MONA 3D -- MOBILE NAVIGATION USING 3D CITY MODELS

Volker Coors[1] **and Alexander Zipf**[2]

[1]**University of Applied Sciences HFT Stuttgart,**
Schellingstr. 24,D-70174 Stuttgart, Germany
volker.coors@hft-stuttgart.de

[2] **University of Applied Sciences FH Mainz and University of Bonn, Department of Geography,**
Chair of Cartography, Meckenheimer Allee 172, 53115 Bonn, Germany
zipf@geographie.uni-bonn.de

Abstract: Within this paper we present and discuss the goals and first results of a new collaborative project on mobile navigation using 3d city models called MoNa3D. In addition to the author's institutions (HFT Stuttgart and FH Mainz/University of Bonn) project partners include Navigon, Teleatlas, CPA Geoinformatik, Heidelberg Mobil and Bureau of Surveying Stuttgart. Here we investigate two main challenges for mobile navigation with 3D city models, which include restrictions considerations regarding compression of 3D geometries and smart handling of textures for building facades using new technologies, both resulting from the limited processing power and bandwith of mobile devices on the one hand side and on the other hand side both conceptual design guidelines regarding interoperability through the use of open standards such as the OpenLS (Open Location Services) specifications by the OGC along with setting up a 3D spatial data infrustructure (3D-SDI) based on OGC open web services (OWS), as well as cognitive considerations on how to present route instructions on mobile devices the most efficient way for supporting navigation of pedestrians or car drivers. A special focus lays on evaluation the proper use of 3D landmarks within 2D, 2,5D and 3D scences on mobile devices, as well as aspects such as personalization and context awareness, which are all important issues of emergening ubiquitous GI Services (UbiGIS).

Keywords: mobile 3d cartography, mobile navigation support, synthetic textures, personalized 3D landmarks

1. Introduction

There is a wide variaty of techniques to present directions and support on mobile devices ranging from spoken instructions to 3D visualization. In order to produce a coherent and cohesive presentation it is necessary to adapt a presentation to the availale technical and cognitive resources of the presentation environment. Coors et al. (2005) evaluated several means of route instructions to a mobile user. 3D visualization seems to be well suited where time and technical resources are not an issue, and where the available position information is imprecise: The realistic 3D visualization allow the user to search her environment visually for specific features, and then to align herself accordingly, thereby compensating for the imprecsion. Especially visual landmarks are very helpful in this context. By using 3D city models, landmarks can be incorporated into both - the route visualization on a 3D map as well as spoken navigation instructions. The aim of the project "Mobile Navigation with 3D City Models - MoNa3D" is to assess and develop the infrastructure, tools and methods for developing a mobile navigation system that enables the user to navigate in a 3D urban environment on mobile device (smartphone, PDA etc.). It provides navigation support through semantic route descriptions, using 3D landmarks. In order to achieve sustainable project outcomes, 3D city models for navigation support have to be available within a functioning 3D spatial data infrastructure (http://www.3d-gdi.de). Further techniques need to be developed for creating storage efficient synthetic textures for 3D city models optimized for mobile devices. Thus the two main goals of the project are:

- To provide a cognitive semantic route description by using landmarks in 3D, which allow context dependent personalized navigation support

