University of Heidelberg, Institute of Geography

EMBEDDING CONTEXT-AWARENESS TO IMPROVE 3D GEO-VISUALIZATION FOR MOBILE USERS

Ming Li, Mohamed Bakillah, Alexander Zipf

Abstract: With today's abundant 3D geo-data from both commercial and open sources, 3D geo-visualization has become quite common on personal computers. Simultaneously, modern tablets and smart phones, which are getting more and more powerful, make the consumption of 3D geo-data on mobile devices more desirable. However, as opposed to desktop computers which operate in a rather static environment, the mobile devices are highly portable, and thus their usage environment is much more dynamic and complicated. In addition, both the physical capabilities of mobile devices and the mental resources of mobile users are limited. Consequently, 3D geo-visualization on mobile devices must be aware of the usage context, and provide only the most relevant information to the user in an efficient manner. This paper presents the argument that 3D geo-visualization can be improved by taking the usage context into consideration, and also demonstrates the requirements and possibilities of embedding context-awareness into 3D geo-visualization.

Keywords: Context modeling, context-awareness, 3D geo-visualization, mobile computing applications

ZUR NUTZUNG VON KONTEXTINFORMATIONEN ZUR VERBESSERUNG DER 3D-GEOVISUALISIERUNG FÜR MOBILE NUTZER

Zusammenfassung: Durch die Vielzahl verfügbarer 3D-Geodaten, sowohl aus kommerziellen als auch freien Quellen, ist auch deren Visualisierung auf PCs weit verbreitet. In den letzten Jahren wurden auch moderne Tablet PCs und Smartphones immer leistungsfähiger, sodass diese durch ihre performante Grafikhardware mit PCs gleichziehen. Im Gegensatz zu Computern, die in der Regel stationär verwendet werden und somit in einer eher statischen Umgebung genutzt werden, sind mobile Geräte ständig in Bewegung. Die Umgebung unterliegt daher sehr dynamischen Änderungen. Die 3D-Geovisualisierung auf mobilen Endgeräten soll daher an das dynamische Umfeld, den Kontext, angepasst werden und die Bedürfnisse des Nutzers berücksichtigen. Die relevanten Informationen müssen dem Nutzer zeitnah und effizient präsentiert werden. Der folgende Beitrag analysiert Anforderungen und Möglichkeiten zur Einbeziehung von Kontextinformationen in die 3D-Geovisualisierung. Es wird gezeigt, wie eine dreidimensionale Visualisierung durch die Berücksichtigung des Kontexts verbessert werden kann.

Schlüsselwörter: Kontextmodellierung, Kontextbewusstsein, 3D-Geovisualisierung, mobile Computinganwendungen

Authors

M. Sc. Ming Li
Dr. Mohamed Bakillah
Prof. Dr. Alexander Zipf
University of Heidelberg
Institute of Geography
Berliner Straße 48
D-69120 Heidelberg

E: ming.li@geog.uni-heidelberg.de
mohamed.bakillah@geog.uni-heidelberg.de
alexander.zipf@geog.uni.heidelberg.de

1 INTRODUCTION

Today's technological innovations in both data acquisition and data handling satisfy human desires of using geo-data in a more natural three dimensional way. The notion of the *"Digital Earth"* was conceived as far back as 1998 by a former American Vice President, Al Gore. Gore (1998) describes a vision that people understand our planet with multi-resolution through a 3D virtual globe which serves as an interface to all kinds of spatial, temporal and semantic information. Besides the utilization of commercial geo-data in the market, 3D visualizations based on open geo-data sources are also very popular. For example, Over et al. (2010) and Goetz & Zipf (2012) present the generation and visualization of 3D city models based on OpenStreetMap[1] data.

Moreover, the aspiration of using geo-data is not limited to the desktop environment, because geo-data can be even more demanded when people are outdoors where a heavy computer is unreachable. Anyway, the use of geo-data is deeply rooted in outdoor environment considering the long history of paper maps. With technological innovations in mobile computing devices, the demands for using geo-data on the move are likely to increase even further, because people continuously use mobile devices more and more often.

