and $G(C, P)$ is a function for getting the values of the specified dimensions P constituting the context.

The model can gradually learn from the user through his/her real world activities and interactions with the mobile system. The formalism of context described above can be used to capture contexts of usage or usage patterns in mobile cartography. If, for instance, in context Q user W asked for information entities V, this is stored in the context space. In a future usage context, if the context is similar to context Q of the context space, the entity set V could be applied.

(Schmidt and Gellersen, 2001)
Schmidt, A. and Gellersen, H.-W. (2001): Modell, Architektur und Plattform für Informationssysteme mit Kontextbezug, *Informatik Forschung und Entwicklung*(16): 213-224

Strongly connected to the modelling of the context space is the approach of **Schmidt and Gellersen (2001)** for determining the validity of context. They argue that the validity of context is dependent on space and time. With increasing spatial or temporal distance from the existence of a context instance the validity is decreasing. The basic principles for their approach are:

- principle of ***locality***: the relevance of a context is maximal for the location of its origin and is decreasing with increasing distance from the origin; after a specified distance from the origin the context has no more relevance
- principle of ***temporality***: the relevance of a context is maximal for the time of its origin and is decreasing with increasing temporal distance from the time of origin; after a specified time from the time of origin the context has no more relevance
- principle of ***independence***: the user and producer of context are independent; several users or producers of the same context may exist independently
- principle of ***distribution*** and ***scalability***: the distribution of information is locally bound (locational scalability); the

existence of information is temporally bound (temporal scalability)

The temporal aspects of geospatial objects could be modelled according to approaches for spatio-temporal models **(Pfoser and Tryfona 1998)**. The importance of temporal information is stressed by **Miller (2003)**: "… LBS can benefit from the time geographic 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?' are in fact queries against space-time prisms. "

(Pfoser and Tryfona, 1998)
Pfoser, D. and Tryfona, N. (1998): *Requirements, Definitions and Notations for Spatiotemporal Application Environments*, Technical Report, CH-98-09

(Miller, 2003)
Miller, H. (2003): What about People in Geographic Information Science?, *in* D. Unwin (Ed.), *Re-Presenting Geographic Information Systems (in press)*: John Wiley & Sons

Schmidt and Gellersen **(2001)** propose a concrete context spatio-temporal relevance model using fuzzy set theory. The basic idea of the fuzzy set theory is that the membership of sets is not binary, i.e. crisp, but that with a certain relevance an element belongs to a set. This is determined by a function, the membership function.

A membership function for a normal set ***S*** looks like $\mu_s(x) = \begin{cases} 1, & x \in S \\ 0, & otherwise \end{cases}$ where *x* is an element, that is *x* is either a member of the set ***S*** or not. In contrast, the membership function for a fuzzy set ***A*** looks like $\mu_A(x) \in [0,1]$, i.e. *x* is assigned a value between 0 and 1. Typical membership functions are the triangle or the trapezoid function.

For the temporal relevance it is assumed that the context arises at t_0. Furthermore, the relevance should decreases with further temporal distance. 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)**. Fig. 26 (top) illustrates the following trapezoid membership function (μ_A) that 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.

For the modelling of the spatial relevance a trapezoid membership function using the spatial distance d_s of the features to the context origin location is applied (Fig. 26 bottom). The spatial distance is calculated as:

$$d_s = \Delta l = |l_0 - l| = \sqrt{(x_0 - x)^2 + (y_0 - y)^2}$$

where l_0 is the location of the context origin.

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.

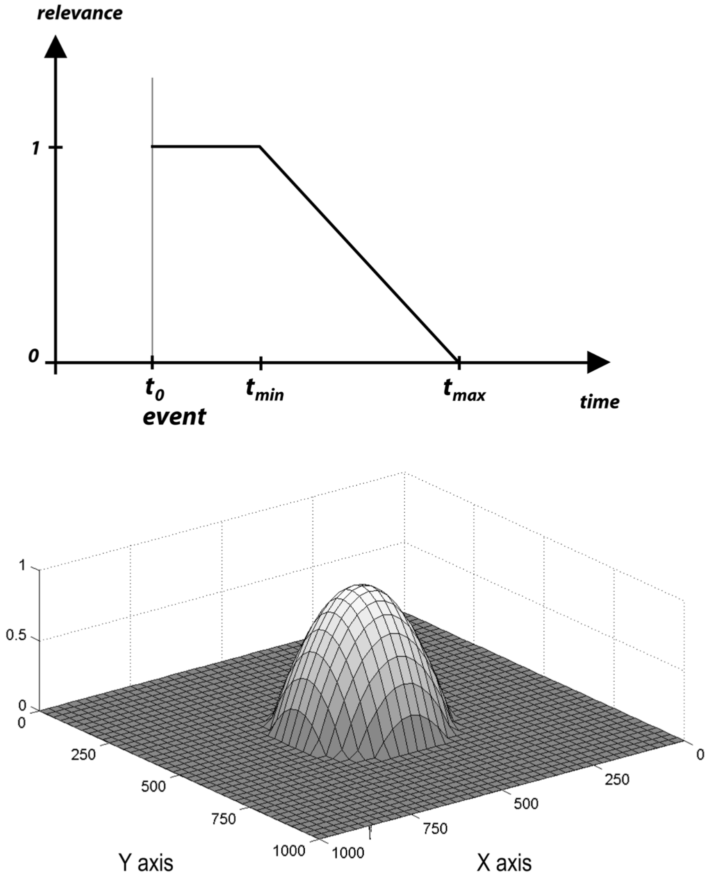


Fig. 26: Spatial and temporal relevance function (adapted from Schmidt and Gellersen 2001)

(Schmidt and Gellersen, 2001)
Schmidt, A. and Gellersen, H.-W. (2001): Modell, Architektur und Plattform für Informationssysteme mit Kontextbezug, *Informatik Forschung und Entwicklung*(16): 213-224

(Mäntyjärvi and Seppänen, 2003)
Mäntyjärvi, J. and Seppänen, T. (2003): Adapting applications in handheld devices using fuzzy context information, *Interacting with Computers* 15(4): 521-538

A similar approach of fuzzy context modelling is proposed in **(Mäntyjärvi and Seppänen 2003)**. This formalisation helps to describe situations and contexts and allows for finding typical patterns. The parameters above are not all available in explicit form. Position, time, device capabilities, and identity are in most cases available or can be sensed. Activities, rules, and constraints have to be inferred from these parameters in an intelligent way.

Apart from the single context dimensions and their formalisation two ways of structuring context are to be mentioned: scope of context and the levels of context. Similar to mobile activities the context in which these activities take place is dependent on scale. Context can be attributed to different scales (see Fig. 22) and can hence be observed locally, regionally or globally. In that sense scale is essential for detecting context patterns. An example where this kind of spatial context is used is the user interface of GISD, a spatial viewer product of the company IONIC. The user interface provides for storing and accessing spatial contexts, i.e. similar to views on the data with different extents and scales. There is also a differentiation in 'local' and 'remote' contexts. Context for mobile cartography can be understood as composed of distinct layers building a context hierarchy. There is a certain grade from general to more specialised context (see Fig. 27). This allows for starting off with the general context that seems to be easier to model.

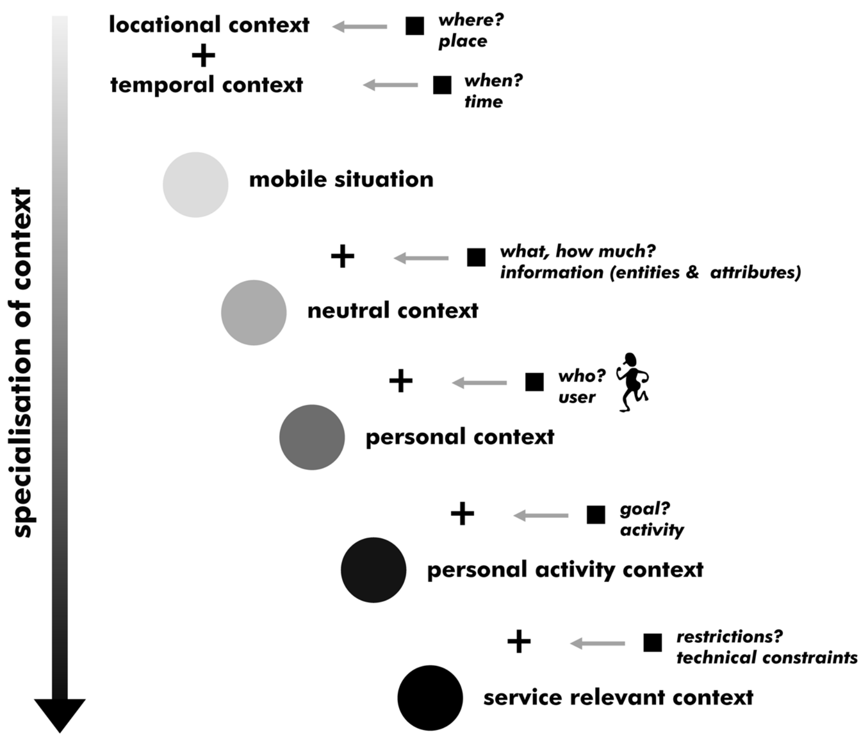


Fig. 27: Hierarchical levels of context

The sensing of context, primarily the tracking of locations, rises many privacy concerns, e.g. **(Ackerman et al. 2001)**. Most important the user must always be informed about the fact that he/she is located and must have the possibility to turn this feature off. However, it should not be forgotten that subscribers of mobile networks are tracked anyway, because the mobile technology relies on the location information. Furthermore, in many circumstances, information about consumers is collected with the knowledge of the people. The connection of such data with location information seems problematic and frightening to many people.

(Ackerman et al., 2001)
Ackerman, M., Darrell, T. and Weitzner, D. J. (2001): Privacy in Context, *Human-Computer Interaction* 16: 167-176

4.2.4 Information in mobile enviroments

The 'raw material' for visualisation in mobile cartography is the geographic information itself. This information can be distributed in different repositories, of different scale, and data types. It can be maps, images, geographic features or other resources. If one has a service concept and mobile devices as target platform in mind, only a flexible information structure can meet the requirements of providing adequate information to the user. The structure of the information is essential for the overall quality of mobile cartography and a crucial factor for an adaptive geovisualisation. The units of information need to be as atomic or granular as possible. In the case of geographic information this is on the feature level for vector data or on the biggest level of detail for raster data. In the OpenGIS Guide the concept of feature collections is defined **(Buehler and McKee 1998, p. 41)**:

(Buehler and McKee, 1998)
Buehler, K. and McKee, L. (1998): *The OpenGIS® Guide: Introduction to Interoperable Geoprocessing and the OpenGIS Specification*, 3rd Edition, OGC Technical Committee of the Open GIS Consortium, Wayland (MA)

> *Feature Collections are comprised of Features, the basic unit of digital geospatial information. Features may be defined recursively, so there can be considerable variation in feature granularity.*

An aggregation, classification or grouping is always possible, whereas the opposite is not. Different approaches to intelligently structuring the information are imaginable. A very pragmatic approach – known from thematic mapping – is to separate core information from additional information, e.g. base map plus dynamic information, i.e. points of interest (POI), routes, etc.

A concise concept of such a procedure is presented in the work of **Goel (2001)**. She distinguishes different layers based on the volatile character of the information. The core layer holds information of more static or permanent nature that is updated in regular periods. For the purpose of this work, this layer would incorporate a base map and further thematic layers such as public transport network. The service layer consists of information layers representing more dynamic and volatile information that can be retrieved real-time from a central server. The service layer acts as a linking structure between the referential objects and related services. A similar approach is taken by **Jung and McKeown (2001)**. They give an example of a conference map consisting of a static part showing the architectural layout of the conference and dynamic parts that can be modified according to quantitative and qualitative changes.

(Goel, 2001)
Goel, A. (2001): *URBAN PILOT - A Dynamic Mapping Tool for Personalizing the City through Collective Memory*, Master's Thesis, Department of Architecture, Massachusetts Institute of Technology

(Jung and McKeown, 2001)
Jung, B. and McKeown, J. (2001): Adaptive Graphics, *Proceedings XML2001*, Orlando (FL)

Another classic work is Lynch's attempt to describe the structure of cities **(Lynch 1960)**. He identified five structural elements forming the image of a city: paths, edges, districts, nodes, and

(Lynch, 1960)
Lynch, K. (1960): *The Image of the City*, Cambridge (MA): MIT Press & Harvard University Press

landmarks. These elements are important for the building of mental maps as well as physical maps. Lynch's work offers useful concepts for structuring information, but also for the extraction of structural information to be included in a map.

The most common information type in LBS are ***points of interest*** (POI). However, it will become necessary to model other information types as well, such as regions of interest (ROI), time (point) of interest (TOI) or time intervals of interest (TIOI). For this purpose geographic information has to be modelled spatio-temporally on the most atomic level. Regarding space only, this implies the usage of simple features. OGC has defined standards, such as the Simple Feature Specification and the Web Feature Server (WFS). In anticipation of the implementation, it has to be said that a WFS typically delivers feature data in the form of GML. The separation of model and view as visualised in Fig. 20 can be found in the use of GML as the modelling language of geographic information, the geographic model, and SVG as the presentation format or presentation model. Above all this differentiation is congruent with ***cartographic model theory***. In this theory a primary model is distinguished from a secondary, derived model that is perceived by the user and consequently constitutes his/her mental model, the tertiary model (see Fig. 28).

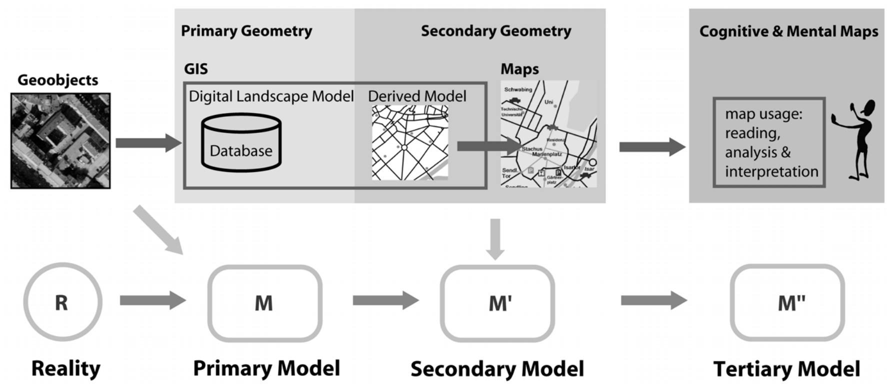


Fig. 28: Geographic information modelling

The framework shown in Fig. 20 also contains another kind of information that is only implicitly indicated with the context frame. It is information belonging to context as discussed above. This type of information has to be distinguished from the information to be displayed. The information belonging to context could be sensorial information, co-located objects or constraints of the context. Fig. 29 illustrates the relationship of reality, sensorial information, and modelled information of the real world.

Geographic information is a subset of reality modelled for different purposes. The sensorial information of the user perceived in the current geographic information usage context is also a subset of reality, but also partly of the geographic information as a model of reality. This knowledge about the user's surroundings is an important part of the context.

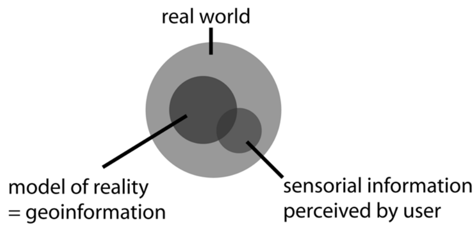


Fig. 29: Relationship of information types

(Gruber, 2001)
Gruber, T. (2001): What is an ontology? http://www-ksl.stanford.edu/kst/what-is-anontology.html

(Smith, 2001)
Smith, B. (2001): Geographical categories: an ontological investigation, *International Journal Geographical Information Science* 15(7): 591-612

In the last few years a lot attention in the geographic information science has been drawn to ontology. An ontology is according to **Gruber (2001)** "… an explicit specification of a conceptualization", or studies according to **Smith (2001, p. 592f.)** "… the totality of objects, properties, processes and relations which make up the world on different levels of focus and granularity …". The specification involves the determination of a standardised taxonomy of objects in a domain. For the geographic information most recently research on geo-ontologies has been undertaken. Geo-ontologies can be understood to provide semantic references for geographic information **(Kuhn 2001; Kuhn 2002)**. It is not the purpose of this thesis to cover ontology, but the development in this field is certainly of major importance for mobile cartography. Ontologies might help to model the information dimension of context in the sense discussed above.

(Kuhn, 2001)
Kuhn, W. (2001): Ontologies in support of activities in geographical space, *International Journal Geographical Information Science* 15(7): 613-631

(Kuhn, 2002)
Kuhn, W. (2002): Geo-Ontologies for Semantic Interoperability, *Proceedings*, Ilkley, UK, September 16, 2002.

Another important aspect of information is its quality. The quality of geographic information may vary substantially. In the case of mobile geographic information usage where the user receives geographic information from different content providers and has to make quick decisions the meta-information about quality is crucial. This information quality affects different dimensions in mobile cartography: it could simply be the accuracy of the position, the completeness or timeliness of the geographic information or it could affect the attributes of geospatial objects, for instance their currency. Another aspect discussed further below is the relevance of the information. In mobile environments the chance for inferior data quality is quite big. **Duckham et al. (2002, p. 89)** coin the term imperfection which comprises the two orthogonal concepts ***error***

Duckham et al., 2002)
Duckham, M., Mason, K., Stell, J. and Worboys, M. (2002): A Formal Approach to Imperfection in Geographic Information, *Computer, Environment and Urban Systems* 25: 89-103

and ***imprecision***, where error (or inaccuracy) designates a lack of correlation of an observation with reality and imprecision concerns a lack of specificity in representation. They further state that the concept of ***granularity*** that has been mentioned above is closely related to imprecision. They define granulation as "… the result of distinct entities becoming indiscernible due to the imprecision in an observation" **(ibid., p. 90)**. Generally, granularity can be understood as the smallest unit (or grains) of information that can be measured or distinguished respectively. Within such a grain, information differences are indiscernible. Thus, coarse granularity results in less detail. These facts have two consequences: first, the mobile user should have access to any kind of data quality information as much as possible. Second, the granularity of information is an important factor for the degree of adaptation that is possible.

Information demand or ***spatial questions*** have been introduced in section 4.2.1 (see Fig. 21). A rather extreme view in the geographic information and cartography community is that in principle all spatially related goals or information demands are reducible to the two basic questions: *where is that?* and *what is there?* The problem of this reduction is that the spatial appearance of certain phenomena or objects can depend on time. Therefore at least the question *when?* is needed as well. This view can for instance be found in a discussion of map meaning. **MacEachren (1995, p. 312)** speaks of a "… space, time, attribute taxonomy of denotative meaning in maps. Maps are about things at particular places and times. The interpretants of map signs (or maps as signs) include not only interpretation of 'what' the sign means but of 'where' and 'when' the meaning holds". The approach of **Mennis et al. (2000)** is along the same lines describing three different cognitive systems, the *what*, *where*, and *when* system. They are separate, but there is a strong interdependency between the *what* and *where*. The basic question types thus focus either on the ***where*** (location), ***what*** (geospatial object, person, activity) or ***when*** (time).

MacEachren, 1995)
MacEachren, A. M. (1995): *How maps work: representation, visualization, and design*, New York (NY): Guilford Press

Mennis et al., 2000)
Mennis, J. L., Peuquet, D. J. and Qian, L. (2000): A Conceptual Framework For Incorporating Cognitive Principles Into Geographic Database Representation

- ***where***: who (person) | what (object, activity) | when (time); for example: *where* is Maria and what is she doing now?
- ***what***: *what* (object, attribute, activity) | when (time); for example: what can you do in X on a Sunday?
- ***when***: who (person) | what (object, attribute, activity); for example: *when* is shop A open?

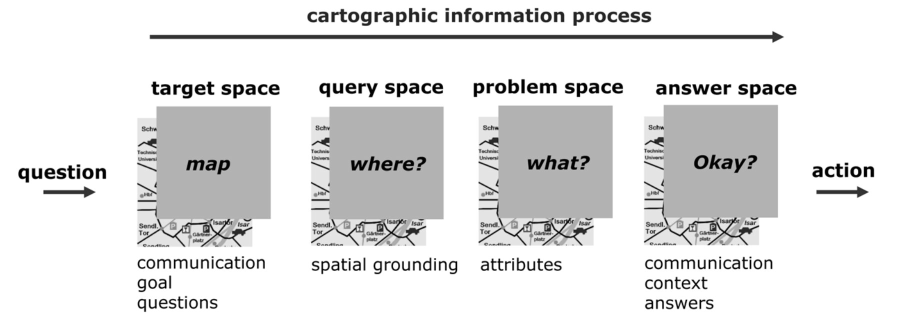


Fig. 30: Question and answer model (adapted from Heidmann 1999, p. 97)

(Heidmann, 1999)
Heidmann, F. (1999): *Aufgaben- und nutzerorientierte Unterstützung kartographischer Kommunikationsprozesse durch Arbeitsgraphik: Konzeptionen, Modellbildung und experimentelle Untersuchungen*, Herdecke: GCA-Verlag

(Edwardes et al., 2003b)
Edwardes, A., Burghardt, D. and Weibel, R. (2003b): WebPark - Location Based Services for Species Search in Recreation Area, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

(Lee et al., 2002)
Lee, D. L., Xu, J., Zheng, B. and Lee, W.-C. (2002): Data Management in Location-Dependent Information Services, *pervasive computing*(July-September): 65-72

A similar approach is taken by the WebPark project, where a model of questions is differentiated from a model of answers **(Edwardes et al. 2003b)**. The question model separates five question types that are very similar to the questions related to the elementary user actions (see Table 7): ***Presence***, ***Distribution***, ***Confirmation***, ***Identification***, and ***Association***. **Lee et al. (2002)** give a somewhat different classification of query types in LBS based on two dimensions. The first is the spatial scope of the query. Local queries are associated to the user's current location. Non-local queries relate to any other location. The other dimension regards the complexity of the query. Simple queries are based on simple attribute conditions. General queries are formed by more complex conditions either spatially-constrained or non-spatially constrained. The spatially constrained queries involve common GIS operations such as *intersect*, *contain*, *contained_by*, *within_distance* etc.