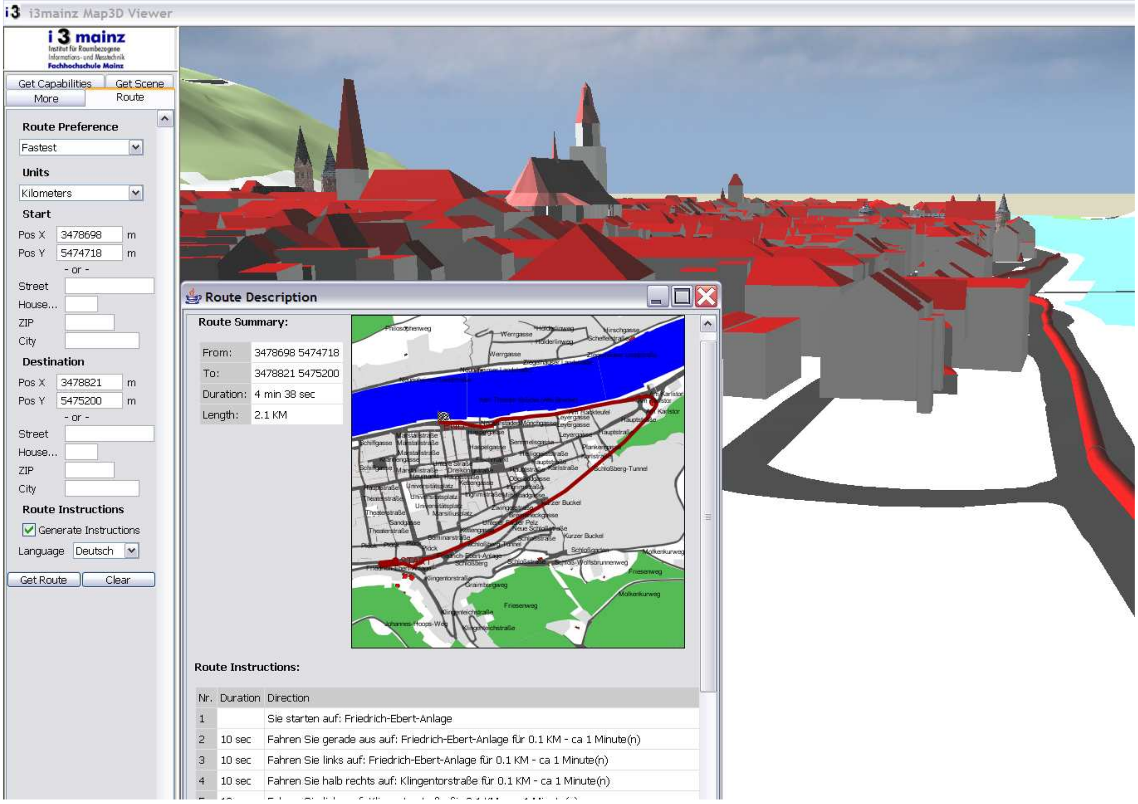
- To develop an approach to create suitable non-photorealistic building textures using image processing methods and synthetic textures along with a corresponding compression system for an efficient storage and transfer of 3D building models.

2. Cognitive Semantic Route Description with Landmarks

Navigation support for wayfinding has a long history of research and the importance of landmarks for orientation purposes is well-known (Golledge 1996, Lovelace et al. 1999) going back even to Lynchs work (1960). But still most commercial route planners and car navigation system do not expoit the potential of landmarks completely, in fact until recently most of them did not provide landmark-based navigation support at all. Reasons include the problem of insufficient data on landmarks (coverage etc.) as well as inadequate algorithms for selecting those from available data sets. This situation is improving (e.g. Elias 2006) and commercial companies start to build up dedicated databases on landmarks at the national or European level. As the perspective view (pseudo 3D) in car navigation systems was a big commercial success these companies put further efforts towards support for the third dimension in those systems. Similar 3D-GIS are becoming more widespread in a range of domains (Coors and Zipf 2005). But due to unsolved problems on data availability, management and update, as well as of performance issues on mobile devices until now these mobile navigation prototypes ususally only provide 2,5D terrain visualisations with individual landmarks in 3D. Only a few research prototypes actually provide real 3D city models on mobile devices (e.g. Nurminen 2006 a,b, Coors & Schilling 2003, Fischer et al 2006) or work on the topic of interoperable management (Schilling et al. 2006, Basanow et al 2007) and their combination with standards-based route planning possibilities (Neis et al. 2007).

For Location Based Services (LBS) the OGC has specified a range of services for supporting route planning etc., that provide a base for realizing interoperable navigation applications. Most of these OpenLS core services have been implemented and combined with 3d city models already (Neis et al 2007, Neis & Zipf 2007). See figure 1. But the result has not yet been optimized for mobile devices which is one of the tasks within the MoNa3D project and some aspects of this will be discussed in the follwing chapters. The topic of how to include landmarks into such a Service Oriented Achitecture (SOA) based on open standards is being discussed by Neis and Zipf (2007) with respect to mobile 2D maps, but a very similar approach utilizing buffers can be used in 3D. This has already been shown by Schilling and Zipf (2003), but without using open standards, as these were not available at that time.