Consequently, using geo-data in three dimensions on mobile devices is a tendency under the two aspects. However, 3D geo-visualization on mobile devices is a challenging task since these devices still suffer severe physical restrictions with respect to display size, processing ability, etc. The mental resources of the mobile users are also limited, as they often have other tasks besides interacting with the mobile application. Furthermore, since the user is outdoor and always on the move, the use environment of the application keeps changing as well, which will have significant impact on decision making. In this respect, 3D geo-visualization on mobile devices must take into account the special mobility context, thereby providing the users only the most relevant information to aid decision making and improve their experiences.

The main contribution of this paper is the illustration of the role of context-awareness in 3D geo-visualization, as well as the discussion of the requirements to model context and approaches to embed it in the visualization process. The rest of this paper is organized as follows: first there is a brief overview about the related work on 3D mobile applications. Thereafter, the main part of this paper describes the definition of context and its role in 3D visualization of geo-data. The requirements of context modeling are explained as well, which are demonstrated by two examples in the next chapter. The last chapter concludes the conducted work and provides an outlook on future research.

2 RELATED WORK

Exploration of 3D visualization on mobile devices has been underway since the last century, at the time when both hardware and software of the mobile devices were still at a very early stage of development. By combining 3D graphics of virtual environment with the freedom of mobile computing, scientists are able to build pervasive computing systems that can support users in their everyday interactions with the world. A pioneer in this area is Feiner et al. (1997), who developed a prototype application that presented information about their campus using a wearable device with both 2D and 3D displays. Similarly, Rakkolainen & Vainio (2001) customized their web-based 3D city info system for mobile users, and attested their belief that the intuitive and life-like 3D graphics can improve the usability of typical GIS functions such as navigation and way-finding. With a similar belief, dozens of projects and systems have been presented in the past years, such as the TellMaris project (Laakso et al. 2003), the LAMP3D system (Burigat & Chittaro 2005), the m-LOMA system (Nurminen 2006), the MONA 3D project (Coors & Zipf 2007), the eSpective2 system (Kjeldskov et al. 2012), etc.

Although these systems explore mobile 3D applications from different aspects, one keyword that exists in almost all of them would be 'location-aware', which means they all understand that the advantages of mobile computing systems can be largely amplified when their systems are aware of the changing location.

Location-awareness can be regarded as the earliest stage and a very important aspect of context-awareness, but it is far away from enough (Henricksen et al. 2002). Research studies in mobile and pervasive computing reveal that many other parameters such as time, weather, user's tasks and profile also have significant impact on decision making (Reichenbacher 2003, Dransch 2005, Nivala & Sarjakoski 2003, Zipf & Aras 2002, Zipf 2002, Zipf & Jöst 2006). There exists therefore a common belief that mobile computing systems should be aware of not only location but also other parameters, i. e., the whole context.

Embedding context-awareness into the 3D mobile systems is not as simple as embedding location-awareness, because context is a much more comprehensive and dynamic whole. To make use of context information efficiently, a context model should be built beforehand, and a mechanism of gathering, managing and disseminating context information should be created. Based on that, the system can visualize the most relevant information, thereby reducing the cognition load and improving the use experience. Such kind of work is vital but still missing in these location-aware 3D mobile systems; therefore a good effort is required to explore the approaches of embedding context-awareness in mobile 3D geo-visualization.

3 EMBEDDING CONTEXT-AWARENESS TO IMPROVE 3D GEO-VISUALIZATION

3.1 THE DEFINITION OF CONTEXT

The notion of context has been considered from various perspectives, including from those of context-aware systems (Abowd et al. 1999, Anagnostopoulos et al. 2007, Teo 2008), semantic interoperability (Brodeur et al. 2003), semantic similarity (Keßler et al. 2007) and Geospatial Semantic Web (Egenhofer 2002). Consequently, context has been given a variety of definitions, which are more or less dependent on the application domain (Bakillah et al. 2012). Among the most frequently cited definitions exists for example the definition by Abowd et al. (1999), which states that context is "any information that can be used to characterize the situation of an entity".