(Horvitz, 1999)
Horvitz, E. (1999): Principles of Mixed-Initiative User Interfaces, *Proceedings ACM SIGCHI Conference on Human Factors in Computing Systems*, Pittsburgh (PA), May, 1999, ACM Press. http://citeseer.nj.nec.com/horvitz99principles.html

The main goal of any geoservice – and a geovisualisation service is no exception – is to give answers to these users' questions related to space and time. Or to put it differently, the service will provide solutions to mobile users' spatial problems by meeting the information needs. The information demand can be explicit or implicit. An explicit information demand is expressed in the form of ***queries*** or natural language questions. The long term goal is that a system recognises implicit information demands of a user and transforms them to explicit queries. This step would require the capability of the system to infer beliefs about users' goals or intentions. This is a very difficult, maybe an impossible task. In **(Horvitz 1999)** this aspect is described for the user interface domain. So far, the user has to take the initiative and make his/her information demands expressive to the system by forming queries. These queries can trigger an adaptation. Hence, this is a state between an interactive system where the user has to do all adaptations and configurations, and a fully adaptive system that would recognise the user's information demands and react to them correspondingly.

The role of adaptation in the context of a mobile geovisualisation service is to assure adequate information or an adequate answer to the user's problem. Adequacy is a quality measure, namely fitness for use. If the information is useful in a current usage context and to an individual user, if it is adequate in amount and form, it is valuable and hence of high quality. However, not only the information content must be adequate, but also the information presentation form has to be adequate. Depending on the usage context and the information content of the answer, a map might not be the adequate presentation form.

Information as described above is related to what, where, and when. In the mobile cartography framework, the main task is to select and maybe filter the relevant information for the current usage context. In what way the selected information is presented is the topic of section 4.2.6, where different visualisation principles and techniques suitable for mobile cartography are discussed. **Raper et al. (2002, p. 44)** take a similar view by stating that " … understanding the individual 'geographical relevance' of information will be necessary for location-based services to provide appropriate information and identifies movement patterns, spatio-temporal constraints, geographical associations and setting as the key components". The relevance of geographic information is dependent on the user's geography. For a personal geography (egocentric) the relevance is mainly influenced by the current activity and for a more detached geography such as an overview (allocentric) the relevance can be determined through an analysis of geographic information retrieval tasks **(Raper et al. 2002)**.

(Raper et al., 2002)
Raper, J., Dykes, J., Wood, J., Mountain, D., Krause, A. and Rhind, D. (2002): A framework for evaluating geographical information, *Journal of information science* 28(2): 39-50

Relevance is also the central issue in adapting to mobile geographic information users. The relevance of information is strongly dependent on the usage context and its dimensions as described in section 4.2.3. Like context relevance is a fuzzy concept. A general introduction to relevance in information retrieval is provided by **Borlund (2003)**. Relevance has to do with information needs, information seeking, and information use. Different models and theories about information needs and relevance have been proposed from different disciplines. In information retrieval (IR) the objective is to " … retrieve all the relevant documents [and] at the same retrieving as few of the non-relevant documents as possible" **(van Rijsbergen 1979, p. 6)**. This can be applied as well to geographic information retrieval and also to its presentation in maps.

(Borlund, 2003)
Borlund, P. (2003): The Concept of Relevance in IR, *Journal of the American Society for Information Science and Technology* 54(10): 913-925

(van Rijsbergen, 1979)
van Rijsbergen, C. J. (1979): *Information Retrieval*, London: Butterworths

(Greisdorf, 2000)
Greisdorf, H. (2000): Relevance: An Interdisciplinary and Information Science Perspective, *Informing Science* 3(2): 67-71

A very early and broad definition of relevance is given by Rees (1966) in **(Greisdorf 2000, p. 67)**:

> *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.*

Pertinence is often used as a synonym for relevance and refers to items that satisfy the user's information needs and build the user satisfaction. In cognitive science the term ***salience*** is used to denote a similar concept.

(Dervin, 1983)
Dervin, B. (1983): An overview of sense-making research: concepts, methods, and results to date, *Proceedings International Communication Association Annual Meeting*, Dallas (TX), May 1983

(Kari, 1998)
Kari, J. (1998): Making Sense of Sense-Making: From metatheory to substantive theory in the context of paranormal information seeking, *Proceedings NordisNet workshop (Meta)theoretical stands in studying library and information institutions: individual, organizational and societal aspects*, Oslo, Norway, November 12–15, 1998

A very broad and general framework for explaining ***information needs*** has been developed by **Dervin (1983)**. This meta-theoretic approach termed ***sense-making theory*** comprises four constituents: a ***situation*** in space and time defining the context in which information needs arise, a ***gap*** that represents the difference between the actual and the desired situation, an ***outcome***, i.e. the result of the sense-making process, and a ***bridge*** that stands for any means closing the gap between situation and outcome. The basic idea of sense-making theory can be illustrated with the sense-making triangle (see Fig. 31): "The situation provides the context in which the individual needs to make sense of something (gap) that forces him to seek for help" **(Kari 1998)**. According to Dervin, the need for information arises from a gap in our cognition of the world and thus information could help us to make sense of the world by filling these gaps.

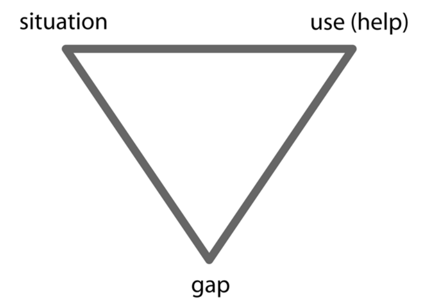


Fig. 31: The sense-making triangle

(Gershman et al., 1999)
Gershman, A. V., McCarthy, J. F. and Fano, A. E. (1999): Situated Computing: Bridging the Gap between Intention and Action, *Proceedings 3rd International Symposium on Wearable Computers*, San Francisco (CA), October 18 - 19, 1999, 3-9

Gershman et al. (1999, p. 3f.) argue that the most important task in situated computing is to bridge the gap between user intentions and the possible actions to achieve them and propose three types of ***discontinuities***: ***physical***, ***informational***, and ***awareness***. A physical discontinuity arises, if one is not in a place where an effective action can be taken. If one knows what to do, but the information necessary to actually perform the action is not available or accessible, this is called an information discontinuity. Finally, an awareness discontinuity happens, if through situational constraints one fails to become aware of present opportunities to achieve a goal. Among other prototypes helping to overcome these gaps, the authors propose an *ActiveMap* tool. This tool supports the awareness of people acting within the physical environment by representing the locations of co-workers and the freshness of the location information.

The ***information seeking*** process can generally be divided in active and passive seeking, for example searching and browsing. There are several measures to determine the efficiency and effectiveness of search or retrieval processes. The most common group of measures is based on a binary notion of relevance, i.e. a document is either relevant or it is not. Based on the binary relevance several measures can be defined. Precision is the ratio between the number of retrieved and relevant and the total number of retrieved documents. Recall is the ratio between the number of retrieved and relevant and the possible relevant documents. A step further is the introduction of ranks for the retrieved documents based on the similarity of the document and the query. Instead of binary, continuous relevance can be used **(Mizzaro 2001)**.

(Mizzaro, 2001)
Mizzaro, S. (2001): A New Measure Of Retrieval Effectiveness (Or: What's Wrong With Precision And Recall), *in* T. Ojala (Ed.), *International Workshop on Information Retrieval (IR'2001), Infotech Oulu, Oulu, Finland, September 19-21, 2001*, 43-52

Two different concepts of relevance are distinguished in literature, e.g. **(Saracevic 1996)**: the system or objective relevance and the user or subjective relevance. In the first case it is assumed that there is an algorithmically measurable objective relevance. In the latter cases the presumption is that only the user can judge the suitability of the retrieved information. Based on these two classes several types of relevance can be identified. The typification is based on the relations of (retrieved) objects and queries, requests, information needs or the underlying situation that triggers the need for information **(Borlund 2003)**. The five relevance types proposed by **Saracevic (1996)** are:

(Saracevic, 1996)
Saracevic, T. (1996): Relevance reconsidered, *Proceedings Second Conference on Conceptions of Library and Information Science (CoLIS 2)*, Copenhagen

(Borlund, 2003)
Borlund, P. (2003): The Concept of Relevance in IR, *Journal of the American Society for Information Science and Technology* 54(10): 913-925

Objective relevance

- System or algorithmic relevance: this relevance type is independent of the context and measures how well the query topic and document topic match.

Subjective relevance

- Topical-like relevance: aboutness, topicality
- Pertinence or cognitive relevance
- Situational relevance

- Motivational and affective relevance

The concept of subjective relevance assumes that the relevance of information can only be determined in ***use***. This view is reflected by the ***situational relevance*** covering the contextual factors of information relevance. Although the spatio-temporal aspect of relevance that is of major importance in mobile cartography could be subsumed under this situational relevance, it is reasonable to express the spatial relevance and temporal relevance (timeliness) explicitly.

(Keim and Kriegel, 1994)
Keim, D. A. and Kriegel, H.-P. (1994): VisDB: Database Exploration Using Multidimensional Visualization, *Computer Graphics & Applications Journal* 14(5): 40--49

Keim and Kriegel (1994) propose an approach for calculating a relevance factor. The method first determines for each feature the distance between the attribute values and the corresponding query values. The distance functions used depend on the data types. For non-metric data types the authors suggest the use of domain-specific distance functions or a distance matrix. The next step combines the independently calculated distances for the selection predicates. Since the relative importance of the selection predicates must be considered, weighting factors for each of them have to be defined. The distances may also vary in magnitude and thus need to be normalised. Finally the normalised values are combined into a single distance value by applying a numerical mean function.

Geographic or spatial relevance can consider the current position and the Euclidean distances to the retrieved features and thus determine the relevance factor. Temporal relevance can be calculated using time differences. For a simple example it is assumed that the user has an information need for events in his/her neighbourhood. That means the user poses a query and the service will return features (events) relevant to the user in his/her usage situation. The event with the highest relevance to the user is assumed to be the one that is closest to the user's position, will begin next in time or has started last, and matches the topical interest best. The spatial, temporal, and topical relevance can be measured according to the method described above. The overall relevance is a combination of spatial, temporal and topical relevance. Table 9 shows the event data for the example calculations.

id	name	x	y	category	date	time	event type
182	Staatstheater am Gaertner-platz	520.09	661.59	56009	23102003	1930	opera
261	Werkstattkino	313.33	627.67	56010	23102003	2015	studio movie
262	Theater am Frauenhofer	306.66	633.10	56009	23102003	2000	comedy
496	Arena	107.98	521.81	56010	23102003	1845	action movie
565	Marionetten-	113.46	755.75	56009	23102003	1530	children

	theater						play
757	VOLLMER Haus Theater	058.65	985.14	56009	23102003	2100	classic play
1185	Maxx	1004.59	997.41	56010	23102003	2045	action movie
1305	Imax	1266.91	694.81	56010	23102003	1700	nature movie
1306	Planetarium	1280.05	682.87	56010	23102003	1730	nature movie

Table 9: Sample event table

The user's position $P_U(x_U, y_U)$ is: 340.00, 925.00 and the current time t_c is 19:00. Fig. 32 shows the spatial distribution of the events and the user's position in relation to the events. Furthermore, the minimal and maximal distance between the user's position and the events is depicted. The user's query encompasses all events for the category cinema and the event type 'action movie'.

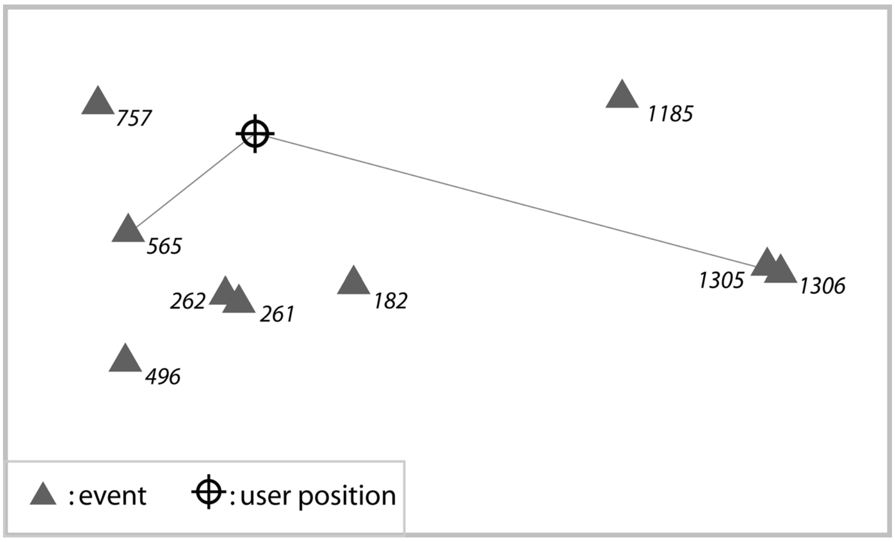


Fig. 32: An example of event relevance

The spatial distance d_s is calculated with the following function:

$$d_s(e_i) = \Delta l = |l_e - l_u| = \sqrt{(x_e - x_u)^2 + (y_e - y_u)^2}$$

where events $e_i = (1, \ldots, n)$ and locations $l(x_i, y_i)$

The temporal distance d_t is calculated with the following function:

$$d_t(e_i) = \Delta t = |t_e - t_c| = |((hour_e - hour_c) * 60) + (mi_e - mi_c)|$$

where events t_e is the time of the event 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: $rel_{tot\_norm}(e_i) = rel_{tot}(e_i) / \max(rel_{tot}(e_i), \ldots, rel_{tot}(e_n))$

The resulting distances and relevance values are illustrated in the table below (Table 10). Although event 496 is not the nearest event, it is the most relevant, because it has the highest topical and temporal relevance values.

id	name	d_s	d_t	d_{top}	$d_s$norm	$d_t$norm	rel_{tot}	$rel_{tot\ norm}$	rel_{tot} %
182	Staatstheater am Gaertnerplatz	319.09	30	0	0.89	0.50	1.39	0.53	53.2
261	Werkstattkino	298.52	75	0.5	0.95	0.20	1.65	0.63	63.2
262	Theater am Fraunhofer	293.80	60	0	0.96	0.25	1.21	0.46	46.5
496	Arena	465.18	15	1	0.61	1.00	2.61	1.00	100.0
565	Marionetten-theater	282.78	210	0	1.00	0.07	1.07	0.41	41.1
757	VOLLMER Haus Theater	287.71	120	0	0.98	0.13	1.11	0.42	42.5
1185	Maxx	668.52	105	1	0.42	0.14	1.57	0.60	60.0
1305	Imax	955.07	120	0.5	0.30	0.13	0.92	0.35	35.3
1306	Planetarium	970.73	90	0.5	0.29	0.17	0.96	0.37	36.7

Table 10: Relevance results for event query

4.2.5 User interfaces and mobile geovisualisation

The user interface in mobile cartography is tightly connected with the general problems of mobile system interfaces. In chapter 2 these problems have been discussed. The interactivity of a mobile map interface will certainly be more limited compared to other digital map interfaces. Even though, as stated in the last section, a map is not always the right answer form, it still can act as a user interface to further information, especially in mobile environments. Clicking, pointing, etc. is much easier and more error free than other input mechanisms. A map interface can for instance ease the complications of textual queries for other applications.

4.2.6 Visualisation in mobile cartography

The visualisation in a mobile context raises many requirements associated with graphics and generalisation. In many ways the visualisation of mobile maps is related to on-demand mapping.

On-demand maps are defined by **Crampton (1999)** as "maps created at the moment of need by the user". **Cecconi (2003)** argues that the primary characteristic of on-demand mapping is that the user specifies the moment (on-demand) and manner of map production. If on-demand mapping happens in real-time, it relies on on-the-fly generalisation which he defines as "the creation of a cartographic product upon a user request appropriate to its scale and purpose" **(ibid., p.3)**. In addition to this definition he gives a set of characteristics of on-demand maps:

- temporarily generated dataset at reduced scale for visualisation
- dataset matches user preferences and display specifications
- scale and map content not pre-determined
- dataset generated automatically without visual control before publishing
- dataset must arrive on the display in a user specified time slot

(Crampton, 1999)
Crampton, J. W. (1999): Online Mapping: Theoretical Context and Practical Applications, *in* W. Cartwright, M. P. Peterson and G. F. Gartner (Eds.), *Multimedia cartography,* Berlin; Heidelberg; New York: Springer-Verlag

(Cecconi, 2003)
Cecconi, A. (2003): *Integration of Cartographic Generalization and Multi-Scale Databases for Enhanced Web Mapping*, Dissertation, Geographisches Institut, Universität Zürich

These definitions are valuable for mobile cartography as well. However, as explained in section 4.1, mobile maps go even further. Apart from purely visualising geographic information, geographic information that is adapted to the usage context and the context itself become the subject of visualisation. This involves visualising information quality (e.g. the current position within a certain tolerance range), the availability and accessibility of objects, the relevance of objects, dynamic information, temporal information, validity and certainty of information, etc. The ***semantics*** of geospatial objects are dependent on context. Thus, there should be much care on visualising these semantics in mobile cartography where the context is due to change by nature.

The demands on visualisation are enormous. At the same time the restrictions are very severe, as mobile users have high expectations. Visualisation on mobile devices should be simple, focussed, clear, and easily legible. The visualisation must fit into the current usage situation, i.e. it has to provide personalised content and the presentation must be adapted. The visualised geographic information needs to be up-to date, accurate, and well conceivable. Furthermore this information must be linkable to other information, i.e. compatible with other services. Moreover, the visualisation should reflect the dynamic changes in the environment and provide information on-demand. Finally, the visualisation has also to arrive quickly on the mobile device and must be rendered fast.

From the elementary user actions listed in Table 7 and the requirements stated above a minimal set of functions mobile maps should offer can be derived. ***Mobile maps*** must be able to visualise at least the following: locations and routes, POIs and ROIs, entities (qualitative and quantitative distinctions), search results (objects, distances, relationships, relevance, importance, availability, time criticality etc.), events, multimedia information (images, text, sound etc.), relevance or importance as a visual ***ranking***, spatial relationships (rather topological than metrics) and spatial patterns and distributions.

Cartography has a rich toolbox at its disposal for accomplishing the task of designing maps that work for the mobile usage context. First, there are general design principles and design methods. And second, there are design guidelines stating when and how to use these methods and which parameter values are to be set.

(Ware, 1999)
Ware, C. (1999): *Information visualization: perception for design*, San Francisco: Morgan Kaufman

(Mullet and Sano, 1995)
Mullet, K. and Sano, D. (1995): *Designing Visual Interfaces - Communication Oriented Techniques*, Englewood Cliffs (NJ): Sunsoft Press - Prentice Hall

(Koffka, 1935)
Koffka, K. (1935): *Principles of Gestalt Psychology*, New York (NY): Harcourt-Brace

(Bertin, 1974)
Bertin, J. (1974): *Graphische Semiologie*, Berlin: de Gruyter

(MacEachren, 1995)
MacEachren, A. M. (1995): *How maps work: representation, visualization, and design*, New York (NY): Guilford Press

Different visual design principles are available, which are well examined and documented in graphic design literature **(**see for example **Ware 1999; Mullet and Sano 1995)**:

- ***Gestalt Theory*** **(Koffka 1935)**: This theory proposes different design principles based on human visual perception: proximity, similarity, continuity, symmetry, closure, relative size, figure and ground.
- ***conciseness*** (*Prägnanz*): this concept was proposed by **Bertin (1974, p.17)**: *Die Prägnanz wird wie folgt definiert: Wenn eine Konstruktion zur richtigen und vollständigen Beantwortung einer gestellten Frage unter sonst gleichen Voraussetzungen eine kürzere Betrachtungszeit erfordert als eine andere Konstruktion, so bezeichne man diese als prägnanter in bezug auf die gestellte Frage. … Die Prägnanz ist gleichbedeutend mit einem Minimum an geistigem Aufwand des Lesers bei jeder Stufe des Leseprozesses einer Zeichnung.*
- ***clarity***: This design principle has two notions. The first refers to the general tidiness of a map. The second means a special graphical variable introduced by **MacEachren (1995, p. 275f.)**: "The three visual variables (or subdivisions of clarity) are crispness, resolution, and transparency."
- ***visual contrast***: the map elements should be different enough

- ***order, grouping, unity***: the symbology should reflect a semantic order and grouping.
- ***harmony***: colours, size, forms etc. should be stepped in a harmonic way forming harmonic symbol sets
- ***structure & balance***: the map elements should show a structure
- ***focus & emphasis***: the important features need to be in focus
- ***visual hierarchy***: based on contrast and focus, the important elements need to lie in the foreground, whereas less important features should be in the background

Several authors have proposed design guidelines for screen maps based on these general design principles, cartographic knowledge, physical and technical conditions, and partly empirical studies. Although all these are targeted at screen maps for static displays, they can in parts be adopted to mobile device displays.

The most comprehensive work has been done by **Neudeck (2001)**.The predominant suggestion is the enforced usage of colour in screen maps. The main reason for this are the problems arising with other traditional design elements (e.g. contours for road signatures) on screens due to the raster technology **(Neudeck 2001; Brunner 2001)**. Most of these design techniques stem from the times when copperplate engraving was used in mapmaking and fine graphics were common. These fine graphics, along with rounded graphic primitives (e.g. circles), oblique lines, and serif fonts should be avoided if ever possible. Map text should run horizontally. A sufficient contrast between different map elements is necessary, especially when considering the changing light conditions of different usage contexts. Furthermore, the minimal dimensions of graphic elements must be increased drastically, both concerning the size of and distances between elements.