The next step is to find out more on how landmarks should be visualized on a mobile device in particular with respect to 3D, and how much realism is needed for that. There are some first publications on this available, but only with prelimnary results. Therefore future work within the project will focus on these questions.



Route Preference: Fastest

Units: Kilometers

Start

Pos X 3478698 m

Pos Y 5474718 m

Destination

Pos X 3478821 m

Pos Y 5475200 m

Route Instructions

☑ Generate Instructions

Language: Deutsch

Route Summary:

From:	3478698 5474718
To:	3478821 5475200
Duration:	4 min 38 sec
Length:	2.1 KM

Route Instructions:

Nr.	Duration	Direction
1		Sie starten auf: Friedrich-Ebert-Anlage
2	10 sec	Fahren Sie gerade aus auf: Friedrich-Ebert-Anlage für 0.1 KM - ca 1 Minute(n)
3	10 sec	Fahren Sie links auf: Friedrich-Ebert-Anlage für 0.1 KM - ca 1 Minute(n)
4	10 sec	Fahren Sie halb rechts auf: Klingentorstraße für 0.1 KM - ca 1 Minute(n)

Figure 1: 3D Navigation in Heidelberg-3D with OpenLS Route Service and 3D Web Service (cmp. Neis et al 2006).

3. Personalized 3D visualizations through Styling Rules for 3D Maps

With the advent of location based services the topic of personalization (Zipf 2002) or context-awareness (Zipf 1998) became a topic within GIScience (see also Meng et al. 2004). In order to extend this to mobile 3D maps both research on cognitive aspects and information visualization is needed on the one hand, and on the other hand also the technical possibilities to define the look of a 3D scene (3D map) in a declarative and interoperable way. Within this paper we will only shortly mentioned the second issue. A possible approach is the definition of specification that allows to style the different objects and feature classes within a 3D scence individually based on rules that can be defined in a document which then is feed into the application (i.e. send to server in case of a SOA). For 2D maps such a specification is the OGC Symbology Encoding (Müller 2007), or its predecessor - the Styled Layer Descriptor (SLD). Therefore Neubauer and Zipf (2007) suggest the extension of the OGC SE into the third dimension (3D-SE) and present an XML schema that allows to do this. This has been implemented into the Heidelberg-3D W3DS successfully which results in the possibility to style the scene individually on request from the client side. Some examples of not pre-configures visualizations that have been dynamically generated by the W3DS only through changing the configuartion of the W3DS files are presented in the following figures.

Not shown here, but also already possible is the inclusion of external 3D graphics (e.g.in form of VRML models) for point-objects, which allows to change these – and therefore also 3D representations of landmarks on the fly – e.g. for different user groups, traffic modalities or other changes of the context. Currently we work on realizing this within first prototypes. Future work then will focus on cognitive aspects of choosing the right landmark with the best visual representation in the given situation.

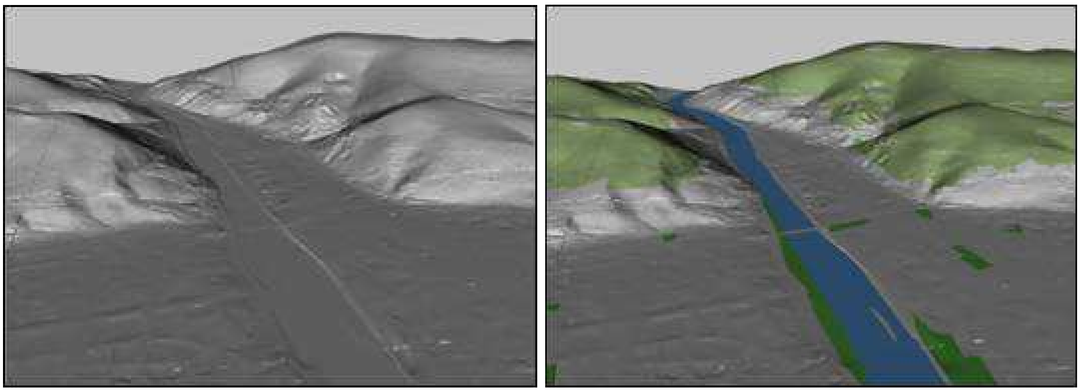


Figure 2: Using 3D-SE we can define rules through using the OGC Filter Encoding which select features according to their attributes and applies different visualization styles to them as specified in the 3D-SE document. Here we see right a not differentiated DEM and left a differentiation between river, forest and green areas and build areas. (cmp Neubauer & Zipf 2007, © Heidelberg-3D, raw data courtesy of Vermessungsamt Heidelberg & EML)