In the field of mobile geo-visualization (e. g.: mobile maps, mobile guides), context is usually considered as a group of parameters that will affect the user's behavior in a certain use case. However, the "information used to characterize the situation of an entity" includes not only the various parameters but also the relationships between these parameters, because context information is highly interrelated and some implicit context can be derived from other context information (Henricksen et al. 2002). It is also noticed that most of context information is dynamic and has a period of validity. All these characteristics must be considered when defining, modeling and managing context information.

3.2 THE ROLE OF CONTEXT-AWARENESS IN 3D GEO-VISUALIZATION

Within GIS there is always a clean cut between raw geo-data and its visualization properties (Neubauer & Zipf 2007) in order to allow multiple presentations of the same data for the needs of different users. Considering these two aspects will enable one to answer the questions of “What will be visualized?” and “How to visualize?” respectively. Therefore, this section will elaborate on the role of context-awareness in 3D geo-visualization from these two aspects.

In terms of visualized data, context awareness can significantly improve the efficiency of both the system and the user. On one hand, 3D applications tend to have a huge data volume and involve complex 3D graphics, despite the fact that mobile devices are normally resource-limited. On the other hand, 3D applications can impose significant conceptual workload to the users although the mental resources of mobile users are limited. Such kind of conflictions can have an impact on decision making, task fulfilment, system performance and various usability aspects. To ensure that the 3D contents can be visualized smoothly on the mobile device and comprehended efficiently by the user, one must eliminate irrelevant geographic information objects while keeping the most relevant ones. But their geographic relevance (Raper 2007, Reichenbacher & De Sabbata 2011) depends heavily on the context. For example, street furniture such as fire hydrants would be very important in an emergency response use case but would only be a source of distraction for car navigation users.

A context-aware system should be able to select and visualize only the most relevant 3D content. In this way, data volume can be reduced and the rendering speed can be increased. On the other hand, since only the most relevant data will be visualized, the users can efficiently focus on, and comprehend the information of interest.

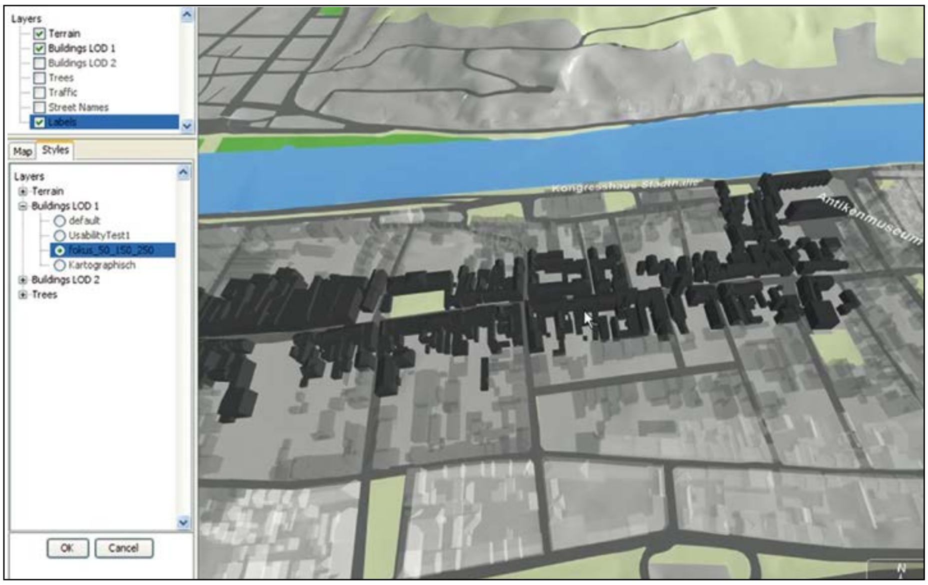

Figure 1: 3D focus map with focus on area around the route (Source: Neis & Zipf 2008)

With regard to the visualization property, context is also important for the visualization of the relevant data in a fast-focus manner by adapting 3D visual variables. The concept of visual variables (2D) was proposed by Bertin when he formulated Image Theory in 1967 (Bertin 1983) (first published in French in 1967 and translated in 1983). He defines seven visual variables, and points out that each visual variable has its own perceptual properties. He demonstrates for example that *hue*, *texture*, *value* and *size* are selective because if a mark changes with these variables, it can be easily selected from other marks. Besides these visual variables inherited from 2D cartography, there are numerous 3D-specific ones (Haeberling 2004), such as viewing angle, shade or shadows, etc., which also possess some perceptual properties. Accordingly, these visual variables should be adapted to satisfy the user’s actual need based on the context.