(Neudeck, 2001)
Neudeck, S. (2001): *Zur Gestaltung topografischer Karten für die Bildschirmvisualisierung*, Dissertation, Schriftenreihe, Heft 74, Institut für Photogrammetrie und Kartographie, Studiengang Geodäsie und Geoinformation Universität der Bundeswehr München

(Brunner, 2001)
Brunner, K. (2001): Kartengestaltung für elektronische Bildanzeigen, *in*, *Kartographische Bausteine*, Band 19, Dresden: Technische Universität Dresden, Institut für Kartographie

Whereas these guidelines are helpful to properly set low level parameters, they cannot help in choosing the appropriate visualisation methods for the context at hand. The work from **Zhou and Feiner (1998)** heads in this direction. The ***visual tasks*** (see Fig. 33) are midlevel components that link the high level ***presentation intents*** to the low level ***visual acts***.

(Zhou and Feiner, 1998)
Zhou, M. X. and Feiner, S. K. (1998): Visual Task Characterization for Automated Visual Discourse Synthesis, *Proceedings CHI'98*, Los Angeles (CA), April 18-23, 1998

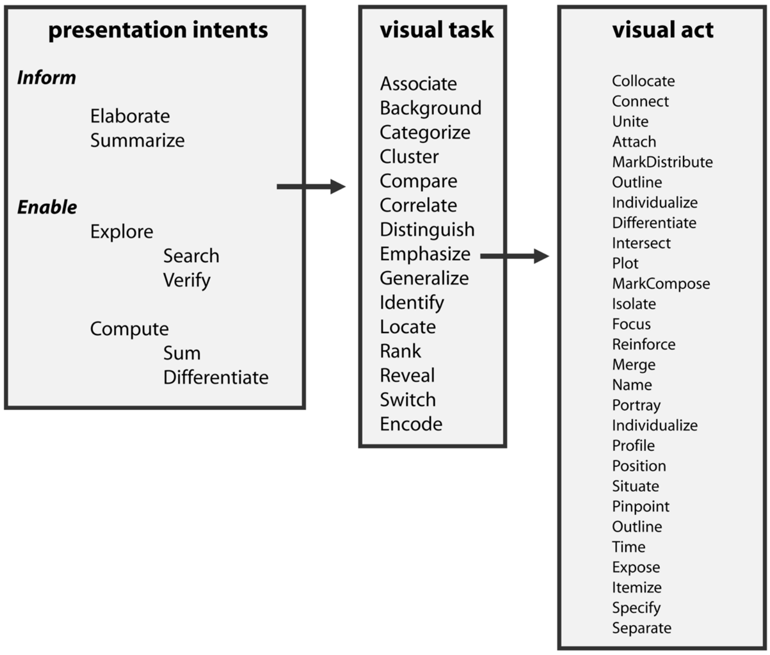


Fig. 33: Visual task taxonomy (after Zhou and Feiner 1998)

Although it is significant to consider the basic cartographic design principles and methods, not all traditional methods are feasible or appropriate anymore (e.g. contours for road signatures etc.). Therefore it is important to integrate also new approaches and strengthening existing means (colour, opacity, animation, etc.). One such interesting idea is to bring more depth into the visualisations. Depth Cue Theory **(Ware 1999)** offers means such as perspective cues, occlusion, depth of focus, and cast shadows to produce depth impressions. A good example of depth impression in mobile maps is the map shown in Fig. 16. The slightly skewed map together with the ***silhouettes*** of major buildings gives a good spatial depth feeling.

(Ware, 1999)
Ware, C. (1999): *Information visualization: perception for design*, San Francisco: Morgan Kaufman

One effect of the very small displays in mobile cartography is the ***focus-context problem***: “If we think of the problem of wayfinding as one of discovering specific objects or locations in a larger landscape, the focus-context problem is simply a generalization of this, the problem of finding detail in a larger context” **(Ware 1999, p. 274ff.)**. Variable-scale maps are one solution to the focus-context problem. Though not the topic of this work, it is important to stress the potential of multimodal user interfaces for providing solutions to the focus-context problem. Apart from relaxing the space problem of the small mobile displays, there are usage situations in which an alternative modality is more appropriate than the visual. In car navigation systems the use of the audio channel is the better solution. Furthermore, the use of more output channels transporting redundant information could help to improve the overall efficiency. Developments of interoperable speech technologies like the Speech Applications Language Tags (SALT) are interesting options for the future. For an introduction to multimodal user interfaces for mobile devices see for example **(Ringland and Scahill 2003; Oviatt et al. 2000)**.

SALT:
www.saltforum.org/downloads/SALT TechnicalWhitePaper.pdf

(Ringland and Scahill, 2003)
Ringland, S. and Scahill, F. (2003): Multimodality — the future of the wireless user interface, *BT Technology Journal* 21(3): 181-191

(Oviatt et al., 2000)
Oviatt, S., Cohen, P., Wu, L., Vergo, J., Duncan, L., Suhm, B., Bers, J., Holzman, T., Winograd, T., Landay, J., Larson, J. and Ferro, D. (2000): Designing the User Interface for Multimodal Speech and Pen-Based Gesture Applications: State-of-the-Art Systems and Future Research Directions, *Human-Computer Interaction* 15: 263–322

Another issue coming up in designing maps for mobile devices are ***emotions***. **Norman (2002)** describes in his article how design affects emotions. The ***affective*** system judges the environment, attributing positive or negative valences. The ***cognitive*** system is interprets the world and trying to make sense. The two systems influence each other. He states "attractive things work better", but concludes that "good design means that beauty and usability are in balance" and further "the products must be affordable, functional, and pleasurable – and, above all, a pleasure to own, a pleasure to use". Along the same lines is the model of **Burmester et al. (2003)**, splitting the overall product quality in a ***pragmatic quality*** and a ***hedonistic quality***. Especially for marketing a product or service the hedonistic quality or 'joy of use' is of equal importance as the pragmatic quality. Although for the scope of this work information communication (simple but clearly designed) is important, a more ludic presentation is imaginable for many services. Especially for marketing reasons the entertainment component of services is becoming more and more important.

(Norman, 2002)
Norman, D. A. (2002): Emotion and Design: Attractive things work better, *interactions*(july + august): 36-42

(Burmester et al., 2003)
Burmester, M., Hassenzahl, M. and Koller, F. (2003). "Usability ist nicht alles - Wege zu attraktiven Produkten." i-com Zeitschrift für interaktive und kooperative Medien(1): 32-40, 2002

4.2.7 Technology in mobile cartography

There are a lot of technical issues involved in mobile cartography. Many of them are already known from information technology, telecommunication, and web mapping. In mobile cartography technology plays two very different, almost contradictory roles:

- ***enabling function***: e.g. mobile devices, mobile Internet
- ***restricting function***: e.g. small display size, processing power and memory, bandwidth, etc.

This research concentrates on developing methods using the enabling functions of technology without addressing the restricting factors in detail, because there is reason to hope that some of these will vanish over time and the developed methods will be ready to use then. Several GI functions common in any commercial GIS count to the enabling functions. Acting as the main 'background' technology these functions are for instance overlay, point-in-polygon test, proximity analysis, buffers, length, perimeter, or area calculations. Other functions have been described in section 2.2.2 in regard to location based services.

4.2.8 Summary

This chapter has introduced a new and comprehensive framework for a mobile cartography. The one-sidedness of most existing approaches and solutions together with a too technology oriented approach mainly in the field of LBS have not yielded appropriate solutions. With this framework a more holistic view of the problem of visualising geographic information on mobile devices has been established. The single aspects of mobile cartography have been examined in depth. However, they are all related to each other.

The central element of the framework is context, because it offers a frame for all the other elements. The user performs his/her activities within a context. Through this activity context a dependence of other elements grows, namely the mobility, information, technology and visualisation.

For the domain of mobile cartography location is the most important element connecting all the others. The user is located, other geospatial objects are located around this location, the activity takes place, technical infrastructure is bound to a location, and the object of visualisation is the location. The matter of scope and scale is connected to this location.

Knowing the context of usage is a prerequisite for adapting the geovisualisation, and of all the context elements the most important one for adaptation is the user activity. It is also the most difficult one to gather.

Chapter 5

Adaptive visualisation of geographic information

"Point the remote control at the video recorder.' V. easy. 'Turn to Index.' Aargh, horror list with 'Timer controlled simultaneous HiFi sound recordings', 'the decoder needed for encoded programmes', etc. Merely wish to record Penny Husbands-Bosworth's rant, not spend all evening reading treatise on spying techniques."
– Helen Fielding, "Bridget Jones's Diary"

5.1 Transfer of the adaptation concept to geographic information visualisation

The adaptation concept described in its general form in chapter 2 can be transferred to the cartographic domain. Although adaptation methods can principally be applied to geovisualisation in general, the major benefits are expected in the mobile domain. The adaptation of mobile geovisualisation is covered in section 5.4 preceded by a discussion of the general concepts and the process of adaptation in the cartographic domain and a study of the relationship between generalisation and adaptation.

As it is the case with adaptive hypermedia and adaptive user interfaces, the goal of introducing adaptation mechanisms into cartography is to help users to employ geographic information more efficiently (usability), fitting the presentation to their needs and the limited resources (small display), and enhancing the overall relevance. The result of adaptation in this setting is an ***adaptive map*** that can be defined here as a map or map-like visualisation adapted to a significant extent autonomously by a system or service. Although the long-term objective is to provide users adaptive maps or geovisualisation that – if at all – only requires marginal adjustments, a few basic principles need to be adhered:

- the adaptation has to be ***transparent***, i.e. the user needs to know that adaptation takes place and it should be whenever possible in the form of ***suggestions***
- the user will always have the overall ***control***, i.e. the user can decide whether he/she wants adaptation at all or at certain stages
- the adaptation needs also to be ***adaptable***, i.e. the user can always change – if desired – the geovisualisation by himself and to the same amount as the adaptive behaviour of the system

Adaptation affects the idea of interactive systems. ***Interactions*** are certainly essential for initiating questions or information demands. However, adaptive behaviour should minimise interactions and on the one hand they should be reduced to the very essential and necessary ones, on the other hand interactions themselves could be adapted in the sense of aggregating or abstracting interactive functions, as well as changing style or structure of interactions. A well known example is the distinction into two major user roles: the novice and the expert. The overall system functionality is the same for both, but some functions could be hidden or aggregated to a more coarse function with fewer parameters for a novice user.

5.2 Adaptation dimensions in geographic information visualisation

If adaptation is studied in cartography, different domains that are affected have to be separated. The following four domains can be identified (Fig. 34):

1) ***information domain***: the information *content* is adapted to the current situation, user, activities, and system in use
2) ***user interface domain***: the user *interface* is adapted to the current situation, user, activities, system in use, physical conditions, and mobility (medium and mode)
3) ***presentation domain***: the *visualisation* of the information will be adapted to the situation, user, activities, co-located objects, system in use, physical conditions and mobility
4) ***technology domain***: the information *encoding* is adapted to specific *devices* with different characteristics (display size and resolution, memory, processing power, etc.) or to the transmission media (e.g. network bandwidth)

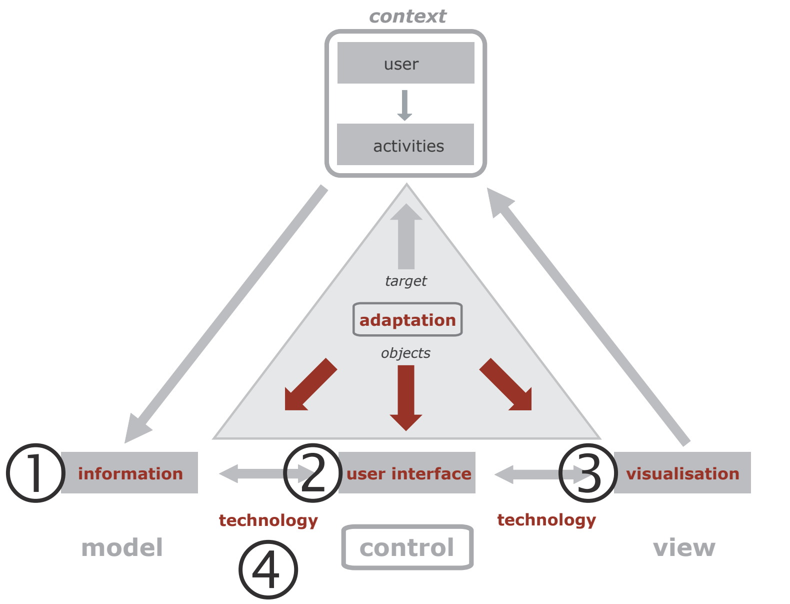


Fig. 34: Domains of adaptation

Basically these domains correspond to the major categories in mobile cartography that can be adapted. They will be explained further in section 5.2.2. As explained earlier, the technological domain is only of secondary interest for this work. Moreover, the user interface domain is only very briefly covered, since the discussing of adapting map user interfaces would overstretch the extent of this research.

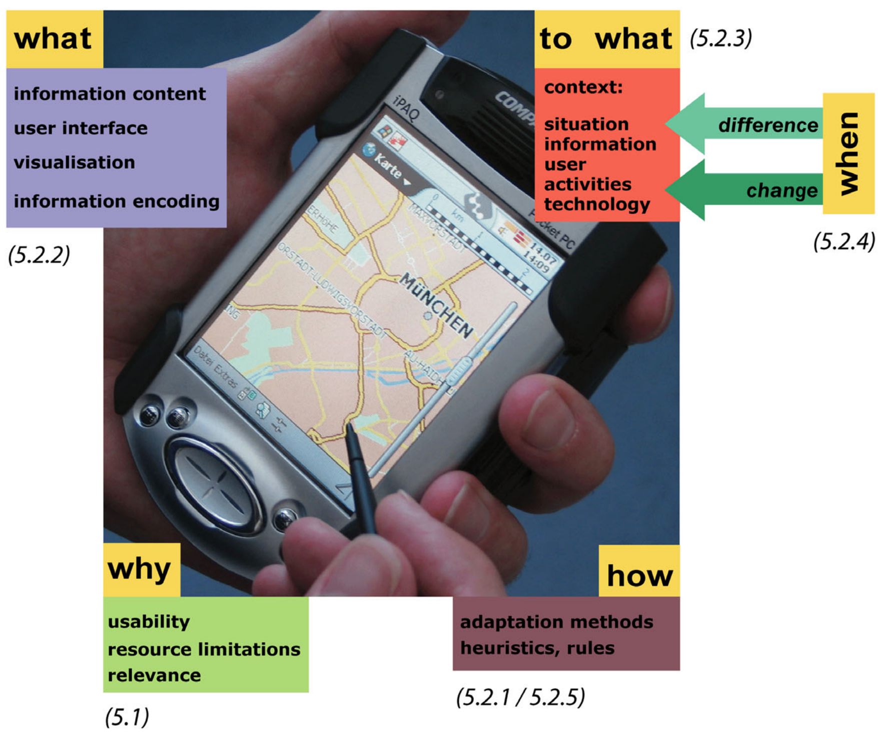


Fig. 35: Dimensions of adaptation in mobile cartography

(Brusilovsky, 1996)
Brusilovsky, P. (1996): Methods and techniques of adaptive hypermedia, *User Modeling and User-Adapted Interaction* 6(2-3): 87-129

Fig. 35 shows the various dimensions of adaptation **(Brusilovsky 1996)** in geovisualisation (the numbers in the figure refer to the sections of this chapter where the dimensions are discussed in further detail):

- ***why***: the reasons for adapting geovisualisation have been mentioned in section 5.1.
- ***what***: section 5.2.2 lists the potential objects that could be adapted
- ***to what***: section 5.2.3 looks on the factors to which the objects are adapted to
- ***when***: section 5.2.4 covers the timing and triggering of adaptation
- ***how***: the process of adapting the adaptation objects (5.2.2) is explained in section 5.2.1 for the overall adaptation process; section 5.2.5 examines the actual methods (adaptors) that perform the adaptation tasks
- ***how well***: the evaluation of the adaptation solution is briefly addressed in section 5.2.6

The dimensions of adaptation depicted in Fig. 35 reflect the most universal structure. Another important differentiation of adaptation can be made for the field of cartography or visualisation in general. Whereas the dimensions mentioned in Fig. 35 refer more to adapting the mobile map to external context factors, the map in itself can internally be adapted. An example is the adaptation of text and symbol placements in order to avoid overlaps. The first case is ***external adaptation*** and the latter ***internal adaptation***.

(Marriot et al, 2002)
Marriott, K., Meyer, B. and Tardif, L. (2002): Fast and Efficient Client-Side Adaptivity for SVG, *Proceedings WWW2002*, Honolulu, Hawaii, May 7-11, 2002

An internal adaptation could be understood as a self-adaptation in the sense as depicted in Fig. 12. All adaptation stages would be controlled by the system resulting in complete ***self-adaptive maps***. An approach to self-adaptive maps is the introduction of constraints. A proposal for using constraint-based SVG is described by **Marriott et al.(2002)**.

5.2.1 Adaptation process

The process of adaptation, as outlined in Fig. 36, takes several steps **(Thévenin and Coutaz 1999; Calvary et al. 2001; Alatalo and Peräaho 2001)**. The first step is the recognition of the context, the ***adaptation target***. The adaptation target comprises the elements to which the geographic information visualisation is adapted to. These target elements for the adaptation are recognised by the system, involving sensing the context. Some elements, such as preferences, could be predefined by the user and stored in a profile. The adaptation is ***triggered*** by any change or difference (between state S and state S') of location, user, activity, information demand or system, exceeding a specified threshold. Therefore, next to sensing the context changes of context need to be detected and change measures have to be defined. Since there exist no threshold values for maps, i.e. for the context change measures, these values need to be found empirically. These threshold values indicate states where either one or all of map encoding, map content, map user interface, or map visualisation do not fit the current context, i.e. are poorly adapted to this context. An adaptation could also be triggered by an event. If an adaptation is triggered, the system has to provide a reaction to the context change. The context parameters are input to the ***decision engine*** that checks, if, based on the identified context, an adaptation is necessary at all and selects an appropriate adaptation strategy. If an adaptation is triggered, the ***adaptation engine*** is invoked that selects appropriate methods with parameter settings and applies rules selected from the adaptation model. Furthermore the adaptation engine chooses the objects that will be adapted. The last step builds the adaptation execution, i.e. the construction of the ***adaptor***. This adaptor effects the changes of the adaptation objects through applying the chosen methods, parameter values, and rules.

(Thévenin and Coutaz, 1999)
Thévenin, D. and Coutaz, J. (1999): Adaptation and Plasticity of User Interfaces, *Proceedings i3-spring99Workshop on Adaptive Design of Interactive Multimedia Presentations for Mobile Users*, Barcelona. http://research.nii.ac.jp/~thevenin/papiers/I3Workshop1999/I3Workshop99.pdf

(Calvary et al., 2001)
Calvary, G., Coutaz, J. and Thévenin, D. (2001): Supporting Context Changes for Plastic User Interfaces: A Process and a Mechanism, *Proceedings Joint Proceedings of HCI 2001 and IHM 2001*, Lille, France

Alatalo and Peräaho, 2001)
Alatalo, T. and Peräaho, J. (2001): A Modelling Method for Designing Adaptive Hypermedia, *Proceedings Eight International Conference on User Modeling (UM2001) - Third Workshop on Adaptive Hypertext and Hypermedia*, Sonthofen, Germany, July 13-17, 2001 http://wwwis.win.tue.nl /ah2001/papers/alatalo-1.pdf

The design of an adaptive system or service requires at least two models **(Krogsæter and Thomas 1994, p. 80 ff.)**:

- ***task model***: this model describes the user tasks or activities and the changing needs of the user over time; a simple model of elementary user actions has been discussed in section 4.2.2
- ***user model***: this model addresses user roles and the belonging to a user group describing different needs for different user groups or roles

(Krogsæter and Thomas, 1994)
Krogsæter, M. and Thomas, C. G. (1994): Adaptivity: System-Initiated Individualization, *in* R. Oppermann (Ed.), *Adaptive User Support: Ergonomic Design of Manually and Automatically Adaptable Software,* Hillsdale (NJ): Lawrence Erlbaum Associates, 67-96

Both models profit from activity theory. Further important models are:

- ***domain model***: in this model knowledge about the real-world domain is captured. It is an information model that could be treated as a geo-ontology in the sense mentioned in section 4.2.4
- ***system model***: this model keeps the knowledge about the system, i.e. the capabilities of the device, the functions available, etc.
- ***adaptation model*** **(De Bra et al. 2003)**: the adaptation model consists of the adaptation rules that basically specify how the adaptation should be effected.

(De Bra et al., 2003)
De Bra, P., Aerts, A., Berden, B., de Lange, B., Rousseau, B., Santic, T., Smits, D. and Stash, N. (2003): AHA! The Adaptive Hypermedia Architecture, *Proceedings HT'03*, Nottingham, UK, 26-30 August, 2003

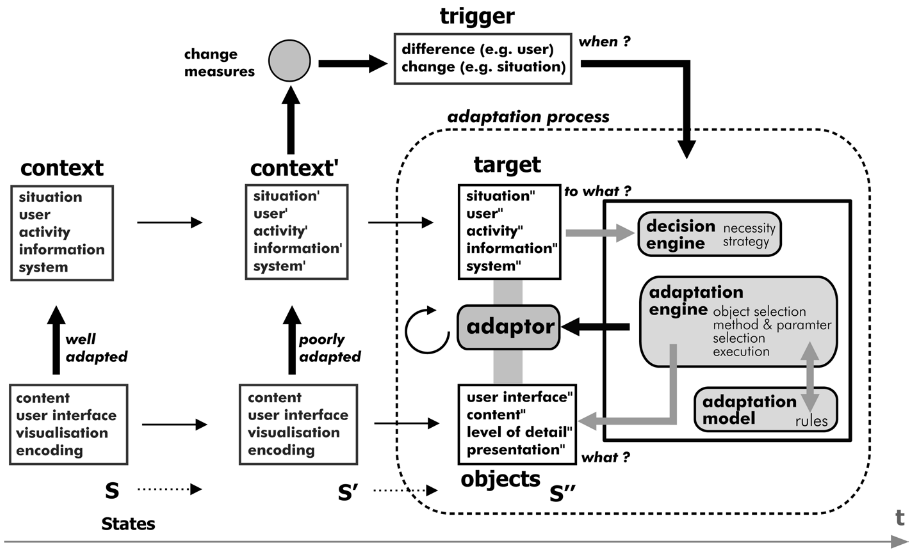


Fig. 36: Adaptation process in mobile cartography

More details on the difficult and very important question of timing, i.e. triggering of adaptation are discussed in section 5.2.4.