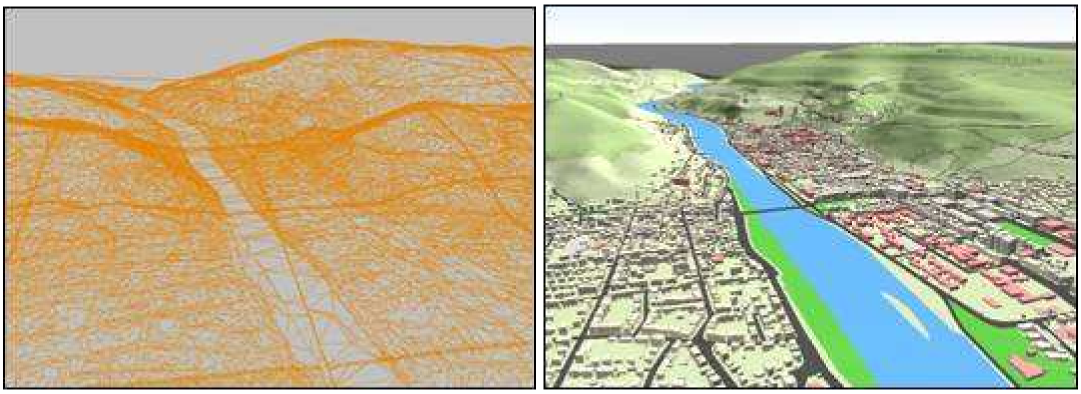


Figure 3: On the left hand the 3D-SE defined only to draw the lines instead of filling the triangle faces with a fill material. On the right side buildings were added and public buildings are highlighted in red instead of grey dynamically on request using the 3D-SE document. (cmp Neubauer & Zipf 2007, © Heidelberg-3D, raw data courtesy of Vermessungsamt Heidelberg & EML).

4. 3D Spatial Data Infrastructure (3D-SDI)

As the previous chapters already suggest it is a goal of the project to evaluate the use of relevant open standards – in particular those of the OGC - with respect to the given scenario. This may lead to suggestions for modifications or extensions, such as in the case of the 3D-Symbology Encoding, or best prectises on how to set up service chains of such services in order to deliver the desired result. Such a combination of standardized services managing, processing and delivering 3D spatial data can be considered as first steps towards a on 3D spatial data infrastructure (3D_SDI). First examples of 3D-GI-applications based on such service oriented architectures have been presented (Basanow et al 2007, Schilling et al 2006, Neis et al 2006). An example is presented in figure N, showing the current GDI-3D (geospatial data infrastructure 3D) for Heidelberg. Future work will not only focus on technical aspects regarding the appropriateness of the used standards, but also questions on how to interact with commercial and proprietary solutions.