An early example of combining both data and style aspects of visualization is the notion of *Focus Maps* raised by Zipf & Richter (2002), who attempt to adapt the application to the user’s context by visualizing the relevant geo-objects or areas with more details and a brighter color. This concept is extended by Neis & Zipf (2008) to the third dimension, as depicted in Figure 1. The geo-objects near the navigation route are considered more relevant than those that are far away, therefore they are visualized in a more attractive color.

To sum up, context-awareness is a key element in the visualization process in terms of both visualized geo-data and visualization properties. When implementing a context-aware 3D geo-visualization application, both aspects should be considered carefully.

3.3 THE REQUIREMENTS TO MODEL CONTEXT

Visualization should possess a number of capabilities in order to be characterized as context-aware. Specifically, as indicated by Anagnostopoulos et al. (2007) in their work on context awareness in mobile computing environments, a context-aware application has to meet some requirements that are related to three areas: context modeling, context processing and adaptation to context.

Firstly, a context-aware application must incorporate some context acquisition capacity, where information on context is gathered from one or several sources. It must also be able to store the context information and aggregate context information from multiple sources. Thirdly, the context-aware application should offer the capability of retrieving the context information that is needed for a given task. This means that a context query mechanism must be available to access context resources.

Once relevant information on context is retrieved, the other main feature of context-aware applications is the adaptation to the current context. This often means that the context-aware application is equipped with a reasoning mechanism that allows inferring the actions that should be performed in a given context. The reasoning mechanism could also integrate the capacity to infer more complex context information from the basic and available context information. Appropriate languages such as Description Logics which allow reasoning with formal semantic can be leveraged to support this task.

Finally, a context-aware application can also integrate the capacity to assess and deal with the quality of context information, as well as its fitness-for-use for a given task.

4 WORKFLOW AND EXAMPLES

The following chapter demonstrates possible adaptations of 3D geo-visualization to the user's context on mobile devices. The test device is a Samsung Galaxy Tab 2 10.1N with Android platform of Version 3.2. The application is developed with OpenWebGlobe SDK[2] and under a series of open standards, such as OGC W3DS (Web 3D Service), SLD (Styled Layer Descriptor) and Khronos WebGL[3], among others.

It works as follows: whenever the users requests for a 3D scene, it will first ask for context information from a context providing service, which is in charge of context management including information acquisition, aggregation, reasoning and provision. After it gets the context, it will send the processed context information together with the normal 3D scene request parameters to a mediate processing server. The processing server will then analyse this information according to certain predefined rules, organize a 3D SLD file and a W3DS accordingly. Thereafter, it will send them to the W3DS server, and get the styled 3D scene.

W3DS is currently an OGC standard candidate (OGC 2010), which offers a portrayal service for 3D geo-data, such as landscape models, city models, vegetation objects and street furniture. With W3DS, geo-data will be delivered as 3D scenes that are comprised of display elements, optimized for efficient real time rendering at high frame rates. Here we use the already existing implementation of W3DS within the project GDI-3D[4]. And the 3D SLD (Neubauer & Zipf 2007) is an extension to the OGC specification Styled Layer Descriptor and is already implemented in our W3DS. Similar to 2D SLD, it is designed to support a client-side definition of visualization rules. With the help of 3D SLD, not only the data but also the visualization styles can be adapted to the context information according to certain rules.

Currently the 3D scene received from W3DS is described in VRML format, but JSON format is required for the mobile application; therefore a small data process for format conversion will be performed after that. Finally, the adapted 3D scene will be sent back to the client and visualized on the mobile device. Figure 2 depicts the workflow in an UML diagram. Based on this workflow we offer two simple examples. The examples are at a very early stage and only serve as demonstrations of our concept here.