5.2.2 Adaptation objects

Theoretically all properties and functions which play a role in the design and usage of geovisualisation are potentially adaptable objects. Fig. 37 shows these adaptable objects grouped in three categories according to the domains mentioned earlier in section 5.2. Table 11 shows these adaptable objects, further divided in more global (e.g. map style) and local (e.g. symbol size) aspects. The user interface is often shaped and constrained by the device in use. For instance, a PDA with a touch-sensitive screen allows for other interactions than a Smartphone with a keypad, thus the interaction style needs probably some adaptation. The interactive map functions' availability or granularity could also be adapted. That means certain functions need to be hidden or aggregated to a more coarse function. Furthermore the interaction mode can be adapted, i.e. depending on the current function the interaction mode is changing (e.g. from pointer to text entry). The geographic information can be adapted in different ways. Selecting, adjusting amount and level of detail (LoD), classifying, and grouping information are all forms of information adaptation. Another form is the adaptation of information encoding due to capabilities of devices or constraints of the mobile network (e.g. bandwidth). However, most important to mobile cartography is the adaptation of the visualisation. Map section and map scale are global objects adaptable in the visualisation. The visualisation method used, i.e. graphics or photo, 2D or 3D, photo-realism or abstraction can also be object of adaptation. A landmark could for instance be displayed as an abstract symbol or a small photograph depicting the object. Dimension is another adaptable object in the visualisation process. Like in generalisation, it refers to the fact in what dimension a feature is represented, e.g. a city as an area or a point element. Last but not least symbolisation parameters (graphical variables) and text attributes are adaptable. It is obvious that certain objects are constrained by or dependent on others. Not all of these potentially adaptable features in the geovisualisation process are equally adequate for adaptation. Further research will have to focus on the relevance and validity of these objects for the adaptation process. So far, it is only fair to assume that adapting all objects at once would definitely overstretch the principle of usability, the main goal of adaptation.

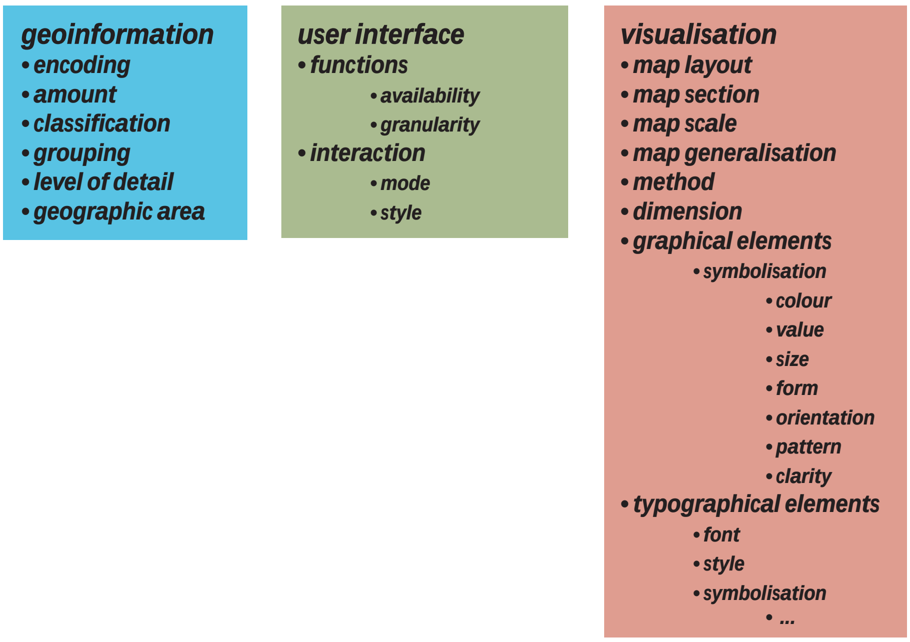


Fig. 37: Adaptable objects in the geovisualisation process

In a next step, the adaptable objects can be listed with their attributes and value domains. The adaptation objects listed in Table 11 can be attached to different levels of adaptation.

- high level: e.g. visualisation method, encoding, scale
- low level: e.g. colour, font

The 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 per se.

adaptation objects	attribute / variable / parameter	value
map features		
	selection	{attribute|spatial|temporal} condition
	grouping	condition
	classification	class definition
	geographic area	boundingbox: xmin, ymin, xmax, ymax
map interaction		
	modality	{visual, acoustic, cross-mode}
	style	{point_and_click, forms, menus, queries, natural language}
	mode	{select, pan, zoom, enter}
map functions		
	pan	{available, hidden, disabled}
	zoom	…
	select map area	…
	select map layer	…
	select map object	…
	point to	…
	show attributes	…
	calculate distance	…
	calculate perimeter	…
	calculate area	…
	redraw	{available, hidden, disabled}
map layout		
	title	{presence, position, size}
	legend	{presence, position, size}
	scale bar	{presence, position, size}
map style		
	method/form/graphic structure	{image, perspective, map, topogram}
	map section (spatial focus)	{bounding box|centre (x, y), radius r|place name|activity region}
	map orientation	degree
	map scale	scale factor

	level of detail generalisation	LoD operators, algorithms, parameters, sequence
map graphics		
	dimension position colour value size orientation form pattern opacity clarity	point, line, area (x,y) CMYK,RGB,HSV,HEX {mm, px, %} degree {square, triangle, circle, ellipse} { … } {{0,1}|%}
map text	*map graphics attributes* + font style	 font_name {plain, bold, italic, bolditalic}

Table 11: Adaptable objects of geovisualisation and their value domains

Not all the objects in Table 11 are adapted and especially not all at the same time. Without empirical studies it is hardly possible to state the objects that have to be adapted and the ones that do not have to. It is important to establish a kind of mapping table between the context dimensions (adaptation target) and the corresponding adaptation objects. Furthermore the degree of adaptation, i.e. the change of attribute values, needs to be empirically found.

5.2.3 Adaptation target

In chapter 4 the primary target of adaptive visualisation, the ***usage context***, has been discussed. The basic dimensions of context which can be adapted to individually or in any combination have been put as user, the current activity, information existent in the usage situation, and the system factors.

A pragmatic categorisation of factors influencing the adaptation of geographic information visualisation is provided by **De Carolis et al. (2001)**. They differentiate the factors on their persistence value. The first group of factors are those that persist during time or evolve slowly. These long living factors are associated with the user, his/her characteristics, preferences, knowledge, skills, and interests etc. The other group comprises factors that are related to a specific usage situation. These factors are more context-dependent and of shorter life. The authors regard the environment (physical and social), the user activity, and the device characteristics as belonging to these 'context factors'.

(De Carolis et al., 2001)
De Carolis, B., de Rosis, F. and Pizzutilo, S. (2001): Context-Sensitive Information Presentation, *Proceedings Eight International Conference on User Modeling (UM2001) - Workshop on User Modelling in Context-Aware Applications*, Sonthofen, Germany

This differentiation mirrors in a way the distinction between user modelling (UM) and context modelling. Although in this work the user is considered as part of the context and would have to be modelled within the context, it is worth considering the work in the field of UM. Any adaptation to the user or personalisation requires a sound model of the user. Substantial research on UM has been done in the fields of web content adaptation, adaptive hypermedia, and adaptive user interfaces. Generally an individual user is the source of modelling. However, as mentioned earlier the user as a target of adaptation does not always have to be an individual, but it could also be a group of users or a whole user community. In analogy **Saari and Turpeinen (2004)** distinguish between ***user modelling*** (individual user profiles), ***group modelling*** (clustered profiles based on similarities), and ***community modelling*** (profile of the social group as a whole).

General UM literature for mobile computing:

(Byun and Cheverst 2001)
Byun, H. E. and Cheverst, K. (2001): Exploiting User Models and Context-Awareness to Support Personal Daily Activities, *Proc. Eight Internat. Conf. on User Modeling (UM2001) - Third Workshop on Adaptive Hypertext and Hypermedia*, Sonthofen, Germany, July 13-17, 2001. orgwis.gmd.de/~gross/um2001ws/papers/byun.pdf

(Kules 2000)
Kules, B. (2000): User Modeling for Adaptive and Adaptable Software Systems. http://otal.umd.edu/UUGuide/wmk/

(Specht *and* Oppermann 1999)
Specht, M. and Oppermann, R. (1999): User Modeling and Adaptivity in Nomadic Information Systems, *Proc. i3 Annual Conference: Community of the Future*, Siena, Italy, Oct. 20 - 22, 1999

(Saari and Turpeinen, 2004)
Saari, T. and Turpeinen, M. (2004): Towards Psychological Customization of Information for Individuals and Social Groups, *in* J. Karat and K. M.-C. (Eds.), *Personalization of User Experiences for eCommerce (in press)*, Boston (MA): Kluwer Academic Publishers

5.2.4 Triggers and control of adaptation processes

The discussion of adaptation is related to the question when a map should or must be adapted. It can be argued that a map is well adapted (needing no adaptation) if it fits well into the context at hand. This means the map shows relevant information matching the user's activity and interests, is capable of answering the user's questions and is clearly legible on the device. These dimensions form a multidimensional value space. The space covered by all value combinations meeting the fitness function, build an ***adaptation zone***. This is similar to the ecological concept of ***niches*** discussed in **(Gatrell 1983, p. 147ff.)**. In ecology a niche is defined by the tolerance ranges for environmental factors such as temperature, humidity, etc. This relationship can be expressed as a function of the organism and the environmental parameters. In biology a distinction between the fundamental niche, delimited by the tolerance values, and the realised niche is made. The realised niche depends on other species. Niches of different species can overlap **(ibid., p. 147)**. Applied to maps, it is possible to speak of ***map niches***. The idea of adaptation zones in which a map is well adapted to its 'environment' is similar to the concept of ***map capacity*** for generalisation proposed by **Ratajski (1967)**. Likewise **Cecconi (2003)** introduced the term ***limits of applicability*** with respects of applying LoD for different scales. Related to these two concepts is the ***saturation*** of maps indicating the threshold for the number of objects displayable on a map screen **(Arikawa et al. 1994)**.

(Gatrell, 1983)
Gatrell, A. (1983): *Distance and Space. A Geographical Perspective*, Oxford: Clarendon Press

(Ratajski, 1967)
Ratajski, L. (1967): Phénomène des points de généralisation, *in* K. Kirschbaum and K. H. Meine (Eds.), *Internatinal Yearbook of Cartography*, 7, Bonn-Bad Godesberg: Kirschbaum, 143-152

(Cecconi, 2003)
Cecconi, A. (2003): *Integration of Cartographic Generalization and Multi-Scale Databases for Enhanced Web Mapping*, Dissertation, Geographisches Institut, Universität Zürich

(Arikawa et al., 1994)
Arikawa, M., Kawakita, H. and Kambayashi, Y. (1994): Dynamic Maps as Composite Views of Varied Geographic Database Servers, *Proceedings First International Conference on Applications of Databases, ADB-94*, Vadstena, Sweden, June 21-23, 1994

For the domain of user interfaces **Calvary et al. (2001)** proposed a concept called ***plasticity***. "… a plastic user interface is able to adapt to different contexts of use while preserving usability. … The ***plasticity domain*** of a user interface is the surface formed by all couples 'platform/environment' that this user interface is able to accommodate; the boundary of this surface defines the ***plasticity threshold*** of the user interface; and a ***plasticity discontinuity*** occurs when a change of context lies beyond this boundary". Applied to maps, the simplest case would be, if the user moves in real space to a place that lies outside the map extent, thus the current context is not covered by the map anymore.

(Calvary et al., 2001)
Calvary, G., Coutaz, J. and Thévenin, D. (2001): Supporting Context Changes for Plastic User Interfaces: A Process and a Mechanism, *Proceedings Joint Proceedings of HCI 2001 and IHM 2001*, Lille, France

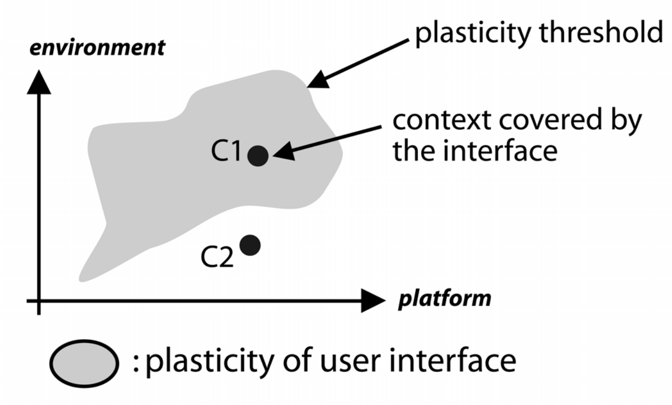


Fig. 38: Plasticity of user interfaces

All possible designs of a single map form a space termed the ***design space***. An individual design, here a map, can fit its environment if certain requirements are met. **Sloman (1998)** argues that such a "… set of constraints and requirements for a design can be called a 'niche' [and that] … different designs may fit the same niche to different degrees." In the context of design spaces adaptation can be seen as design alternatives ready to be picked by the user or self-adaptation **(Totterdell and Rautenbach 1990)**.

(Sloman, 1998)
Sloman, A. (1998): The "Semantics" of Evolution: Trajectories and Trade-offs in Design Space and Niche Space, *Proceedings IBERAMIA'98*, Lisbon, October, 1998

(Totterdell and Rautenbach, 1990)
Totterdell, P. and Rautenbach, P. (1990): Adaptation as a problem of design, *in* D. Browne, P. Totterdell and M. Norman (Eds.), *Adaptive User Interfaces*, London: Academic Press, 59-84

The central question is when the context (all or parts of) has changed so much (measures for degree of change) that the current design, i.e. map, does not fit the context, i.e. niche, anymore and an adaptation is indicated or necessary. In analogy to biology, this change could be termed adaptation pressure. The threshold values for context change can be deferred from the generic context model and have to be found empirically. These values need to be normalised, generally transposed on an interval {0,1} and are possibly weighted according to their influence. The total threshold value is an addition of the single threshold values:

$$\Delta_{total} = \Delta_{location} \cup \Delta_{time} \cup \Delta_{user} \cup \Delta_{activity} \cup \Delta_{information} \cup \Delta_{technology}$$

An ***adaptation space*** is a collection of possible adaptations of a system or service, termed adaptation cases **(Bowers et al. 2000)**. Formally, an adaptation space is a set of adaptation cases, partially ordered by the relation 'more specialised than'.

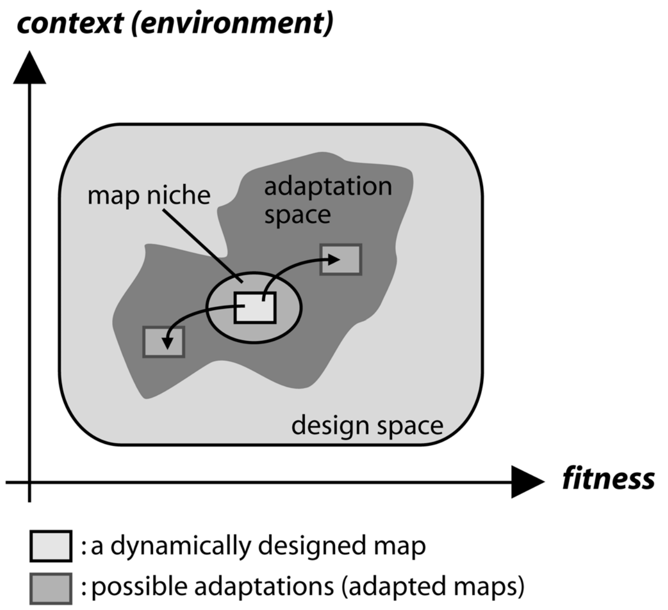


Fig. 39: Design space, adaptation space and map niche

(Bowers et al., 2000)
Bowers, S., Delcambre, L., Maier, D., Cowan, C., Wagle, P., McNamee, D., Le Meur, A.-F. and Hinton, H. (2000): Applying Adaptation Spaces to Support Quality of Service and Survivability, *Proceedings DARPA Information Survivability Conference and Exposition*, January, 2000

Bowers et al. (2000) define two spaces, performance space P and resource space R. P is dimensioned along user oriented parameters (e.g. play-out quality, response time, etc.). The acceptance region (AR) or map niche is defined as the region in which the map is considered to be working properly. R is dimensioned by resource characteristics in the operational environment (processing power, memory, bandwidth, etc.). Without adaptation there exists a mapping M: P $\Rightarrow$ R that maps AR onto region B in R. Introducing adaptation changes M so that AR now maps onto a larger region A where A normally includes B.

Adaptations may occur due to changes in ***qualitative*** aspects of usage, such as user activity, user role, place name, daytime, season, etc., or due to ***quantitative*** changes, for instance location, time, network bandwidth or device capabilities. The triggering of an adaptation through these changes invokes a strategy that determines which adaptation method is most appropriate for the current context and has to be applied. The automatic application of adaptation methods by the system requires adaptation rules in the form of production rules (if <condition> then <action>) or constraints. Both threshold values of the quantitative measures and qualitative factors can be used in such production rules. Quantitative factors could also be transferred into qualitative values. An example is the inference from speed to a means of transport (foot, bicycle, car) and then an application of the rule if (means_of_transport) = "car" then scale = 1:150'000. In that sense an adaptive system can be understood as an expert system. For showing an adaptive behaviour, i.e. being able to perform valid and appropriate adaptations, the system must have a built-in learning component for the knowledge acquisition. Constraints can be used for adaptive maps in regard to their self-adapting behaviour, for example the adaptation to 'map capacity'. If a user request returned a map that is too overloaded and cluttered for a PDA, an adaptation in the form of a prioritisation would have to take place. Or, if graphical conflicts such as symbol or text overlap arise from the automatic generation of a map (Fig. 40, left), an internal constraint-based adaptation could solve these problems (Fig. 40, right).

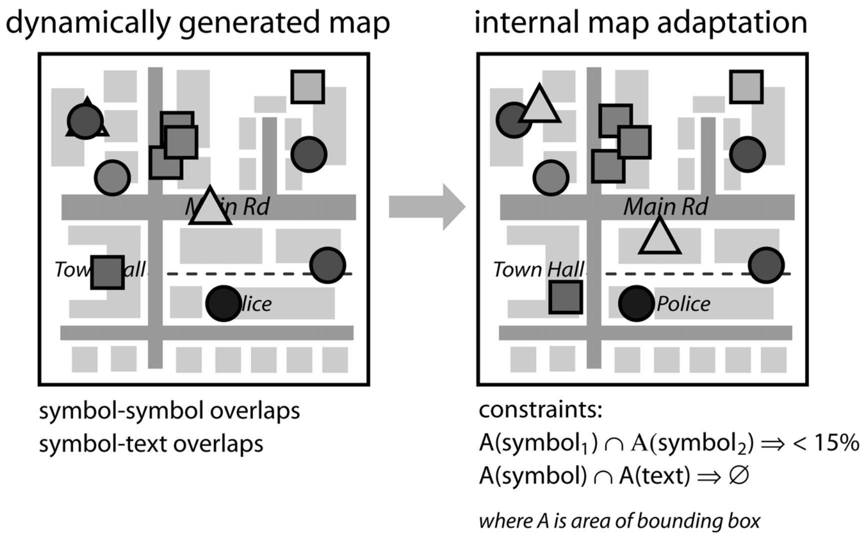


Fig. 40: Internal map adaptation based on constraints

Constraints are a common tool in design methodology and can be understood as "… a limitation that reduces the number of possible acceptable solutions to a problem. … [or] a design specification to which solutions should adhere …" **(Weibel and Dutton 1998, p. 2)**. The constraint-based approach to map generalisation can also be used in map adaptation. **Beard (1991, p. 124)** distinguishes graphic, structural, application, and procedural constraints. Graphic constraints are mainly determined by the display properties and correspond approximately to minimal dimensions. Structural constraints relate to maintaining spatial and attribute relationships. Application constraints are dependent on the map purpose and are for instance the geographic area to be displayed,

(Weibel and Dutton, 1998)
Weibel, R. and Dutton, G. (1998): Constraint- based Automated Map Generalization, *Proceedings 8th International Symposium on Spatial Data Handling*, Vancouver, B.C., July 1998

(Beard, 1991)
Beard, M. K. (1991): Constraints on rule formation, *in* B. P. Buttenfield and R. B. McMaster (Eds.), *Map Generalization - Making Rules for Knowledge Representations,* Harlow, U.K.: Longman Scientific & Technical, 121-135

the size and scale of the display, symbol types etc. These constraints are strongly connected to the constraints in contexts and are most important for mobile cartography. Finally, procedural constraints specify the sequence of actions and the order in which the constraints are satisfied. **Neema and Ledeczi (2003)** describe a constraint-based approach to self-adaptive systems. The design space is modelled as an explicit enumeration of design alternative. An adaptation is then the transition from one element in the design space into another. A concrete example of client-side adaptivity for SVG based on one-way constraints present **Marriott et al. (2002)**. One-way constraints allow the declaration of element attributes in SVG as expressions that are evaluated during runtime, i.e. rendering of the document, as the following SVG code snippet shows:

(Neema and Ledeczi, 2003)
Neema, S. and Ledeczi, A. (2003): Constraint-Guided Self-Adaptation, *in Self-Adaptive Software, Proceedings Second International Workshop, IWSAS 2001, Balatonfüred, Hungary, May 17-19, 2001, LNCS 2614*, Berlin; Heidelberg: Springer-Verlag, 39-51

(Marriott et al., 2002)
Marriott, K., Meyer, B. and Tardif, L. (2002): Fast and Efficient Client-Side Adaptivity for SVG, *Proceedings WWW2002*, Honolulu, Hawaii, May 7-11, 2002, 496-507

```
<svg width="20mm" height="20mm">
<var id="boxwidth" val="url( #(/descendant::text/[ename="tl"]))-width"/>
<var id="boxheight" val="url( #(/descendant::text/[ename="tl"))_height"/>
<rect id="bl" class="box" x="1.0in - url(#boxwidth)/2" y="0.75in -
url(#boxheight)/2" width="url(#boxwidth)" height="url(#boxheight)"/>
 </svg>
```

Any adaptation strategy must consider the user as an important factor. As stated in section 5.1 the user should always have the overall control over the system. A good adaptation strategy has to allow the user to interfere at any time. However, the internal adaptations (self-adaptive maps) will probably not need any user interaction. External adaptations should be embodied by adaptivity and adaptability. A combined approach, including adaptability and adaptivity, that might serve as model is described in **(Krogsæter et al. 1994)**.