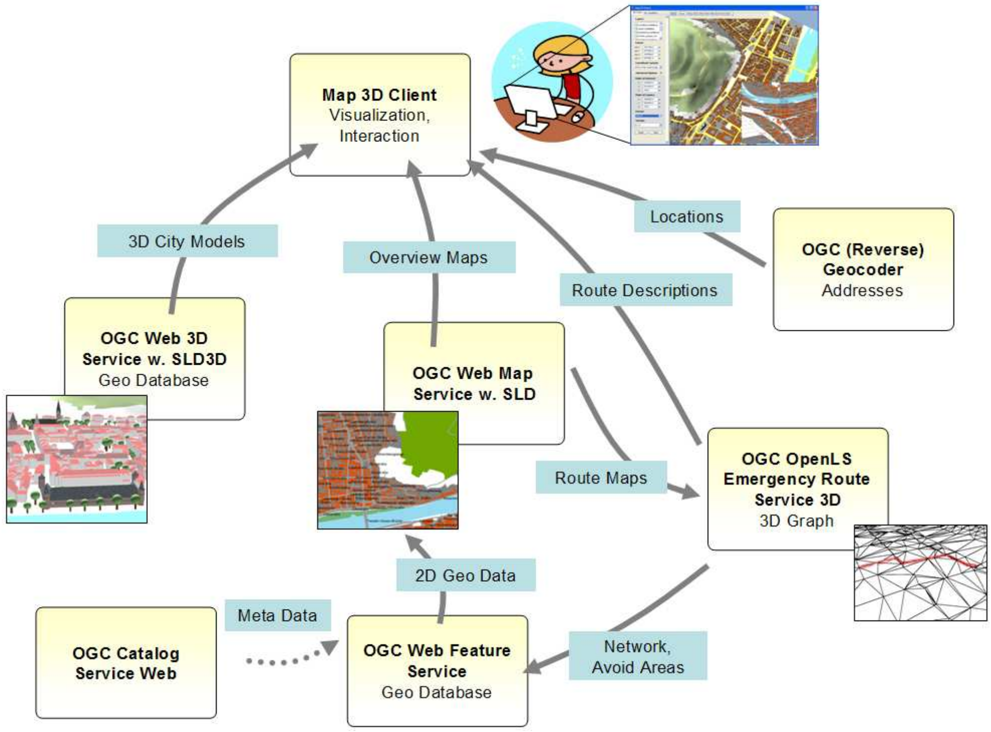


Figure 4: OGC Services in the Heidelberg 3D-SDI (Basanow et al. 2007)
(WPS to be added soon for pre-processing of terrain data)

5 Synthetic textures for 3D Navigation

There is a wide variaty of techniques to present directions and support on mobile devices ranging from spoken instructions to 3D visualization. In order to produce a coherent and cohesive presentation it is necessary to adapt a presentation to the availale technical and cognitive resources of the presentation environment. Coors et al. (2005) evaluated several means of route instructions to a mobile user. 3D visualization seems to be well suited where time and technical resources are not an issue, and where the available position information is imprecise: The realistic 3D visualization allow the user to search her environment visually for specific features, and then to align herself accordingly, thereby compensating for the imprecsion. These are typical conditions of mobile navigation for pedestrians in urban areas, especially for tourists visiting a city. For this reason two different types of buildings in a 3D urban model for pedestrian navigation will be distinguished: on the one hand buildings that act as visual landmarks and on the other side normal buildings that do to serve as landmarks. It is assumed that most of the buildings belong to the second category. While landmark building could be represented in high detail with resonable efford, this is not possible and even not necessary for building of the second category. It seems to be sufficient to represent these buildings as models that are not photorealistic but have only a visual similarity with the real feature. Synthetic texturing seems to be a good approach to achieve this goal with reasonable efford.

Assuming that the building geometry is given by airborne laser scan, photogrammtry method or just extruded from 2D-GIS texturing the fassades and roofs is the remaining challange. A fassade texture is generated based on libraries of typical window, door and material images. Under the assumption that the building geometry is given as a boundary representation based on polygons, each wall of a building is represented by a least one polygon. For each of these polygons one pulse function for each dimension control the process of texture creation. For a rectangular polygon these pulse functions are fairly easy to define:

A pulse function p: [0,1] -> {0,1} is used to place features as windows and doors on a given background texture. If the product of the two pulse functions px and py is 1 the given feature image is inserted, otherwise the background image is used for texturing. To be more flexible, layers of feature textures can be used, for example one layer for windows and a second layer for doors. Each layer should make use of different pulse functions.

Example:

Figure 5: pulse function to generate a window pattern on a facade

The pulse functions can be mapped to any geometry using the local surface coordinate system of this geometry.

Implementation:

On GPUs the pulse functions can easily implemented directly in the Pixel shader. On mobile device currelty generate the facade texures using M3G based on image library and pulse funstion. No image texture will be generated which saves an enourmos amout of image data.

To simplify the definition of the pulse functions, the position of window rows and columns specific user interface is developed.

Fensterspezifikation

MoNa 3D

Fenster

Anzahl Reihen: 3

Anzahl pro Reihe: 9

Anzahl pro Gruppe: 3

Abstand in der Gruppe Gruppe: 7

Fenstertyp: Dunkel

Figure 6: Upper left: User Interface to specify the pulse function for window layer, upper right: the facade generated by this pulse function with an additional layer to position a door; lower left – similar with another position of the door; lower right – variation of the window layer pulse function.