When starting the application, the user will get a globe which is already centred at the user's current location. It can be regarded as the first adaptation to the user's context, since location itself is an important parameter of context. Such kind of information can be further emphasized by setting a specific visualization style based on user's preference. Figure 3 depicts the result which emphasizes the location by highlighting the buildings around the location according to user's preference.

Context can also be used to parameterize "contextual commands" (Schilit et al. 1994), i. e., queries on contextual information can produce different results according to the context in which they are issued. Figure 4 therefore illustrates an adaptation to the user's profile. When asking for "transportation information", car drivers might mean parking lots while pedestrians, for instance, care more about taxi and bus stops. As a result, different information should be selected and visualized for different users.

5 CONCLUSION AND OUTLOOK

Nowadays, human desire to utilize geodata in its natural 3D form has extended to mobile world, despite the fact that the mobile devices still suffer severe physical restrictions. By taking advantage of both mobility and the visual similarity of the real

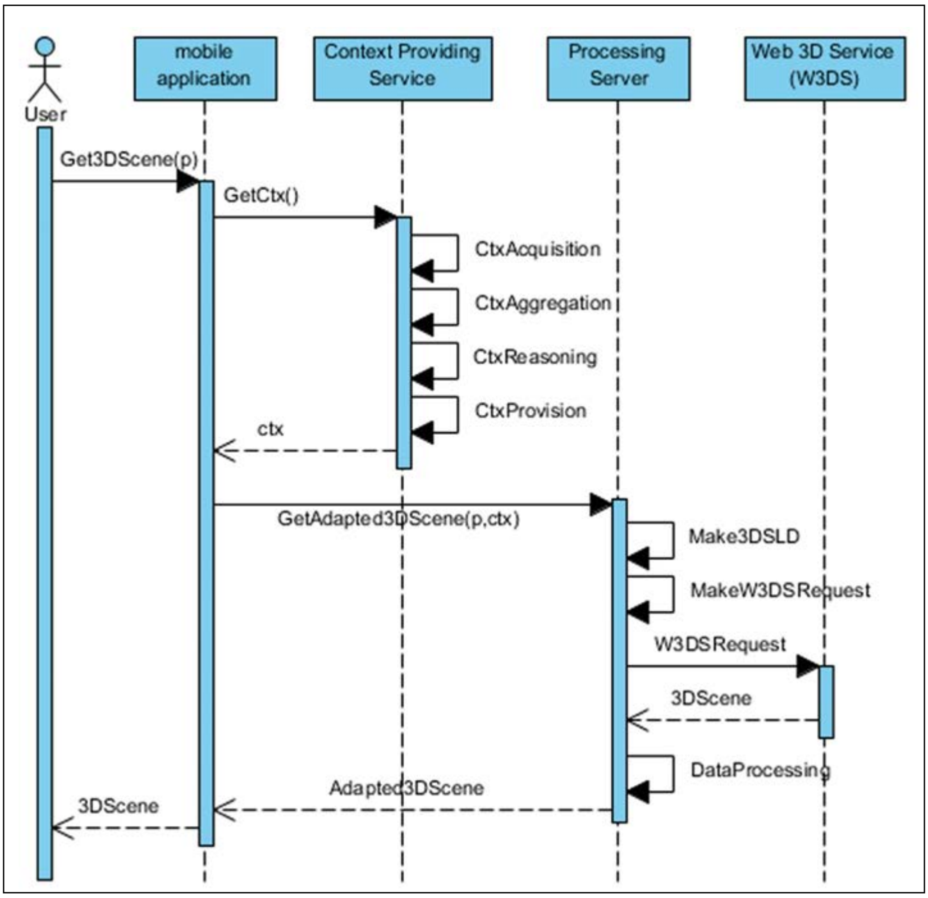

Figure 2: UML diagram of the workflow oriented context

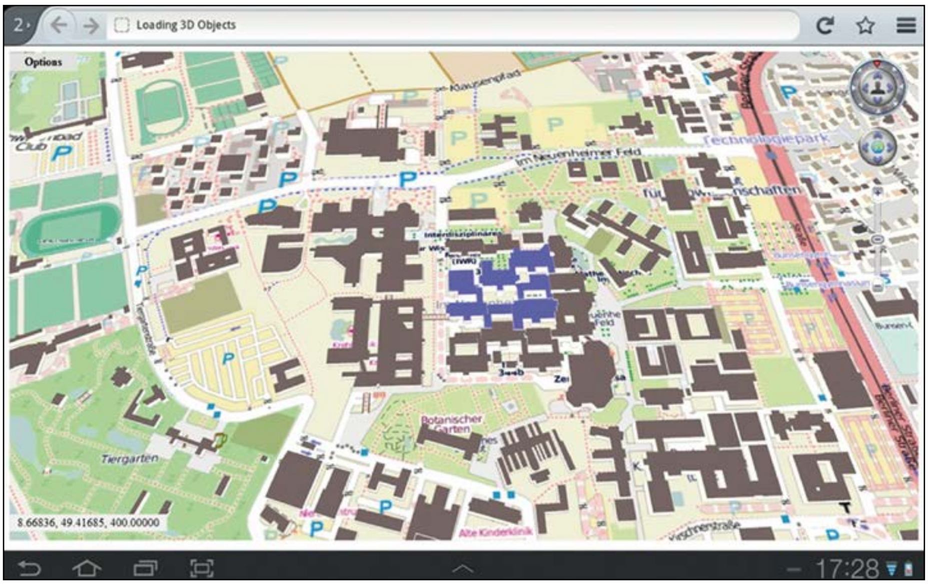

Figure 3: Adaptation to user's location and preference

a)

b)

Figure 4: Adaptation to user's profile (visualize parking lots for car drivers (a) and public transports for pedestrians (b))

world, 3D geo-visualization on mobile devices is a promising undertaking in aiding mobile users for decision-making. However, both sides give rise to great challenges to mobile 3D geo-visualization that must be considered carefully. We believe an adequate mobile 3D geo-visualization system should be able to select the most relevant information according to the mobility context, and visualize them in an adaptive way, so that the user can easily grasp the information of their interests, and at the same time the system's performance can be ensured.