(Krogsæter et al., 1994)
Krogsæter, M., Oppermann, R. and Thomas, C. G. (1994): A User Interface Integrating Adaptability and Adaptivity, *in* R. Oppermann (Ed.), *Adaptive User Support: Ergonomic Design of Manually and Automatically Adaptable Software,* Hillsdale (NJ): Lawrence Erlbaum Associates, 97-125

5.2.5 Adaptation methods

Adaptation methods form the last major dimension of the adaptation concept. They are part of the adaptation engine. Their responsibility is to offer procedures to adapt the adaptation objects to the adaptation target. To get a better idea of adaptation methods it is useful to contemplate the following intuitive examples:

- if a service encounters a device with a monochrome display, a colour map is reduced to grey scale
- if a service registers a significant increase in movement speed, the LoD is adjusted, i.e. the more detailed map is exchanged by a map of less detail or switches to the corresponding LoD

In analogy to the different domains of adaptation discussed in the introduction of this chapter (see Fig. 35), adaptation methods for mobile cartography can affect the information content and encoding, the information structure, the user interface or the information presentation. Content adaptation methods adapt map features; structural adaptation methods adapt map features, interaction or functions; and morphological adaptation methods adapt map style, graphics and text (cp. Table 11).

The following list gives an overview of feasible adaptation methods for mobile maps. These methods

- ***select map features*** (filters, e.g. based on user profiles)
- ***reduce*** the map content (only few object classes)
- ***reduce*** the information density (limitation to selected, important objects and information)
- ***remove, omit or eliminate map objects*** (based on map saturation or capacity)
- ***prioritise information***
- ***substitute*** or exchange equivalent presentations (map – topogram – image – text – language; e.g. symbol through image)
- ***switch*** between predefined design alternatives (e.g. map symbol styles) or encodings (e.g. languages)
- ***change presentation; (re)change symbolisation*** (e.g. different opacities for relevance) colour depth reduction; colour to greyscale; change dimensionality (area to line/point)
- ***(re)configure map components*** (e.g. different base maps or scales for different purposes or movement speeds); dynamic composition of layers for the base map (e.g. with or without public transport network)
- ***adapt the user interface*** (reducing the degrees of freedom for interactivity)
- ***change encoding*** (e.g. vector to raster, SVG to JPEG)

For the adaptation of mobile geovisualisation services, the parameters need to as ever possible be dynamically inferred from the context. The ***operationalisation*** of the parameters constitutes a big problem. If the view of **Totterdell and Rautenbach (1990, p. 61)** that "… conventional systems are special cases of adaptive systems in which the parameters have been pre-set" is accepted, the parameter values of these conventional systems could be used to guide the operationalisation process.

(Totterdell and Rautenbach, 1990)
Totterdell, P. and Rautenbach, P. (1990): Adaptation as a problem of design, *in* D. Browne, P. Totterdell and M. Norman (Eds.), *Adaptive User Interfaces,* London: Academic Press, 59-84

5.2.6 Evaluation of adaptation processes

(Höök, 2000)
Höök, K. (2000): Steps to take before intelligent user interfaces become real, *Interacting with Computers* 12(4): 409-426

(Paramythis et al., 2001)
Paramythis, A., Totter, A. and Stephanidis, C. (2001): A modular approach to the evaluation of Adaptive User Interfaces

The difficulties encountered when evaluating adaptations are discussed by **Höök (2000)** and approaches for the evaluation of adaptive user interfaces are proposed in **(Paramythis et al. 2001)**. The major problem with the attempt to answer the question when an adaptation is good is similar to the question of relevance or the quality of a generalisation solution. There are some objective criteria, but since the user is affected by the adaptation, there is always a subjective judgement involved.

Several methods and techniques for evaluating an adaptation are imaginable:

- the objective relevance could be used as a rough measure for adaptation quality
- the costs of the adaptation process
- if a map is adapted to the network bandwidth, the document size is a measure for the effectiveness
- if a map is adapted to the user, the match between the user profile and the features (e.g. categories) in the map indicate user satisfaction. The match could be determined by similarity measures and topical relevance
- log of user interactions (mainly the number of single interactions) after the reception of an adapted map could be an indicator for adaptation success

The last point emphasizes the need for a learning component in adaptive systems that takes the evaluation results as a feedback and improves the adaptive behaviour over time. The importance of learning has already been stressed in relation to the context space model (sec. 4.2.3), where through the user's interaction with the system a 'history' of contexts is captured that can be used to provide appropriate system reactions in future usage situations.

5.3 Adaptation and generalisation

As stated above, the major limitation for the geographic information visualisation on mobile devices is their small display. State-of-the-Art PDA have a display with a resolution of 240x320 pixel or a format of 60 x 80 mm. The display area ratio from an average paper map (700 x 1000 mm) to a PDA is approx. 1:150 and from a Laptop screen (12") to PDA 1:12. Of course these figures imply the necessity for map generalisation. Some approaches for map generalisation for mobile maps have been discussed in chapter 3. The question arising is whether adaptation means the same as generalisation.

Many researchers in the cartographic community do not see small display cartography or mobile cartography as an independent research field in the discipline. They believe that mobile cartography is basically a matter of map generalisation with very hard constraints due to the small display. The author argues that more fundamental issues linked to mobility are involved, and hence aims at elaborating where generalisation and adaptation are different and where they do overlap.

The author holds the opinion that generalisation and adaptation are related concepts, but that generalisation is more objective, aiming at reflecting the basic characteristics of map elements and their distribution in a preferably uniform and balanced manner. Adaptation is more subjective. The balance is often abandoned for the sake of emphasizing a relevant element. Furthermore, adaptation as understood in this work considers more factors than scale and map purpose usually applied in generalisation. Generalisation is mainly caused by the technology dimension, i.e. the small device display. As aforementioned, adaptation principally takes into account the context of the map usage, i.e. location, time, user, activities, goals, information around, and technology. In addition, adaptation potentially affects more objects in the cartographic design process.

Two different approaches for applying adaptation and generalisation are feasible: either generalisation first and adaptation second or adaptation first and generalisation second. Nevertheless in the author's opinion adaptation is the more general concept affecting objects in the cartographic design process that are not covered by generalisation (e.g. colour). In this sense, methodologically one would first apply adaptation and then generalisation. Adapting to a specific usage situation reduces the problem space for succeeding generalisation. Adaptation, however, might also make use of generalisation methods, but implements them differently. This is possible, since methods of adaptation and generalisation are very similar. The most important method for adaptation to mobile geographic information usage as well as generalisation for small displays is ***selection***. Other well known generalisation operators applicable as an adaptation method are exaggeration, elimination, combination, and typification.

Adaptation	Generalisation
broad	narrow
emphasis	abstraction
fitness to use	fitness to scale
adaptation to context	adaptation to scale

Table 12: Comparison of adaptation and generalisation

Table 12 summarises the major characteristics of map adaptation and map generalisation. It is obvious that the two concepts are not concurrent, but are completing each other.

5.4 Adaptive visualisation of geographic information on mobile devices

As discussed in chapter 3, little research has been conducted so far on the visualisation of geographic information on mobile devices. However, there are a few guidelines for the design of screen maps in general. Some of the solutions and approaches provided can also be applied to mobile cartography, but need some modifications or additions.

(Reichenbacher and Meng, 2003)
Reichenbacher, T. and Meng, L. (2003): Themenheft 'Mobile Kartographie', *Kartographische Nachrichten*(1 & 2)

(Zipf, 2002)
Zipf, A. (2002): User-Adaptive Maps for Location-Based Services (LBS) for Tourism, *in* K. Woeber, A. Frew and M. Hitz (Eds.), *Proc. of the 9th Internat. Conf. for Information and Communication Technologies in Tourism, ENTER 2002, Innsbruck, Austria, Springer Computer Science,* Berlin; Heidelberg: Springer-Verlag. http://www.eml.villa-bosch.de/english/homes/zipf/ENTER2002.pdf

There are many research questions dealing with the design of geovisualisation services, see for example **(Reichenbacher and Meng 2003; Zipf 2002)**. As a wrap-up this allows for a preliminary list of requirements for adaptive geovisualisation services. Adaptive geovisualisation services should be:

- personalised
- minimal intrusive
- location-based
- timely
- context-aware
- attentive
- proactive
- reactive
- prioritised

To meet these requirements at least partially, new or enhanced visualisation methods are demanded. Before these new ways of visualising geographic information in mobile environments will be studied, a few scenarios of mobile geographic information usage are sketched.

5.4.1 Scenarios for adaptive visualisation of geographic information on mobile devices

As mentioned above the concept of mobile cartography might seem to many people quite visionary. The author tried to explain why it is crucial to the discipline of cartography to cope with new technologies and adapt its methods to new challenges. As a proof of concept a few example usage scenarios are sketched. The scenarios are set in an urban context. One reason is that the base technologies, mobile communication infrastructure and mobile devices are first installed in urban areas. Besides the consumer base is larger in densely populated areas such as big cities. Another factor is the huge bandwidth of spatially-related activities and the immense availability of options for leisure, shopping, work etc. Another reason is related to ***technology adoption***: urban lifestyle followers tend to adopt new technologies faster than other population segments. In his theory of technology diffusion **Moore (1991)** distinguishes 5 phases of technology use or 5 groups of technology users: innovators, early adopters, chasm, early majority, traditionalists. The second group, the ***early adopters***, is of special interest for the design of the following usage scenarios. This group is technology focussed, willing to take risks, wealthy, keen on new gadgets, optimistic, and visionary. The innovator group is also the peer group for potential adopters of the future majority.

(Moore, 1991)
Moore, G. (1991): *Crossing the Chasm - Marketing and Selling Technology Products to Mainstream Customers*. New York (NY): Harper Business

The difficulty in analysing the requirements of a new mobile geovisualisation service with adaptation capabilities is that most people if asked to name their demands have problems in articulating them without a prototype. This is due to the mutual influence of activities and technologies to support them. This observation is described by **Carroll (2000, p. 67)** as the task-artifact cycle:

(Caroll, 2000)
Carroll, J. M. (2000): *Making use: scenario-based design of human-computer interactions*, Cambridge (MA): MIT Press

> *In the large, information technology appears as a coevolution of tasks and artefacts. People engage in tasks and activities. They make discoveries and encounter difficulties. They experience insight and satisfaction, frustration, and failure. At length, their tasks and experiences help to define requirements for future technology. Subsequent technological tools open up new possibilities for tasks and activities, new ways to do familiar things, and entirely new things to do. They entrain new skills to learn and perform, new opportunities for insight and satisfaction, and new pitfalls of frustration and failure. Ultimately the new tasks and new technology become a baseline, helping to evoke requirements for further technology development. This pattern, … the task-artifact cycle, emphasizes the dynamically moving window of technology development within which technical design occurs … . The task-artifact cycle is pervasive in information technology.*

Apart from the agreement that geographic information is a key demand in mobile or wireless services, studies on more concrete user requirements are rare. Yet, to capture some potential requirements for the prototypical implementation of a geovisualisation service a scenario-based design approach was taken. According to **Jarke et al. (1998)** "a scenario describes (textually or graphically) a possible set of events that reasonably take place; a scene captures the same in some form of multimedia" and thus is a middle-ground abstraction between models and reality. ***Scenarios*** are like little stories telling which activities people do in specific situations. As stories they mention or presuppose a setting, include agents or actors with goals or objectives **(Carroll 2000)**. A scenario illustrates what people can do with a new system or how this system can be used. In this sense they are a good method for describing user roles within a context or what has been termed "lifestyle snapshots" **(ui 2000)**. Scenarios are valuable here, because they are centred on the user's activities:

(Jarke et al., 1998)
Jarke, M., Tung Bui, X. and Carroll, J. (1998): Scenario Management: An Interdisciplinary Approach, *Requirements Engineering Journal* 3(3): 155-173

(ui, 2000)
ui (2000): Lifestyle Snapshots - Solving the Context Problem for Wireless Design, *ui - The Webzine for Interaction Designers*. www.uidesign.net/2000/papers/lifestylesnapshot.html

> *Scenarios evoke task-oriented reflection in design work; they make human activity the starting point and the standard for design work. Scenarios help designers identify and develop correct problem requirements by being at once concrete and flexible. They help designers to see their work as artefacts-in-use and, through this focus, to manage external constraints in the design process. Scenarios help designers analyze the varied possibilities afforded by their designs through many alternative views of usage situations. And scenarios help designers cumulate their knowledge and experience in a rubric of task-oriented abstractions* ***(Carroll 2000, p. 68f.)***.

Scenarios fit in the overall usability design process. Fig. 41 shows a general process of user requirement analysis and the role of scenarios within that process **(BTexactTechnologies 2003)**.

(BTexact Technologies, 2003)
BTexactTechnologies (2003): *Usability matters - A methodology for the design of high usability internet content*, Whitepaper, 42742, BTexact Technologies, Ipswich

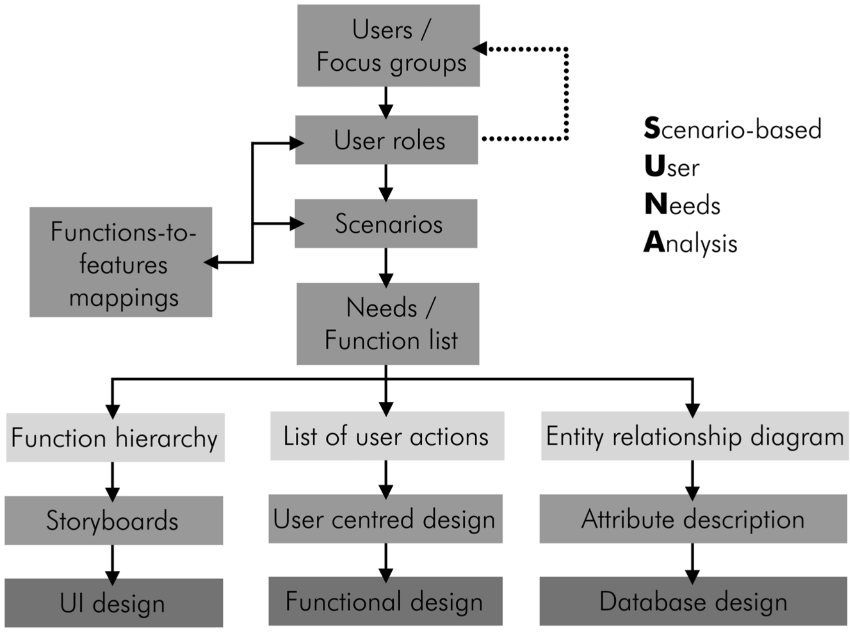


Fig. 41: Scenario based design approach (BTexactTechnologies 2003)

For the test implementation and the scenarios a city district of Munich called *Gärtnerplatz* has been selected (see Fig. 42). This district is very close to the centre, hosts a major theatre, a famous technical museum, and many bars and restaurants. Most of the people living here, but also those spending their leisure time in the area, are part of the 'yuppie' segment and belong to the early adopter group.

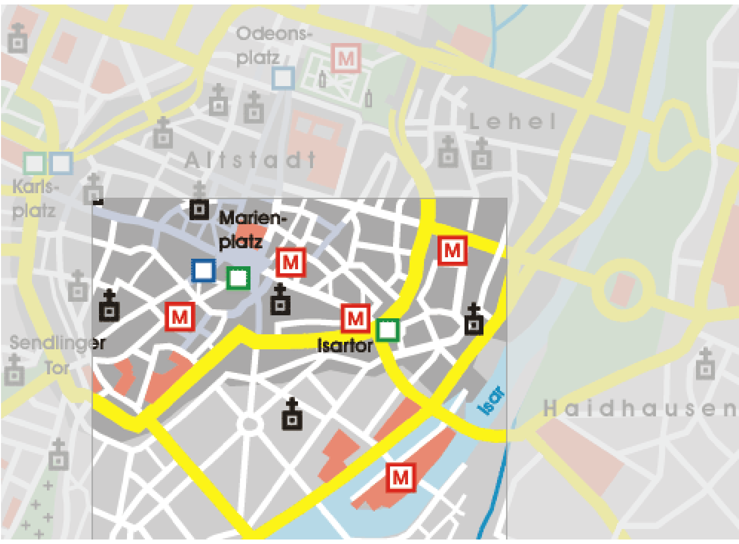


Fig. 42: Test area (map from Neudeck 2001)

Scenario 1: YUPPIE

Susan and Martin have just left their flat in the north of Munich. They are on their way to the city centre to have a good time with some friends. While Susan is driving, Martin checks on his PDA for bars with attractive Happy Hour *offers and decides to go to the* Indian Bar. *To* *know how much time they have left for finding a parking space he checks if their friends are also already on their way and where they are. Instead of calling them one by one or sending them an SMS, a quick look on the map suffices to see that they are not further than Susan and Martin. To guide Susan he searches for the nearest parking storey with spaces available. He does not know this area very well and especially has no knowledge of the one-way roads here. To be on the safe side, he has the system propose the fastest route that also includes the current traffic situation. Five minutes later Susan parks the car and the system displays them the way to the* Indian Bar *where they wait for their friends while enjoying a cocktail.*

The key issue in this scenario is the partial unfamiliarity with the surrounding and the community aspect of young urban lifestyle people. Additionally the aspect of time criticality is exemplified. For car drivers decisions have to be made rather quickly.

Scenario 2: MACHO

Friday evening, 18:57, close to 'Viktualienmarkt'. Once again John is at the last minute heading for a bunch of his girlfriend's favourite flowers. It is her birthday today. The booths on the market are of course sold out by now; time is getting scarce. He enters a spatial search for the nearest flower shop in his PDA and the received map shows him that the nearest flower shop closes at 19:00. He changes the spatial scope of the search and gets the nearest open shops. The on-the-way-home function chooses the shop closest to the route home. After having purchased a huge bunch of flowers, he presents it slightly exhausted at 19:20 to his girlfriend and they spend a relaxed evening.

In this scenario the user is a male resident knowing the spatial environment very well, i.e. has a strong mental map, but is forced to make a quick decision. For users familiar to the geographic area an adaptation could include another, more generalized base map and fewer or different landmarks.

Scenario 3: TOURIST

At 13:47 after a walk through the old part of Munich Claire Bouderin, a French tourist would like to know where she is. After a look at the map on her PDA that shows her current position, she decides to go for a shopping tour. In addition she would like to visit the 'Deutsches Museum' for at least two hours. Before visiting the Museum she wants to drop in at the hotel and leave her purchases there. The system proposes a route passing the major shops and leading to the hotel. Calculating backwards from the closing time of the museum and the time to reach it from the hotel, alerts to pass on are regularly displayed on the map and notified with sounds. Claire manages to resist a tempting shop and arrives at the hotel at 15:00. On the way to the museum she searches for restaurants in the neighbourhood and events in walking distance of these restaurants. Happy with the offers, she books a ticket for an opera at the 'Staatstheater am Gärtnerplatz' that is close to a typical Bavarian restaurant she has decided to go to for dinner after the museum visit.

The significant momentum in this scenario is the unfamiliarity of the user with her spatial surrounding. The user has no mental map of her surrounding. The base map must be much more detailed and show the basic structure of a city in Lynch's sense. The map should be poster-like, striking, and pithy. For tourists the public transport network is important. This can be visualised as a topogram connected with the time table. Further information needs of tourists are sightseeing spots (POI), food and drink, accommodation, and service points (ATM, kiosks, toilets, etc.).

The different treatment of familiar and unfamiliar geographic environments is an important issue in spatial cognition, see for some examples in **(Lovelace et al. 1999)**. This geographic familiarity has a strong influence on the selection and number of landmarks and map labels to be integrated in the map. A detailed discussion of criteria and measures for the selection of landmarks can be found in **(Raubal and Winter 2002)**. An approach for automatically extracting landmarks from geospatial data is proposed by **Elias (2002)**.

(Lovelace et al., 1999)
Lovelace, K. L., Hegarty, M. and Montello, D. R. (1999): Elements of Good Route Directions in Familiar and Unfamiliar Environments, *in* C. Freksa and D. M. Mark (Eds.), *COSIT'99, LNCS1661*, Berlin; Heidelberg: Springer-Verlag

(Raubal and Winter, 2002)
Raubal, M. and Winter, S. (2002): Enriching Wayfinding Instructions with Local Landmarks, *in* M. J. Egenhofer and D. M. Mark (Eds.), *Geographic Information Science: Second Int. Conf., GIScience 2002, Boulder, CO, USA, September 25-28, 2002. Proceedings, LNCS 2478*, Berlin; Heidelberg: Springer-Verlag, 243-259

(Elias, 2002)
Elias, B. (2002): Automatic Derivation of Location Maps, *Proceedings IAPRS Vol. 34, Part 4 Geospatial Theory, Processing and Applications*, Ottawa, Canada

In addition to the scenarios mentioned before, a few other ideas of map-related services are:

- ***everyday life planner***: activities are shown on a map and can be visualised according to their time schedule. New activities can be added by selecting in the agenda dropping on the map. The service notifies, e.g. with blinking symbols or sounds, if activities get in conflict or following activities cannot be performed in time. Such a service could be termed 'spatial diary', since it gives the user in addition to the temporal aspect a holistic overview of the spatial distributions of appointments or other activities. With an agent approach, an agent could autonomously adapt the activity plan, inform affected persons (e.g. appointments) if needed and propose alternatives. This kind of service combines decision support systems (DSS) and geographical information systems and presents all the plan information in a spatio-temporal framework.
- ***computer supported cooperative work*** (CSCW): the aspect of collaboration, touched in the preceding example, could be extended to a service supporting mobile work forces co-ordinating their activities, information, etc. with one another

(Kolbe et al., 2003)
Kolbe, T. H., Steinrücken, J. and Plümer, L. (2003): Cooperative Public Web Maps, *Proc. 21st Internat. Cartographic Conf.*, Durban, S. Africa, August, 10-16

- ***community services***: an example of such a community service is described by **Kolbe et al. (2003)**
- ***visual journal service***: (where have I been today?)