6. Mobile communication and Bandwidth

Often UMTS is claimed to be the solution for any performance problems of mobile applications. However, the bandwidth within an UMTS cell cannot be predicted. All devices which are logged in to a cell have to share the available bandwidth. This leads more or less to unpredictable bandwidth situation and limits – depending on the actual infrastructure development – the use especially where it might be required the most.

There is a clear need to reduce the network traffic as much as possible. Here, 3D scenes formatted as VRML or CityGML are growing too big. M3G is a much more compact format, but still can be optimized by using compression techniques. One solution is the use of ZIP encoding as it is already supported by J2ME. However, by using a mesh compression that takes into account the specific properties of 3D models, especially the topological information of meshes, much higher rates could be achieved. An example for such a compression is the Delphi algorithm (Coors and Rossignac 2004), that uses a prediction scheme to reduce connectivity information down to less that 2 bits per triangle. Adding support for such a compression scheme to a standard like M3G as an optional feature would allow a very network-efficient transfer of even complex geometries, at the cost of slightly higher computing time on the side of the server and the client.

The Delphi copmpression scheme was tested on portions of a 3D city model of Stuttgart (LoD , no textures). Two different parts of the model have been chosen to represent the experiments:

Figure 7: 3D-Model of the city of Stuttgart, © Stadtmessungsamt Stuttgart.

A small model of Stuttgart downtown with 111 buildings (2908 vertices, 5802 triangles) as shown in Figure 5 and a larger residential area with 6771 buildings (153697 vertices, 280306 triangles). Table 1 shows the mesh compression results:

	Stuttgart downtown	**Stuttgart residential area**
Buildings	111	6771
Triangles	5802	280306
VRML file size (triangulated IFS)	435 kB	13694 kB
Compressed file size	31 kB (7%)	1108 kB (8%)
Compression runtime	309 ms	8078 ms
Decompression runtime	247 ms	6588 ms

Table 1: Mesh compression results. Runtime was measured on an IBM Thinkpad T41p 1700 MHz 1 GB RAM within an Eclipse development environment.

Summary

Within this paper we have discussed important technical questions when providing navigation support with 3D city odels on mobile devices. This included both the needed spatial data infrastructure as a backbone and that this needs to be extended to 3D and integrated with standards relevant for location based services, such as OpenLS , the support (and extension) of open standards in order to reach a higher deegree of interoperability, solutions for handling textures of building facades on devies with very limited power, as well as issues of compressing 3D city models efficiently. On the other hand a range of future research questions regarding the personalized and context aware appropriate usage and visualization of landmarks and 3d city models were raised and discussed shortly. These need further discussion and work within the project and in general and could not dealt with in sufficient detail within this paper so far.

As can be ssen easily from the figures our test areas currently include the city of Stuttgart and the city of Heidelberg, but in future work we also plan to provide navigation through rural areas between these cities.

Ackowledgements

This work has been supported by the Germany Ministry of Education and Research (BMBF) within the project MoNa3D and through the Klaus Tschira Foundation Heidelberg (KTF). We thank all of our project partners and co-workers for their valuable support and input and the data providers for their contributions (Vermessungsamt Heidelberg, European Media Laboratory, EML Heidelberg).

References

Basanow J., P. Neis, S. Neubauer, A. Schilling, Zipf, A., (2007): Towards 3D Spatial Data Infrastructures (3D-SDI) based on Open Standards - experiences, results and future issues. In: "3D GeoInfo07". ISPRS WG IV/8 International Workshop on 3D Geo-Information: Requirements, Acquisition, Modelling, Analysis, Visualisation. Delft, NETHERLANDS

Coors, V., and Rossignac, J. (2004): Delphi: geometry-based connectivity prediction in triangle mesh compression. In: The Visual Computer, International Journal of Computer Graphics, Vol. 20, Number 8-9, Springer Verlag, Berlin Heidelberg, November 2004, pp 507 – 520.

Coors, V. und Zipf, A, (eds.)(2005): 3D-Geoinformationssysteme. Grundlagen und Anwendungen. Wichmann - Hüthig Verlag. Heidelberg. 525 pages.