After the short introduction of the demand of embedding context-awareness into 3D geo-visualization, a brief overview about related work on context has been conducted. Following this, the role of context-awareness in improving 3D geo-visualization together with the requirements of embedding context-awareness is elaborated. Based on that, two adaptation examples are given, both of which are from a mobile application which is developed on Android platform under a series of standards.

In the future, we will elaborate a more detailed context model which can be used to further improve the 3D geo-visualization on the one hand, and on the other hand, explore the approach of evaluating the relevance of geo-data, and also investigate different visualization approaches as well as their perceptual performances. In general, a context-aware geo-visualization in three dimensions on mobile devices is a challenging task, and will be an integral part of our future research efforts.

[1] http:// www.openstreetmap.org

[2] http:// wiki.openwebglobe.org

[3] http:// www.khronos.org/webgl

[4] http:// koenigstuhl.geog.uni-heidelberg.de/gdi-3d

References

Abowd, G. D.; Dey, A. K.; Brown, P.; Davies, N.; Smith, M.; Steggles, P. (1999): Towards a Better Understanding of Context and Context-Awareness. In: Handheld and Ubiquitous Computing, 1707, pp. 304-307.

Anagnostopoulos, C. B.; Tsounis, A.; Hadjiefthymiades, S. (2007): Context awareness in mobile computing environments. In: Wireless Personal Communications, 42 (3), pp. 445-464.

Bakillah, M.; Liang, S. H. L.; Zipf, A.; Mostafavi, M. A. (2012): A dynamic and context-aware semantic mediation service for discovering and fusion of heterogeneous sensor data. In: Journal of Spatial Information Science (accepted).

Bertin, J. (1983): Semiology of Graphics: Diagrams, Networks, Maps. University of Wisconsin Press.

Brodeur, J.; Bedard, Y.; Edwards, G.; Moulin, B. (2003): Revisiting the Concept of Geospatial Data Interoperability within the Scope of Human Communication Processes. In: Transactions in GIS, 7 (2), pp. 243-265.

Burigat, S.; Chittaro, L. (2005): Location-aware visualization of VRML models in GPS-based mobile guides. In Proceedings of the tenth international conference on 3D Web technology. In: ACM, pp. 57-64.