5.4.2 Adaptive visualisation methods for geographic information on mobile devices

For this work, the adaptive geovisualisation service will produce mobile maps. Such mobile maps are simple and highly generalized, should be based on cartographic principles, rendered fast, graphically concise, attractive, crisp, and legible. In addition their content should be flexible, i.e. the content should be dynamically updateable and linkable to other information. They should be adaptive to different users, activities, and situations and fit other web services. At least these services must be capable of displaying points of interest (POI) and landmarks, the geolocation of people, objects, and events, routes, and search results (i.e. people, objects, events). They should also visually emphasize order in relation to relevance, importance, priority, availability, time criticality, etc.

Scalable Vector Graphics for adaptive mobile maps

The vector approach has some advantages over the raster format, such as smaller file size, flexibility, which will be honoured in the mobile environment. Among different vector formats on the Web, SVG seems to be especially useful for good reasons. SVG has a couple of features making it almost predestined for usage on mobile devices:

- open XML based format
- compact, i.e. small file size
- programmatically changeable through the Document Object Model (DOM)
- scriptable using the DOM
- linkable
- adaptable
- legible, i.e. no detail loss while zooming; better text readability
- searchable
- animations are incorporated

(Neumann and Winter, 2000)
Neumann, A. and Winter, A. (2000): *Kartographie im Internet auf Vektorbasis, mit Hilfe von SVG.* http://www.carto.net/papers/svg/index_d.html

SVG & Cartography: www.carto.net

If this list of features is compared with the requirements of adaptive maps or an adaptive geovisualisation service, a significant match is obvious. **Neumann and Winter (2000)** describe the features of SVG that can be applied to cartography. From a cartographic perspective the prominent elements of SVG are the `<path>` element for describing irregular geometric boundaries of map features, the `<g>` tag for grouping similar map elements for symbolisation or manipulation, the `<script>` tag for including some logic into to documents allowing for interactivity or event-based manipulation of elements, the `<textPath>` element which can display texts along a path, and eventually the `<symbol>` and `<use>` tag to define reusable elements such as point symbols.

SVG

SVG 1.1 Specification: www.w3.org/TR/SVG11 Mobile SVG

Profies: www.w3.org/TR/SVGMobile

Meanwhile quite a few map applications and projects use SVG as format (see for examples on www.carto.net). Although these examples address rather the desktop web mapping environment, they show the advantages and major methodology that will also apply to some degree for mobile cartography. SVG 1.0 was mainly designed with desktop PCs in mind. It works well for them as the applications mentioned above show. However, since mobile devices can differ quite a lot in their characteristics and are all more or less limited compared to desktop PCs, SVG 1.0 runs into some problems in the mobile environment. The current specification SVG 1.1, a W3C recommendation, tackles this problem. The modularisation of SVG 1.1 lays the basis for an adapted subset of SVG more suitable for mobile devices. In SVG 1.1 the content of SVG 1.0 plus some additional features are grouped into a set of modules. ***Mobile SVG*** uses these modules to set up two profiles, ***SVG Basic*** and ***SVG Tiny*** that are part of the 3GPP platform for third generation mobile phones. SVG Basic is aimed at PDAs and SVG Tiny at mobile phones. SVG Basic is of special interest for the purposes of a more advanced geovisualisation service as used in this work. It comprises a subset of the 1.1 modules. The idea is that SVG 1.1 can be transcoded to SVG Basic with the least loss of functionality necessary. Apart from text, clipping, and filter module all modules of SVG Basic correspond to the full specification of SVG 1.1.

Information organisation concepts and information layering

Structuring relates to the decomposition of a mobile map into several single SVG documents, but also to the arrangement of unique elements or layering within a single SVG document. A first simple approach is the separation of the geospatial information into two groups: the core layer is constituted by the base map including the geometric reference, (e.g. buildings, major roads, rivers and so on), maybe enriched by public transport network and major landmarks. The second group are the superimposed thematic layers of information that will be changed more often and maybe dynamically (e.g. POI, routes, point symbols, further text/labels, dynamic landmarks, geolinks, routes, directions, events, weather, traffic information etc). The base map and the dynamic map are stored in separate SVG documents. These additional layers can be referenced from the main map, generally the base map, as SVG fragments using `xlink:href`. With geospatial hyperlinks (geolinks) the representation of associations between different resources (features, images, documents, etc.) become possible.

In a single SVG document the structure affects order, grouping, and reusability of elements. Most importantly the order of elements in the document has the major impact on the visualisation, due to the SVG rendering principle which paints the elements in the document in the order of appearance. Point symbols within a SVG document can for instance be defined as `<symbol>` within the `<defs>` tags at a central place and be referenced using the `<use>` tag and an `xlink:href` at the place needed. The referencing of external SVG documents is currently only supported by the Batik 1.1 Squiggle Browser.

Apache Batik:
xml.apache.org/batik

Adaptation methods examples with SVG

For some of the adaptation methods discussed in section 5.2.4 a counterpart can be found in geovisualisation adaptation. In the following some adaptation methods are described as a combination of map theory (syntactical rules, e.g. graphical variables) and constraints of mobile devices (e.g. graphical effects of raster technology).

Probably the most important task in adapting the geovisualisation is highlighting important features to emphasize their importance or relevance. Graphical means to put a ***visual emphasis*** or ***focus*** on a feature are:

- highlighting the object using a signal colour, e.g. pink or yellow (***colour***)
- emphasizing the outline of the object
- enhancing the contrast between the object and the background
- increasing the opacity of the object while decreasing the opacity of the others (***opacity***)
- focussing 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)

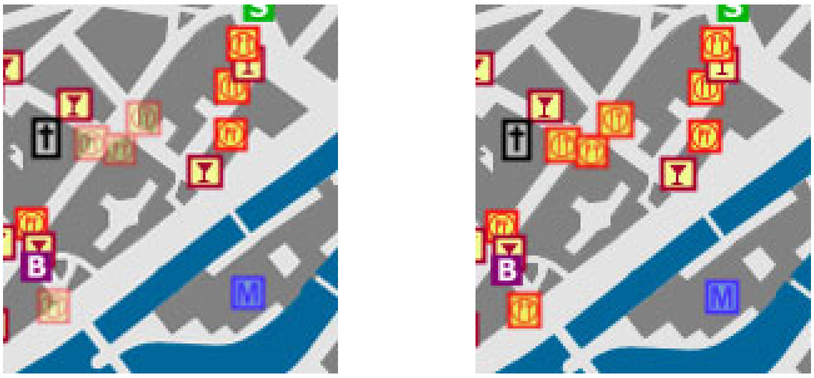


Fig. 43: Methods for emphasizing map objects: opacity and crispness

The geometric basis depicted in Fig. 43-44, Fig. 45 left, Fig. 46 right, Fig. 48-51, and Fig. 57 are all based on data form and are copyright 'Städtisches Vermessungsamt München'
Fig. 45 right and Fig. 47 are based on data from and are copyright 'Bayerisches Landesvermessungsamt', München

Fig. 43 shows two examples of relevance symbolisation using the graphical variable opacity (left) and crispness (right). Size is not a useful graphical variable, because the map space is limited anyway. An exception is the use of size as a variable of animation, e.g. the increasing and decreasing of size by clicking on a map feature or text label.

Apart from emphasizing 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. The total relevance value from the event example (see Table 10) can be directly mapped to the opacity value of the SVG style attribute. The result set of a search activity 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.

The spatial relevance of map features might also be visualised with ***buffers*** depending on the spatial relevance measure. ***Data quality*** or ***context validity*** can be visualised as ***zones*** that can be transparently overlaid over the actual geographic information. Also other information types could be overlaid as additional semitransparent layers, e.g. a ***compass*** for orientation purposes (Fig. 44, left), the ***map scale*** as a ***distance ring*** or buffer or temporal reachability as time rings (Fig. 44, right). The user can interactively switch on and off such information.

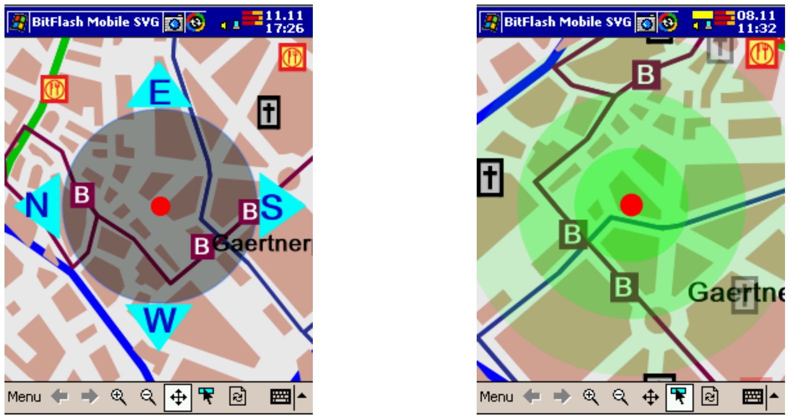


Fig. 44: Semi-transparent overlay in mobile maps for orientation or distance information

Less important or less relevant information can be displayed as layers or groups of map features with lower opacity or lighter colour. This moves this information in the visual middle ground and emphasizes the more important information. This could also 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***. 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.

The change of activities can also result in a change of spatial scope. For example the first user activity has a local scope, thus a large scale map is used. Then, the user performs an activity with a regional scope. The large scale map is not covering the whole area of interest for the activity and a change of scale is appropriate. The change of mobility medium can have the same effect, for example the change from walking to riding a bus. Fig. 45 shows two base maps of different scales.

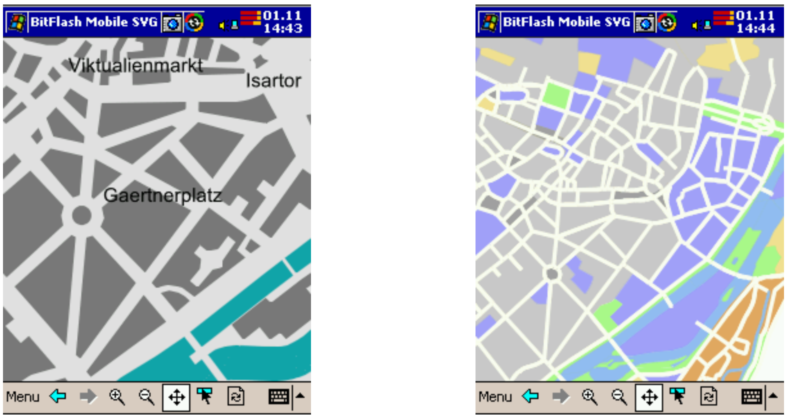


Fig. 45: Map scale adaptation

Hierarchy in user activities according to AT (activity, action(s), and operation(s)) should be if possible mirrored in a hierarchy or sequence of information presentation: e.g. from an overview map to a detail map, from an overview schematic map (or topogram) to a detailed map or first an address search, second display of address location on map, and third textual route description to the address. The begin of an activity can be triggered by a local action requiring a local map. The planning or further performance of the activity might require a more global map, and the actions to take again further local maps.

When regarding the usability of a map, an important criterion is ***utility*** in the sense of being useful for conducting the current ***activity***. There is no consistent terminology for maps that are designed for user activities: 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)**. The view taken here is that maps applying adaptation methods as mentioned before can be termed ***ego-maps***, because they are egocentric in the sense that the user is in the centre. This centre can be the spatial centre, the centre of activity, the centre of interest and so on.

An ***activity map*** is a map that is adjusted to the current user activity and focuses on one or more included elementary spatial action (locating, navigating, searching, identifying, and checking). The view to design a product or service around a user activity is best grasped by **Rosson and Carroll (2002, p. 81)** stating:

> *We prefer the phrase "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.*

(Zipf and Richter, 2002)
Zipf, A. and Richter, K.-F. (2002): Using Focus Maps to Ease Map Reading: Developing Smart Applications for Mobile Devices, *Künstliche Intelligenz*(4): 35-37

(Barkowsky and Freksa, 1997)
Barkowsky, T. and Freksa, C. (1997): Cognitive Requirements on Making and Interpreting Maps, *in* H. S. and A. Frank (Eds.), *Spatial Information Theory A Theoretical Basis for GIS*, Berlin; Heidelberg: Springer-Verlag, 337-361

(von Hunolstein and Zipf, 2003)
von Hunolstein, S. and Zipf, A. (2003): Towards Task Oriented Map-based Mobile Guides, *Proc. Internat. Workshop "HCI in Mobile Guides" at Mobile HCI 2003, 5th International Symposium on Human Computer Interaction with mobile Devices and Services*, Udine, Italy, September 8-11, 2003

(Rosson and Carroll, 2002)
Rosson, M. B. and Carroll, J. M. (2002): *Usability Engineering: Scenario-Based Development of Human-Computer Interaction*: Morgan Kaufmann

(McCullough, 2001)
McCullough, M. (2001): On Typologies of Situated Interaction, *Human-Computer Interaction* 16: 337-349

Such an approach requires an ***activity ontology*** or ***activity typology***. **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. **Wang and Cheng (2001)** offer a spatio-temporal data model to support activity based transport demand modelling in a GIS environment. Their approach models activity patterns as a sequence of staying at or travelling between activity locations and supports location-based, time-based, and person-based analysis and querying of activities. The notion of activity patterns suggests that some activities show regularities regarding space and time (e.g. locations, sequence, and frequency) and can be attached to specific geospatial objects.

(Kuhn, 2001)
Kuhn, W. (2001): Ontologies in support of activities in geographical space, *International Journal Geographical Information Science* 15(7): 613-631

(Wang and Cheng, 2001)
Wang, D. and Cheng, T. (2001): A spatio-temporal data model for activity-based transport demand modelling, *International Journal Geographical Information Science* 15(6): 561-585

Despite setting up activity ontologies ***activity zones*** have to be modelled for the purpose of activity maps. An activity zone can be defined as the region or spatial scope of an activity (see Fig. 22). However, the zoning cannot always easily be done based on geometry, because for activities other dimensions are important. **Von Hunolstein and Zipf (2003)** refer to social zoning as a way for searching for clusters of facilities, events or attractions within cities. The example depicted in Fig. 46 (left) gives an idea of an activity map taken from **Graham and Kjeldskov (2003)**. Robert Kauper, a colleague at the Department of Cartography, developed a similar example depicted in Fig. 46 (right). The map visualises the movement of underground and tramways around the Technische Universität München in real-time. The animation is based on the time-table and implemented using JavaScript. Both examples demonstrate how useful this kind of geovisualisation can be for the support of everyday activities (e.g. catching a tramway).

(Graham and Kjeldskov, 2003)
Graham, C. and Kjeldskov, J. (2003): Indexical Representations for Context-Aware Mobile Devices, *Proceedings IADIS International Conference on e-Society*, Lisbon, Portugal, June 3-6, 2003

Fig. 46: Route-focussed maps

In the following several examples of maps adapted to specific elementary user actions are presented.

Locating

Simple forms of location maps show the user's current position on a map. This can be done with a YAH symbol. If accuracy values for the position are available, the position could be marked along with a tolerance circle around it. Furthermore the positions of objects and other people could be presented in location maps.

Fig. 47: Location map

Navigating

Route or navigation maps focus on the route and the necessary landmarks for getting a route overview or direction following. The map in Fig. 48 (left) shows the symbolisation of routes with different colours depending on the modality (bus and walk). The map example in Fig. 48, right illustrates the emphasizing of the public transport network.

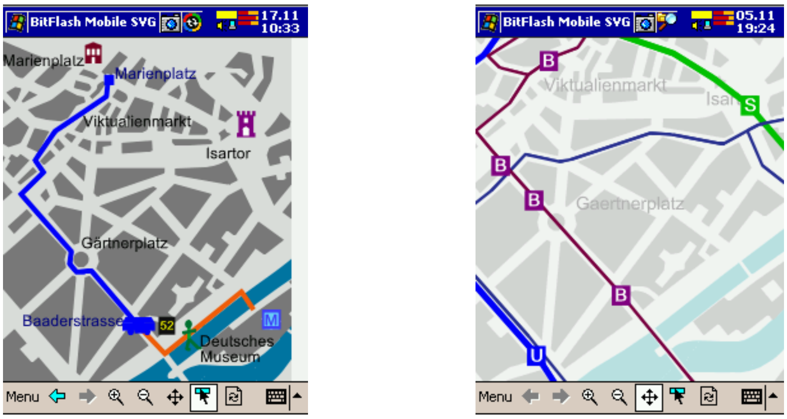


Fig. 48: Route maps

Searching

A map related to a search action presents the search result in maps. The map example in Fig. 49 shows the result of a search for theatres and bars. In addition to thematic or category search, spatial or temporal conditions (e.g. proximity) can be applied to refine the search. Interesting is the integration of social zones in the search process. Instead of Euclidean space, more activity oriented spaces can often be more appropriate.

Fig. 49: Search result map

Identifying

The example in Fig. 50 shows the use of a popup information box that gives further details about the identity of a selected geospatial object. Such informative 'boxes' compensate for the reduced information density of the map.

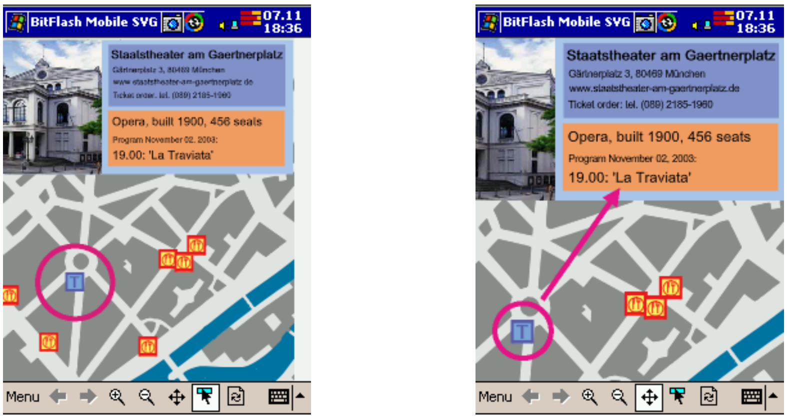


Fig. 50: Map with further information for identified feature

Checking

Maps showing events or the state of objects can either show the qualitative or quantitative differences. Qualitative differences can comprise event type, availability, state, etc. The example depicted in Fig. 51 shows the state regarding available spaces of multi-storeys. The multi-storey with free spaces is displayed in full opacity, whereas the second one with no vacancies is displayed with a lower opacity. Similarly the bars that are closed at the moment are displayed with lower opacity.

Fig. 51: Event and object state map

This method catches the user's view and directs it to the important and more relevant information without completely neglecting other information that could become important. An example of a quantitative difference is the water temperature of outdoor swimming pools.

Functionality

A good example of an adapted map function is the 'helicopter zoom' tool built in the Falk City Guide product (Fig. 52, left). This tool zooms out (as if a helicopter would lift up) and displays the map smoothly up to a smaller scale showing less detail. This gives the user an overview and shows the spatial context. After a

Falk City Guide: www.falk.de

Pocket Street Map: www.streetmap.co.uk

moment of time the tool zooms back to the original zoom level. Another example of a map specially designed for mobile devices is Pocket Streetmap (Fig. 52, right).

Fig. 52: Design for mobility: Falk Cityguide and Pocket Streetmap

Information for which there is not enough space on the map can be switched on and off by clicking on hot spots. Relevant text labels (e.g. street names) can for instance be selected from database and incorporated in the map as hidden elements. By clicking on the map feature the hidden text is switched to visible through an 'animation' and switches back after a while or another click. The same method can be applied to the map legend that is only visualised on-demand.

Other visualisation tools

As mentioned in different places of this work, there are more ways to communicate geographic information on mobile devices than just maps. Apart from vector maps, orthophotos, photographs of landmarks or POIs, 3D views derived from city models (e.g. VRML or X3D), perspective views (Fig. 53, left), silhouettes of important geospatial objects, e.g. landmarks (Fig. 54), and 3D symbols (Fig. 53, right) are alternative ways of presenting geographic information.