Coors, V., and Schilling, A. (2003): 3D Maps on Mobile Devices. Mensch und Computer 2003, Workshop Design kartenbasierter mobiler Dienste, Proceedings, Stuttgart, 2003

Elias, B. (2006): Extraktion von Landmarken für die Navigation, Wissenschaftliche Arbeiten der Fachrichtung Geodäsie & Geoinformatik der Uni Hannover, Nr. 260.

Fischer, M., Basanow, J., A. Zipf (2006): Mainz Mobile 3D - A PDA based OGC Web 3D Service Client and corresponding server. International Workshop on 3D Geoinformation 2006 (3DGeoInfo'06). Kuala Lumpur. Malaysia.

GDI-3d.de – http://www.gdi-3d.de

Golledge, R. (1996): Human wayfinding and cognitive maps, In: Wayfinding Beheaviour, R. Golledge, Ed. Baltimore, John Hopkins University Press, 1999, pp. 5-46

Kray C, Elting C, Laakso K, Coors V. (2003): Presenting Route Instructions on Mobile Devices. Proceedings of IUI'03, ACM Press, New York, NY, pp. 117-124.

Lovelace K., M. Hegarty, and D. Montello (1999): Elements of Good Route Directions in Familar ans unfamiliar Environments. In: Freska, C. and Mark, D. (Eds.): Spatial Information Theory, Proceedings COSIT 1999, Springer, pp 65-82

Lynch, K. (1960): The Image of the City. The MIT Press, Cambridge

MoNa3D – http://www.mona3d.de

Meng, L., Zipf, A. and Reichenbacher, T. (eds.) (2004): Map-based mobile services – Theories, Methods and Implementations. Springer Geosciences. Springer Verlag. Heidelberg.

Müller, M. (ed) (2007): OpenGIS Symbology Encoding Implementation Specification v.1.1.0.nr. 05-077r4

Müller, G. Zeng, P. Wonka, and L. Van Gool. 2007. Image-based Procedural Modeling of Facades. In Proceedings of ACM SIGGRAPH 2007.

M3G Specification: Mobile 3D Graphics API for J2MET. http://jcp.org/jsr/detail/184.jsp

Neubauer, S., Zipf, A. (2007): Suggestions for Extending the OGC Styled Layer Descriptor (SLD) Specification into 3D – Towards Visualization Rules for 3D City Models, Urban Data Management Symposium. UDMS 2007. Stuttgart. Germany.

Neis, P., A. Schilling, A. Zipf (2007): 3D Emergency Route Service (3D-ERS) based on OpenLS Specifications. GI4DM 2007. 3rd International Symposium on Geoinformation for Disaster Management. Toronto, Canada.

Neis, P. and Zipf, A. (2007): Realizing Focus Maps with Landmarks using OpenLS Services. LBS and Telecartography 2007. Hongkong.

Nurminen, A. m-LOMA - a Mobile 3D Portal to Location-based Information, Eurographics 2006.

Nurminen, A. m-LOMA - a mobile 3D city map Proceedings of the eleventh international conference on 3D web technology, 2006.

Parish Y. I. H. and P. Müller. 2001. Procedural Modeling of Cities. In Proceedings of ACM SIGGRAPH 2001, ACM Press

OGC: OpenGIS® Styled Layer Descriptor (SLD) Implementation Specification v. 1.0 doc.nr. 02-070

OGC (2005): Styled Layer Descriptor Profile of the Web Map Service Implementation Specification version 1.1 doc.nr. 05-078

Schilling, A. and Zipf, A. (2003): Generation of VRML City Models for Focus Based Tour Animations. Integration, Modeling and Presentation of Heterogeneous Geo-Data Sources. 8th Int. Symp. on Web 3D Technology. Web3D 2003. Saint Malon. France.

UbiGIS: www.ubigis.org

Zipf, A. (1998): DEEP MAP - A prototype context sensitive tourism information system for the city of Heidelberg. In: Proc. of GIS-Planet 98. Lisboa, Portugal.

Zipf, A. (2002): User-Adaptive Maps for Location-Based Services (LBS) for Tourism. In: K. Woeber, A. Frew, M. Hitz (eds.), Proc. of the 9th Int. Conf. for Information and Communication Technologies in Tourism, ENTER 2002. Innsbruck, Austria. Springer Computer Science. Heidelberg, Berlin.