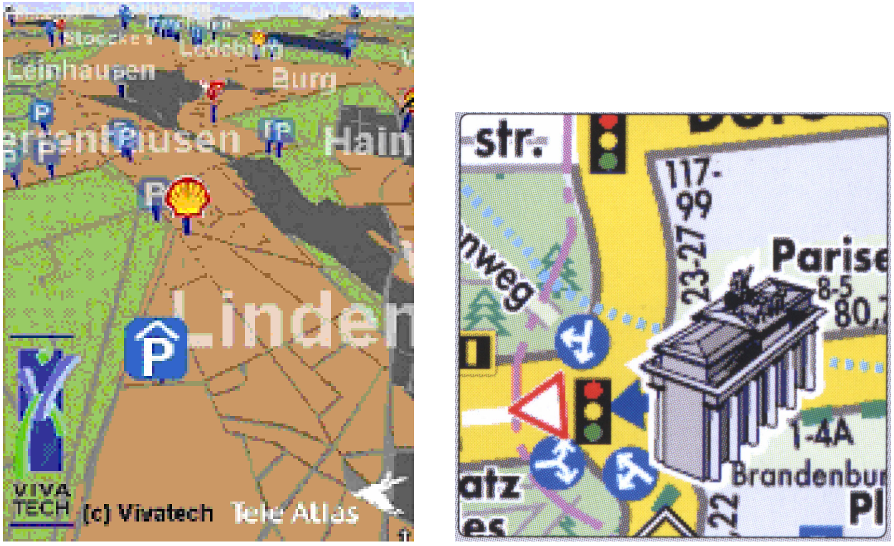


Fig. 53: Perspective views (left) and 3D landmark symbol (right; © Falk)

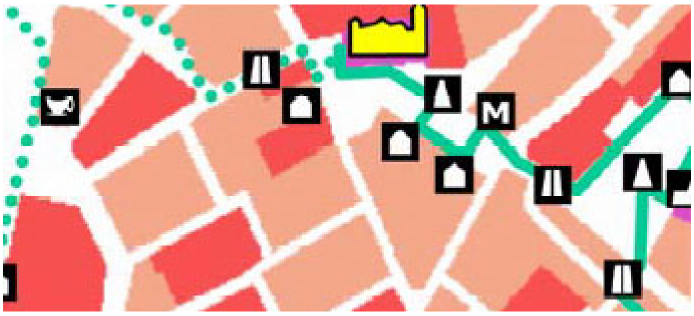


Fig. 54: Silhouette view of landmarks (Gartner 2003)

(Gartner, 2003)
Gartner, G. (2003): Pedestrian Navigation Services: A Multimedia Cartography Approach To Mobile Internet Applications, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

Fig. 55 shows an orthophoto with a thematic overlay. Several problems arise with the use of images. Firstly, the size of (raster) images is generally bigger than for vector maps. Secondly, the usage of text on top of images leads to the known legibility problems. And finally, the lacking abstraction makes it difficult to extract information efficiently. On the other hand, an orthophoto is useful to give a general impression of the geography and helps to get an overview of the activity region.

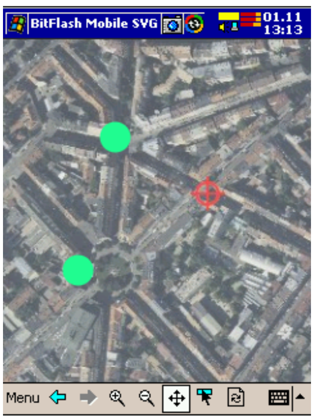


Fig. 55: Orthophoto with thematic overlay (Image: © Bayerisches Landesvermessungsamt, München)

Furthermore, multimedia maps combining images, video, text, sound and graphic or animated maps are an imaginable means to communicate geographic information on mobile devices. These kind of maps are beyond the scope of this dissertation; for an example see **(Gartner 2003)**. Besides performance issues, their ability and value in efficient geographic information presentation has still to be proven.

From the experience gained with the design of the mobile examples following recommendations for the design of mobile maps can be given:

- low information density
- high generalisation degree
- primacy of relevance over completeness
- poster-like style
- unobtrusive base map
- drastically enlarged minimal dimensions
- no fine design elements from paper maps; no patterns and contours
- colour as main design element (value and saturation), but not too many colours in the same map
- thrifty use of text; only sans-serif fonts
- self-explaining, pictogram-like symbols

Chapter 6

Service design for integrating adaptation into geovisualisation

The wireless telegraph is not difficult to understand. The ordinary telegraph is like a very long cat. You pull the tail in New York, and it meows in Los Angeles. The wireless is the same, only without the cat.
– Albert Einstein

6.1 Use cases for adaptive geovisualisation services on mobile devices

After the discussion of methods for mobile geovisualisation, some of these ideas are implemented in a prototypical geovisualisation service. The implementation is far from complete. It aims at demonstrating the feasibility of the adaptation approach and at serving as proof of concept. For matters of simplicity only the case of POI maps is implemented. However, the simplicity allows for grasping the essence of the approach and reveals the possible enhancements and extensions. Apart from demonstrating the concept of adaptation, the goal of this chapter is to propose a possible design of an architecture for adaptive geovisualisation services. First, a few use cases are sketched based on the scenarios developed in the preceding chapter. "A use case is a typical interaction between a user and a computer system [that] captures some user-visible function [and] achieves a discrete goal for the user" **(Fowler and Scott 1997, p. 43)**. The use cases lay the ground for the implementation platform. Secondly, the overall architecture, the hardware and software platform used, and the test bed are described. Thirdly, the partial implementation of the functionality is documented.

(Fowler and Scott, 1997)
Fowler, M. and Scott, R. (1997): *UML Distilled: Applying the Standard Object Modelling Language*, Reading (MA): Addison-Wesley

In mobile cartography the two most general use cases are the

stationary and mobile usage: the device is first used stationary, stand-alone with fixed network connection (e.g. at home) and later mobile with a wireless network connection (e.g. on a trip). An example for such a use case is trip planning on a desktop machine with loading the required static maps and other relevant and foreseeable information on the mobile device (generally over a synchronisation process). On the trip the user only downloads further dynamic, unforeseen or changed information to his/her device.

mobile usage: the user is mobile and has no information related to the current usage situation on the mobile device. Information relevant to this situation is downloaded over a mobile network and adapted due to changes in reality (in the environment) or due to spontaneous decisions.

Depending on these general use cases described above and the capabilities of the device as well as the network infrastructure the following cases for adaptation can be imagined:

- a completely new map is generated and adapted on the server and sent to client for rendering
- only adapted fragments of information content are sent to the client and replaced (e.g. only SVG documents holding the new information are sent with references to the client). A somewhat different approach of incremental updating on mobile devices is proposed by **Girow (2003)**.
- the adaptation is performed completely on the client-side (e.g. with JavaScript). The amount of data and functionality to be stored on the client is big. However, if all the necessary information is stored locally and the positioning technique is embedded in the device (e.g. GPS receiver), an autonomous adaptation is possible, at least a continuous client-side position tracking and mapping.

(Girow, 2003)
Girow, A. (2003): Incremental SVG mobility and update, *Proceedings SVG Open 2003*, Vancouver, Canada. http://www.svgopen.org/2003/papers/Incremental_SVG_mobility_and_update/

So far no statement can be made about whether the adaptation should take place server-side, client-side or in a mixed constellation on both. It must be tested in practice and the tradeoffs, such as waiting time, network bandwidth, download costs, processing power, memory requirements, need to be studied. The strategy itself is probably dependent on the usage situation. For the positioning it is obvious that most users feel more comfortable, if they know the position is calculated by their device and not on a service provider's platform.

The requirements for the 'mobile' use case could be described as follows: the system must recognise the usage situation X, indicated by the context indicators *i1*, *i2*, *i3*, … After that the system needs to define the context and the goal of adaptation. Then it selects an appropriate service and configures this service based on the context parameters. Possibly adaptation is iterated until the adaptation goal is met.

The system, i.e. the client application provides the following context parameters automatically: position, time, user, and device. The user has to select one of the elementary actions: locating, navigating, searching, identifying, and checking. Depending on this selection different additional parameters have to be defined by the user in the different use cases as shown in Table 13.

Locating

task	mode	parameter(s)	system functions	additional service(s)
select item to locate	person	id, name	contacts list	
	object		list of POI	geocoder
	address	street, house nr	address list	geocoder
	place	place name		gazetteer, reverse geocoder

Navigating

task	mode	parameter(s)	system functions	additional service(s)
select start, end, mid points	show graphically	click	'mouse' listener	
	coordinate	x,y value	text entry mask	geocoder
	object	object-id, click	list of POI, 'mouse' listener	geocoder
	address	street, house nr	address list	geocoder
	place	place name		gazetteer, reverse geocoder
select kind of routing	routing criteria	routing criteria	selection list	

Searching

task	mode	parameter(s)	system functions	additional service(s)
select category	code, name	click	category list	
select attributes	attribute domains	x,y value	menu, text entry mask	
select search area	distance radius	metres, minutes	predefined list, text entry mask	

Identifying

task	mode	parameter(s)	system functions	additional service(s)
select item	show graphically	click	'mouse' listener	
	coordinate	x,y value	text entry mask	geocoder
	object	object-id, click	list of POI, 'mouse' listener	geocoder

Checking

task	mode	parameter(s)	system functions	additional service(s)
select item for check	show graphically	click	'mouse' listener	
	coordinate	x,y value	text entry mask	geocoder
	object	object-id, click	list of POI, 'mouse' listener	geocoder
	address	street, house nr	address list	geocoder
	place	place name		gazetteer, reverse geocoder
select time frame	date or time	date or time	text entry mask, calendar	

Table 13: Use cases for the elementary spatial actions

6.2 Implementation of a prototypical adaptive geovisualisation service

For the design of a prototypical geovisualisation service a few basic ***assumptions*** have been made. The client is supposed to be a PDA (or a Smartphone) connected to the Internet with GPRS or UMTS and it is assumed that the position of the device is known, i.e. that is provided by a positioning service or a GPS receiver. The position is available in the form of coordinates. Furthermore, the existence of a rich database holding POIs and their attributes is presumed. To invoke the geovisualisation service and realise a basic set of functions, it is assumed that the PDA has a Personal Java compliant VM and is capable of running applets. The encoding of the visualisation format is done with SVG. Thus the client is presumed to be able to render SVG content.

At Fraunhofer Computer Graphics Center (IGD) a Graphics Engine for Mobile Devices (GEMoDe) based on SVG has been developed. In addition to SVG features this engine allows situative display adaptation (egocentric maps, adjusting font- and display sizes) and can easily be integrated into different mobile platforms by providing only the required components.

A good overview of the core technologies and some rough guidelines for the development of location based applications that can be applied to the design of geovisualisation services is given in **(Hjelm 2002)**. Frameworks for geoservices based on Open Source software have recently been developed, e.g. **(Badard and Braun 2003)**. Furthermore, many proposals for the architecture of map services specifically based on SVG can be found in the SVG community, e.g. **(Schaer 2003; Spanaki and Lysandros 2003; Takagi and Kobayashi 2003)**.

(Hjelm , 2002)
Hjelm, J. (2002): *Creating Location Services for the Wireless Web*, New York (NY): John Wiley & Sons

(Badard and Braun, 2003)
Badard, T. and Braun, A. (2003): Oxygene: An Open Framework For the Deployment of Geographic Web Services, *Proc. ICC 2003*, Durban, South Africa, August 10-16, 2003

(Schaer, 2003)
Schaer, P. (2003): Database Driven Generation of SVG-Maps with the Apache Cocoon 2 Framework, *Proc. SVG Open 2003*, Vancouver, Canada. http://www.svgopen.org/2003/papers/DatabaseDrivenSVGMapswithApacheCocoon/

(Spanaki and Lysandros, 2003)
Spanaki, M. and Lysandros, T. (2003): A Holistic Approach of Map Composition Utilizing XML, *Proc. SVG Open 2003*, Vancouver, Canada. http://www.svgopen.org/2003/papers/MapCompositionUtilizingXML/

(Takagi and Kobayashi, 2003)
Takagi, S. and Kobayashi, A. (2003): Activities for realization of interoperability of location based services using SVG, *Proc. SVG Open 2003*, Vancouver, Canada. http://www.svgopen.org/2003/papers/InteroperabilityofLBS/

6.2.1 Platform

The general platform used for the implementation of the prototypical geovisualisation service is shown in Fig. 56. The core technology is XML. The implementation is based on the Model – View – Control paradigm.

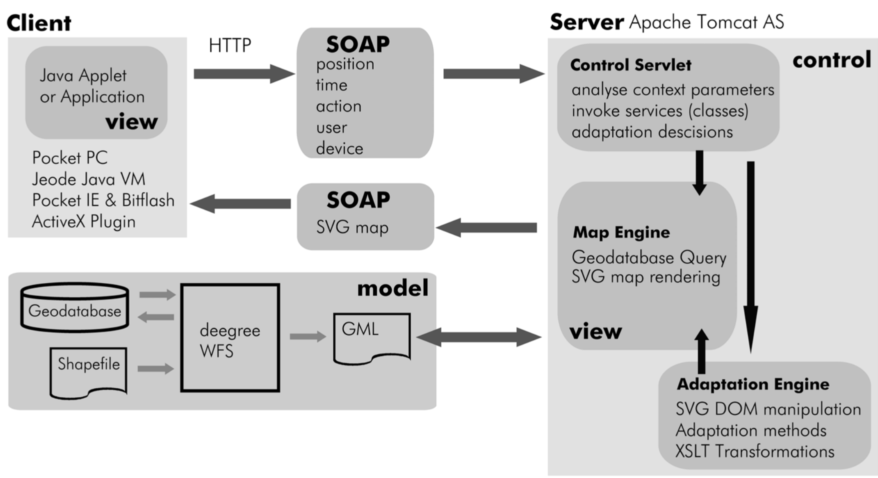


Fig. 56: Implementation platform architecture

Client Hardware and Software

The implemented solutions have been tested on a Compaq Ipaq 3970 PocketPC running under the PocketPC2002 operating system. To display the SVG encoded maps on the PocketPC the TinyLine Viewer, a Java based renderer for the SVG Tiny profile, is used. The Java applet responsible for requesting and displaying SVG content is running on the Jeode VM. Apart from platform-neutral software the Bitflash Mobile SVGB Player 2.0 beta supporting the SVG Basic profile has been used. This version also includes an ActiveX Control for the PocketIE. In HTML embedded SVG documents can be displayed directly in the browser window. For simulating a wireless connection to the server, a Compact Flash 802.11b Wireless LAN card (*Wireless Networker*™) from Symbol Technologies Inc. was utilized.

TinyLine:
www.tyniline.com
Jeode VM:
www.esmertec.com
Bitflash:
www.bitflash.com
Symbol Technologies Inc.:
www.symbol.com

Server Hardware and Software

Apache Tomcat:
jakarta.apache.org
Apache Batik:
xml.apache.org/batik
Deegree WFS:
www.latlon.de
D-Link:
www.dlink.com

Server-side a Windows 2000 Server machine hosts an Apache Tomact (version 4.1.24) application server providing the servlet engine. The adaptive component of the prototype is realised server-side by dynamic generation of SVG with a Java web service (based on Apache SOAP 2.3.1) and Batik 1.5. Batik is an Apache open source Java API for generating and manipulating SVG documents. The SVG maps are adapted to context based on information sent with the client request and transferred back to the Client. The data sources are accessed with the Deegree WFS 1.1.0. Apart from Batik XSLT transformations are used to transform GML data to SVG. For the wireless client server communication a Wireless LAN access point DWL 900AP+ from D-Link Inc. was installed.

6.2.2 Testbed

SVGMapper:
www.svgmapper.com

Different data sources were used in developing the service and producing the sample maps shown in section 5.4. Table 14 summarises the data sources and their characteristics. For the geometric base map surveying data from the Surveying Office of Munich was available as DXF-Files. These DXF-Files were imported in Arcview and converted to native Shapefiles. Minor adjustments to the data were necessary. The base data from the Bavarian State Surveying Office (BLVA) were available as EDBS data. These were converted to Shapefiles before they were loaded in Arcview. All the Shapefiles were exported to SVG documents using the SVGMapper 1.3. These exported base data comprise the feature classes buildings, roads, and rivers. These features build the core layer of information or the base map. Image data for the test data was available as an orthophoto. It was mainly used as a visual backdrop during editing tasks. In addition car navigation data from the company *Navtech* was available for the whole city of Munich. Some tests with geocoding made use of this data, but no further use has been made for the generation of the mobile map examples. The public transport network in the test area has been digitised in Arcview. Together with the POIs these two data sets build the thematic layer.

Layer	Format	Scale
Geometric base data		
Digitale Stadtgrundkarte (Vermessungsamt München)	Vector	1:5000
ATKIS Basis DLM 25 (BLVA)	Vector	1:25000
Image data		
Digital Orthophoto (BLVA)	Raster	
Thematic data		
Car Navigation Database (Navtech)	Vector	
Public transport (MVV)	Vector	
Points of interest (POI)	Vector	

Table 14: Geospatial data sources

For the test area 1418 POIs with attributes were captured and stored as a Point Theme in Arcview (Table 15). These points represent the service layer. The x and y coordinates along with the point ID were exported from the point theme utilising the Arcview script *shp2gen* into an ASCII file. These x and y coordinates were thereafter stored in the attribute table of the point theme, i.e. in the dBaseIV file. Additionally a few sample events were captured (see Table 9).

id	name	category	street	hnr	x	y	prior
0	Park Cafe- Next door	15000	Klenzestr.	19	4468366.20	5332529.61	4
1	Comic Company	32004	Fraun-hoferstr.	21	4468387.0	5332503.61	0
2	Lederwaren	32012	Fraun-hoferstr.	23	4468392.46	5332495.15	0
3	Plus Ultra	32012	Fraun-hoferstr.	23	4468401.56	5332485.14	0
4	Bei Vassilis/ Griech. Restaurant	11005	Fraun-hoferstr.	27a	4468427.03	5332458.40	0
5	Tauchsport Manta	50002	Fraun-hoferstr.	23	4468388.76	5332500.59	0
6	Werner's Fahr-schule	62002	Fraun-hoferstr.	29	4468434.00	5332449.95	0
7	Gerlindes Frisurenstueberl	74005	Fraun-hoferstr.	29	4468441.18	5332442.76	0
8	Kunstgiesserei/ Andr. Mayer	73002	Fraun-hoferstr.	31	4468468.80	5332444.79	0
9	Textil-Reinigung	72001	Fraun-hoferstr.	35	4468474.12	5332404.48	0
10	Der kleine Chinese	11011	Fraun-hoferstr.	35	4468480.46	5332397.47	0

Table 15: POI table

Web Feature Server

For the testbed two different data repositories have been configured. Firstly, the dBaseIV table containing the POI data (Table 15) acts as a simple data source that can be accessed from a Java application over a JDBC:ODBC bridge. Secondly, in the Tomcat server the ***Deegree WFS***, a freeware implementation of the OGC WFS specification, was deployed. The point database (dBaseIV file) was therefore converted to a MS Access table. This table was registered as a data source in the WFS Capabilities description file:

```
    ...
<FeatureTypeList>
        <FeatureType>
            <ResponsibleClass
className="org.deegree_impl.services.wfs.db.PointDBDataStore"
configURL="file:///C:/deegreewfs/webspace/WEB-INF/xml/poi_config.xml"/>
            <Name>poi</Name>
            <Title>main POI around TUM</Title>
            <SRS>EPSG:4326</SRS>
            <LatLonBoundingBox minx="-8" miny="15" maxx="240"
maxy="290"/>
        </FeatureType>
        ...
    </FeatureTypeList>
</WFS_Capabilities>
```

6.2.3 Prototype functionality

The prototype geovisualisation service has only very basic functionality. The client acts as a geographic information viewer and the server provides the handling of client requests and basically generates the SVG maps. The overall architecture is depicted in Fig. 56.

Functionality of Client

TinyLine:
www.tyniline.com

The client tier is constituted by an ***applet*** running on the mobile device. As a map viewer the TinyLine viewer is used. Although TinyLine only supports the Mobile SVG Tiny Profile, this use case demonstrates the core functionality of the geovisualisation service and shows basic visualisation possibilities of SVG on mobile devices. The main map functions provided by the viewer are the display of SVG maps and the panning and zooming within the displayed map. Fig. 57 (left) shows a screenshot TinyLine viewer and its available map functions: select, pan, zoom in, zoom out, and reload.

To show some more advanced features (e.g. opacity, filters, transformations of text (rotate) etc.) supported by Mobile SVG Basic Profile, the Bitflash ActiveX Plugin for the PocketIE is used. With the Bitflash viewer SVG documents embedded in HTML are directly displayed in the PocketIE browser window.

Fig. 57: TinyLine viewer applet and mock-up client

The applet should at least provide a very basic interface for initiating user requests. Fig. 57 (right) depicts a mock-up of such an interface. The button panel on the bottom is only visible if needed and through a click on one of the icons, a specific mobile spatial action is selected. Depending on the action chosen the user interface would extrude further widgets according to the use cases shown in Table 13. With the chosen actions and its associated parameters the user goal is at least roughly defined.

Functionality on Server

The server side functionality is more ample and complex. A Java web service implemented as a SOAP service accepts SOAP requests from the client as input and invokes the adaptation methods. The responsibility of the service is to extract the SOAP message and analyse the contained context. Then decisions about adaptation necessity and appropriate methods have to be taken. A next step includes the design of filters and the generation of a WFS request or an SQL string for a direct database connection that looks like sketched below:

```
<?xml version="1.0" encoding="iso-8859-1"?>
<wfs:GetFeature outputFormat="GML2"
xmlns:gml="http://www.opengis.net/gml"
xmlns:wfs="http://www.opengis.net/wfs"
xmlns:ogc="http://www.opengis.net/ogc">
    <wfs:Query typeName="poi">
        <ogc:Filter>
            <ogc:PropertyIsEqualTo>
                <ogc:PropertyName>/poi/code</ogc:PropertyName>
                <ogc:Literal>11001.0</ogc:Literal>
            </ogc:PropertyIsEqualTo>
        </ogc:Filter>
    </wfs:Query>
  </wfs:GetFeature>
```

The service then accesses the WFS or the POI database and retrieves the features. In the case of the WFS the features are returned as GML and are transformed to SVG with XSLT. If a database table with point data is directly accessed the data can be processed form the service with Batik to generate SVG elements. The following code snippet shows parts of an XSL stylesheet:

```
<xsl:stylesheet xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
version="1.0"
    ...
    <xsl:template match="/">
        <svg width="799.167" height="936.903" viewBox="4468150 -5333450
1000 1333">
            <defs>
                <!--  Museum     -->
                <symbol id="56006.0">
                    <rect x="10" width="50" y="10" height="50"
style="fill:rgb(90,90,255);stroke:rgb(64,64,255);stroke-width:7"/>
                    <text x="15px" y="52px" style="fill:rgb(64,64,255);font-
size:48;font-family:Arial">
                        M
                    </text>
                </symbol>
            </defs>

            <g id="dynamic">
             <xsl:apply-templates select="//poi.Code"/>
            </g>
        </svg>
    </xsl:template>
<xsl:template match="//poi.Code">

        <xsl:element name="use">
            <xsl:attribute name="x"><xsl:value-of select="substring-
before(..//gml:coordinates,',')"/></xsl:attribute>
            <xsl:attribute name="y"><xsl:value-of select="-substring-
after(..//gml:coordinates,',')"/></xsl:attribute>
               <xsl:attribute name="xlink:href">#<xsl:value-of
select="."/></xsl:attribute>
           </xsl:element>
    </xsl:template>
</xsl:stylesheet>
```

In both cases a transformation has to be applied to the coordinates, because SVG has an image oriented coordinate system (Fig. 58). In order to be displayed correctly, the y-coordinate from the GML document or the database table has to be set negative. The test data are encoded in the German Gauss-Krüger spatial reference system with a positive y-coordinate. Therefore a flip transformation has to be applied. In addition, a transformation to an 'image' coordinate system, the normal SVG coordinate system, can be applied.

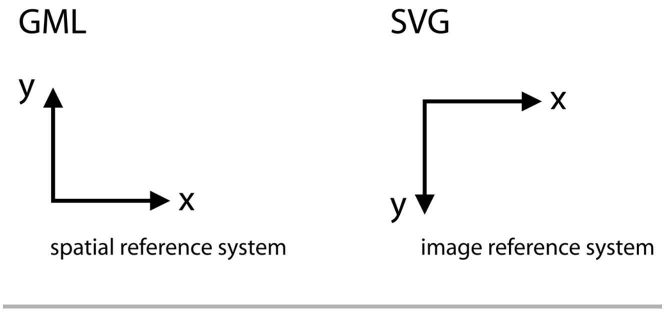


Fig. 58: Coordinate systems of GML and SVG

The service can have several methods to adapt the map that is sent back to the client. The two basic groups of methods are:

- map symbology adaptors: these methods can have global or more local effects. Changing the symbology for the complete map can be done with an exchange of the style sheets (CSS or XSLT). For partial changes the elements can be manipulated through the DOM (e.g. assigning a different opacity value).
- map components configuration adaptors: these methods can either configure the individual components of base map and/or configure additional landmark and thematic components (e.g. transport network).

Fig. 59 illustrates the communication sequence of the geovisualisation service between the client and the server.

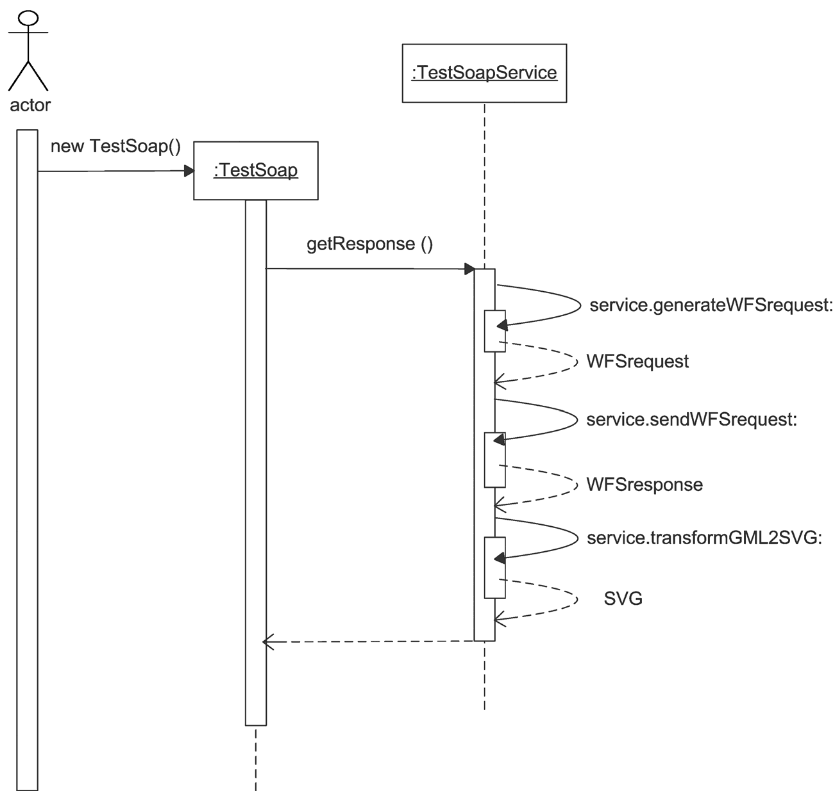


Fig. 59: Sequence diagram of the geovisualisation test service

Adapmap engine

The proposed design of the '*adapmap*' map adaptation engine is illustrated in the following UML diagram (Fig. 60).

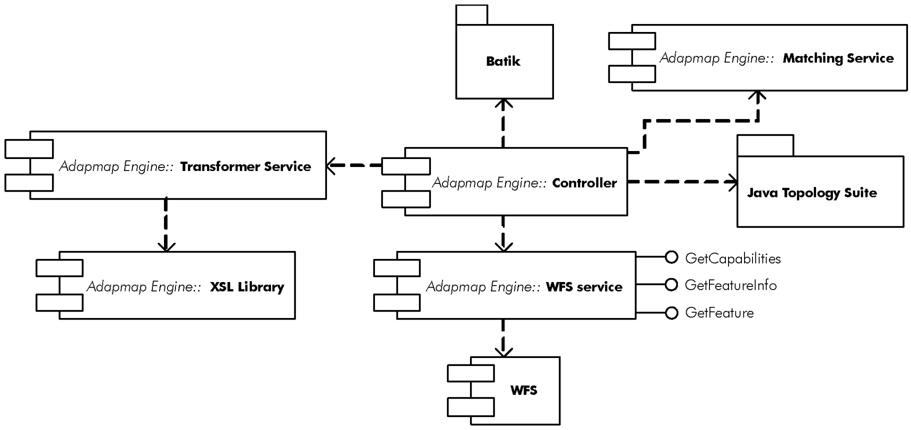


Fig. 60: *Adapmap* architecture

This high-level architecture of the *adapmap* engine aims at showing the basic components and the utilisation of several open source APIs. The WFS service is based on the Deegree WFS. Batik is used for generating and manipulating SVG. The transformer service relies on XSLT. To compute spatial relationships Java Topology Suite might be used. Among other additional services the matching service can be used for integrating other data sources.

The *adapmap* engine uses different XML technologies to manipulate the map features encoded as SVG. For the adaptation of SVG encoded maps the DOM is specifically important. The DOM is a language and platform independent representation of an XML document in the memory and can thus be accessed during run time of an application. Fig. 61 shows besides the DOM the other important mechanism for XML processing: the Simple API for XML (SAX). SAX can be used to parse an XML document. This process is event-based, i.e. if the parser gets an event (an element), it notifies the application which will take some action.

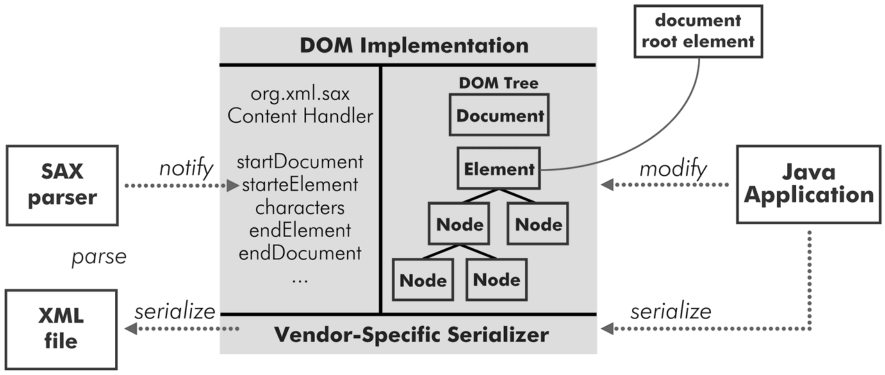


Fig. 61: SAX and DOM cooperation (McLaughlin 2001)

(McLaughlin, 2001)
McLaughlin, B. (2001): *Java and XML*, Sebastopol (CA): O'Reilly & Associates

SOAP

For the communication between client and server the SOAP protocol is used. SOAP is a platform neutral, XML based message protocol for web services specified by the W3C. SOAP has no language and transport protocol binding, though in most cases it is used over HTTP. A SOAP service is based on exchanging messages. Such a ***SOAP message*** is an XML document with the following structure **(Cerami 2002)**:

(Cerami, 2002)
Cerami, E. (2002): *Web Services Essentials*, Sebastopol (CA): O'Reilly & Associates

- an Envelope element, the root element containing all other elements
- an optional Header element specifying header information such as authentication
- a Body element giving details about call and response information
- an optional ***Fault*** element providing information about errors that occurred while processing the message

The following code example shows the SOAP request of the client with the basic context parameters:

```
<?xml version="1.0" encoding="UTF-8"?>
<SOAP-ENV:Envelope xmlns:SOAP-
ENV="http://schemas.xmlsoap.org/soap/envelope/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
    <SOAP-ENV:Body>
        <ns1:retResponse xmlns:ns1="urn:examples:testservice" SOAP-
ENV:encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
            <loc_x xsi:type="xsd:int">4468540</loc_x>
            <loc_y xsi:type="xsd:int">-5332680</loc_y>
            <cal xsi:type="xsd:date">2003-11-18</cal>
            <screen_x xsi:type="xsd:int">240</screen_x>
            <screen_y xsi:type="xsd:int">320</screen_y>
            <usergrp xsi:type="xsd:string">C</usergrp>
            <cat xsi:type="xsd:string">11001.0</cat>
        </ns1:retResponse>
    </SOAP-ENV:Body>
</SOAP-ENV:Envelope>
```

SOAP can be used to encode the context and parameters and the user request in an interoperable standard protocol.

Several improvements and refinements of the implementation are imaginable regarding extent of adaptivity, client functionality and user interface, and adjustments to other implementation approaches.

Chapter 7

Conclusion

Inanimate objects are classified scientifically into three categories - those that don't work, those that break down, and those that get lost.
– Russell Baker.

7.1 Achievements

The basic hypothesis of this research is that introducing adaptation mechanisms into geovisualisation services can significantly improve the usability of geographic information on mobile devices. The adaptation concept is embedded in a coherent conceptual framework of visualisation for mobile users. The assessment of existing approaches and solutions (sec. 3.3) has justified the applied top-down methodology of combining existing theories and approaches to the mobile cartography framework. The strength of widening the scope of awareness services from location-aware to context-aware has been demonstrated in chapter 4.

As stated in chapter 1, the primary goal of this research has been the elaboration of a new research field in cartography by extending cartographic theories to the application domain of mobile computing. For the understanding of map usage several useful theories have been studied in cartography. A review of these theories in chapter 2 reveals that activity theory, human-computer interaction, and cognitive theory have been applied to map usage independently from one another and without taking the mobile context into account. Context theory was reduced to a matter of location. The proposed conceptual framework presented in chapter 4 combines these theories to improve the usability of mobile geographic information usage.

The conceptual framework contributes to enriching and extending the cartographic theory and methods in the field of geographic information communication in mobile environments and incorporating adaptation methods into geovisualisation. Specifically, this research has achieved the following:

- introduction of new concepts for mobile cartography and a differential definition of mobile cartography opposed to traditional cartography and web cartography
- extension of cartographic theory through the transfer of adaptation concepts and the proof of its value to the domain of cartography in general and mobile cartography in particular
- enrichment of cartographic theory by introducing a service oriented concept
- design of adaptation methods that enhance the cartographic methodology and enable the discipline to cope with numerous challenges posed by new technological and societal advancements
- proposal of first design studies of adapted geovisualisation for mobile cartography for subsequent research and usability tests
- proof of applicability of adaptivity within a mobile geovisualisation service through a prototypical implementation

The main accomplishment of this research is the demonstration of how beneficial the development of a systematic framework is for mobile map usage. The examples of adapted maps that were partially generated with the geovisualisation service described in chapter 6 express how adapted geovisualisation can contribute to improve the usability of mobile geovisualisation and geographic information usage. The results confirm the proposed methodology and are reasonably congruent with other studies **(Edwardes et al. 2003b; Heidmann and Hermann 2003; Zipf 2002; von Hunolstein and Zipf 2003)**.

(Edwardes et al., 2003b)
Edwardes, A., Burghardt, D. and Weibel, R. (2003b): WebPark - Location Based Services for Species Search in Recreation Area, *Proc. 21st Internat. Cartographic Conference*, Durban, South Africa, August 10-16, 2003

(Heidmann and Hermann, 2003)
Heidmann, F. and Hermann, F. (2003): Visualisierung raumbezogener Informationen für ultraportable mobile Systeme, *in*, *Visualisierung und Erschließung von Geodaten - Seminar GEOVIS 2003*, Kartographische Schriften, Band 7, Bonn: Kirschbaum Verlag, 121-131

(Zipf, 2002)
Zipf, A. (2002): User-Adaptive Maps for Location-Based Services (LBS) for Tourism, *in* K. Woeber, A. Frew and M. Hitz (Eds.), *Proc. of the 9th Internat. Conference for Information and Communication Technologies in Tourism, ENTER 2002, Innsbruck, Austria, Springer Computer Science*, Berlin; Heidelberg: Springer-Verlag. http://www.eml.villa-bosch.de/english/homes/zipf/ENTER2002.pdf

(von Hunolstein and Zipf, 2003)
von Hunolstein, S. and Zipf, A. (2003): Towards Task Oriented Map-based Mobile Guides, *Proc. Internat. Workshop "HCI in Mobile Guides" at Mobile HCI 2003, 5th Internat. Symposium on Human Computer Interaction with mobile Devices and Services*, Udine, Italy, September 8-11, 2003

7.2 Insights

The value of the framework has been demonstrated by subjecting the basic user actions to the adaptation methods developed before within the context of the sample scenarios. The combination of different context dimensions has several advantages over a more one-sided approach as for instance LBS. The sole use of location as context parameter does not always lead to value-added solutions. The 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. The use of more context parameters also facilitates the interoperability with other services which once more can enforce the effect of a relevance improvement. The consultation of a multi-dimensional context allows to generate egocentric geovisualisation beyond the spatial notion of ego-centre.

This work has concentrated on bringing together the relevant building blocks. Yet, a precondition for a successful implementation of more comprehensive, adaptive mobile geovisualisation services is the formalisation of context, cartographic knowledge, as well as rules and constraints governing them. First attempts to formalise relevant context parameters have been proposed, a refinement of the formal models gives rise to hopes for improved results.

The map examples have revealed that generalisation alone guarantees legible maps, but not necessarily egocentric and relevant maps. Generalisation is absolutely indispensable for small display geovisualisation in mobile cartography. However, it is a prerequisite on mobile devices, but not sufficient to improve the usability. Especially in mobile usage situations an adaptation of the geovisualisation is needed.

It should be noted that this research has examined only the adaptation of presentation objects. Yet, the adaptation of the user interface to the mobile usage context is of equal importance. The style and modes of interactions, the functionality offering have to be reconsidered. Most promising are multimodal interfaces that use more than one input and output channel. Such multimodal interfaces provide a greater potential of adaptation in mobile usage situations.

One basic assumption for the service design was the availability of a rich geospatial data pool. In reality it is much more complicated. Several data sources with different geographic coverages, scales, feature classes, projections etc. could be available for an area of interest causing manifold interoperability challenges. Service roaming constitutes another problem. Apart from roaming in mobile networks, a geovisualisation service should provide geographic and thematic roaming. This means a service should possibly offer the same data in the whole area of its coverage. The problems of syntactic and semantic interoperability caused by such geo data 'roaming' require data integration (matching and conflation) and harmonisation mechanisms that are examined in the GiMoDig project.

It has been found difficult to capture the user requirements for an adaptive geovisualisation service. The thesis presented scenarios as a method of analysing user requirements for supporting services in a mobile, everyday life. These oversimplified examples certainly need systematic improvements for being useful in designing a concrete service. Strongly connected to that point is the catalogue of basic user actions in mobile cartography. It has proven its usefulness for the purpose of reducing the complexity and designing first adaptation methods. Further developments might reveal a different, adjusted categorisation. In this context the establishment of activity ontologies will become a prime issue in the future.

The thesis has addressed only questions of the adaptation potential for mobile cartography. For any kind of context-aware service privacy issues are a major factor. The handling of these issues will be the gauge for success or failure of such services. Collaboration with specialists from other fields is therefore vital.

7.3 Outlook

7.3.1 Suggested improvements

The framework developed in chapter 4 and the application of the adaptation concept in chapter 5 have introduced a broader view of cartography for mobile users. Nevertheless, both the framework and the adaptation are still far from being exhaustive and can be refined in many dimensions.

For the work in general extensions have to be made regarding the test set. More and different test areas (urban, rural, dense, wide, alpine, tourist areas, etc.), additional scenarios and concrete use cases may bring to light further requirements, problems, and difficulties. Experiences from other projects **(Krug et al. 2003; Nivala et al. 2003)**, could help in new test designs.

So far the results have only been judged subjectively by the author. Although the utility and usability of adapted maps seem to be present, the hypothesis can hardly be confirmed with confidence unless the subjective judgement is integrated with well defined objective criteria. Empirical ***usability*** studies, for instance, have proved feasible for the evaluation of the proposed solutions and can be conducted in the manner presented by **(Nivala et al. 2003; Heidmann and Hermann 2003)**.

For the geovisualisation, incorporating recent approaches from the ***generalisation*** community (e.g. MRDB, radial generalisation, etc.) and solutions for the automatic generation of topograms or schematic maps are crucial to achieve appropriate graphic results.

(Krug et al., 2003)
Krug, K., Mountain, D. and Phan, D. (2003): WebPark: Location-Based Services for mobile users in protected areas, *Geoinformatics*(March). http://www.soi.city.ac. uk/~dmm/research/pubs/WParticle_by_Consortium _ GeoInformatics_nr2_March_2003.pdf

(Nivala et al., 2003)
Nivala, A.-M., Sarjakoski, L. T., Jakobsson, A. and Kaasinen, E. (2003): Usability Evaluation of Topographic Maps in Mobile Devices, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

(Heidmann and Hermann, 2003)
Heidmann, F. and Hermann, F. (2003): Visualisierung raumbezogener Informationen für ultraportable mobile Systeme, in, *Visualisierung und Erschließung von Geodaten - Seminar GEOVIS 2003,* Kartographische Schriften, Band 7, Bonn: Kirschbaum Verlag, 121-131

A closer integration of the presented service architecture within a general platform as proposed by **(Edwardes et al. 2003a)** is able to reduce the development efforts and use synergetic effects.

(Edwardes et al., 2003a)
Edwardes, A., Burghardt, D., Bobzien, M., Harrie, L., Reichenbacher, T., Sester, M. and Weibel, R. (2003a): Map Generalisation Technology: Addressing the Need for a Common Research Platform, *Proceedings 21st International Cartographic Conference*, Durban, South Africa, August 10-16, 2003

The integration and modelling of constraints in adaptive maps is important to solve graphical conflicts arising from dynamic map generation in a mobile geovisualisation service. Approaches of embedding constraints in SVG and constraint-based generalisation need to be evaluated for their usefulness.

A major challenge of any adaptivity approach is the anticipation of user information needs. In mobile cartography this particularly concerns the inference mechanisms for mobile user activities (spatial behaviour). Thus research on ontologies of 'mobile user activities' has to be continued. Again, empirical research has to find mappings from typical activities to most commonly used information types and presentations.

Similarly ***context modelling*** has to be refined. Especially the modelling of the inter-relationships of different context domains requires extended investigations. Methods of extracting rules valid for specific context types are essential and could be found in other disciplines.

With regard to adaptation the domain could be enlarged from mobile cartography to cartography and geoinformatics in general. In cartography many more applications can be envisaged that would profit from adaptation. For this sake the adaptation approach described in this dissertation needs to be refined and extended along with the development of their evaluation methods. An important extension of the adaptation approach is the adapting of geo ***user interfaces***. The rich research work from adaptive user interfaces could be combined with approaches considering users acting with cartographic and/or geographic information systems. Questions are how the user interface might be adapted according to mobile user actions, different user groups, user roles, etc.

Future work can be done in many fields. The service implementation requires many enhancements. First of all further adaptation methods have to be implemented. Additionally interfaces to different context sensors (e.g. GPS) must be incorporated. The design should be adjusted to be compatible with common generalisation architecture and can be extended with other modules (e.g. generalisation, conflation, feature matching). Furthermore stricter conformance to OGC services should be attempted.

An interesting addition to the geovisualisation service concept is the development of ***adaptor tools***. The idea behind adaptor tools is that the user can configure his/her own '***adaptors'*** for known contexts on a desktop computer and take these adaptors with him on the mobile device. These adaptors can include e.g. profile, preferences, filters, style, etc.

Finally, it should be evaluated how new technologies like Augmented Reality (AR) relate to mobile cartography and how they can meaningfully be combined with this approach.

7.3.2 Concluding remarks

The euphoria of 3G telecommunication and LBS in its entourage has receded. The promise of an *'anything, anytime, anywhere'* world does not seem to come true in the near future. Nevertheless, the trend to more individualised, mobile used services is irreversible. The future-oriented research that deals with questions of adaptation, privacy concerns, representations, etc. already bears fruits in today's cartography. The methodological progresses and the insights gained have opened new perspectives for the follow-up work.

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Appendix: Abbreviations

- A-GPS: Assisted Global Positioning System
- AT: Activity Theory
- DOM: Document Object Model
- GML: Geography Markup Language
- GPRS: General Package Radio System
- GPS: Global Positioning System
- HCI: Human Computer Interaction
- HSCSD: High Speed Circuit Switched Data
- LBS: Location Based Service
- OGC: Open GIS Consortium
- PDA: Personal Digital Assistant
- POI: Points of Interest
- SMIL: Synchronized Multimedia Integration Language
- SOAP: Simple Object Access Protocol
- SVG: Scalable Vector Graphics
- UDDI: Universal Description, Discovery, and Integration
- UM: User Model
- UMTS: Universal Mobile Telecommunications System
- WLAN: Wireless LAN
- WFS: Web Feature Server
- WMS: Web Map Server
- WSDL: Web Service Description Language
- XML: Extensible Markup Language
- XSL: Extensible Stylesheet Language
- XSLT: Extensible Stylesheet Language Transformation