Coors, V.; Zipf, A. (2007): MONA 3D – Mobile Navigation using 3D city models. 4th International Symposium on LBS and Telecartography 2007. Hongkong.

Dransch, D. (2005): Activity and Context – A Conceptual Framework for Mobile Geoservices. In: Meng, L.; Reichenbacher, T.; Zipf, A. (Eds): Map-based mobile services: Theories, Methods, and Implementations. Springer, Berlin/Heidelberg, pp. 31-42.

Egenhofer, M. J. (2002): Toward the semantic geospatial web. In: Proceedings of the tenth ACM international symposium on Advances in geographic information systems – GIS '02. ACM Press, New York, USA, pp. 1-4.

Feiner, S.; MacIntyre, B.; Höllerer, T.; Webster, A. (1997): A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. In: Personal and Ubiquitous Computing, 1 (4), pp. 208-217.

Goetz, M.; Zipf, A. (2012): OpenStreetMap in 3D-Detailed Insights on the Current Situation in Germany. 15th AGILE International Conference on Geographic Information Science, Avignon, France, 2012.

Gore, A. (1998): The digital earth: Understanding our planet in the 21st century. In: Australian Surveyor, 43 (2), pp. 89-91.

Haeberling, C. (2004): Selected design aspects and graphic variables for 3D mountain maps. In: Proceedings of the 4th Mountain Cartography Workshop, pp. 1-9.

Henricksen, K.; Indulska, J.; Rakotonirainy, A. (2002): Modeling context information in pervasive computing systems. In: Pervasive Computing, pp. 79-117.

Keßler, C.; Raubal, M.; Janowicz, K. (2007): The effect of context on semantic similarity measurement. On the Move to Meaningful Internet Systems 2007. OTM 2007 Workshops. Springer, Berlin/Heidelberg, pp. 1274-1284.

Kjeldskov, J.; Skov, M. B.; Nielsen, G. W.; Thorup, S.; Vestergaard, M. (2012): Digital urban ambience: Mediating context on mobile devices in the city. In: Pervasive and Mobile Computing.

Laakso, K.; Gjesdal, O.; Sulebak, J. R. (2003): Tourist information and navigation support by using 3D maps displayed on mobile devices. ICT-Conference Proceedings.

Neis, P.; Zipf, A. (2008): Extending the OGC OpenLS Route Service to 3D for an interoperable realisation of 3D focus maps with landmarks. In: Journal of Location Based Services, 2 (2), p. 22.

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

Nivala, A.-M. M.; Sarjakoski, L. T. (2003): An approach to intelligent maps: Context awareness. 2nd Workshop on'HCI in Mobile Guides.

Nurminen, A. (2006): m-LOMA – a mobile 3D city map. In: Proceedings of the eleventh international conference on 3D web technology – Web3D '06. ACM Press, New York, USA, p. 7.

OGC (2010): Draft for Candidate OpenGIS® Web 3D Service Interface Standard. Schilling, A.; Kolbe, T. H. (Eds.).

Over, M. et al. (2010): Generating web-based 3D City Models from OpenStreetMap: The current situation in Germany. In: Computers Environment and Urban Systems, 34 (6), pp. 496-507.

Rakkolainen, I.; Vainio, T. (2001): A 3D City Info for mobile users. In: Computers & Graphics, 25 (4), pp. 619-625.

Raper, J. (2007): Geographic relevance. In: Journal of Documentation, 63 (6), pp. 836-852.

Reichenbacher, T. (2003): Adaptive methods for mobile cartography. Proceedings of the 21st International Cartographic Conference (ICC).

Reichenbacher, T.; De Sabbata, S. (2011): Geographic relevance. In: SIGSPATIAL Special, 3 (2), pp. 67-70.

Schilit, B.; Adams, N.; Want, R. (1994): Context-aware computing applications. In: First IEEE Workshop on Mobile Computing Systems and Applications, 1994. WMCSA 1994, IEEE, pp. 85-90.

Teo, H.-S. (2008): An activity-driven model for context-awareness in mobile computing. In: Proceedings of the 10th international conference on Human computer interaction with mobile devices and services. ACM, pp. 545-546.

Zipf, A. (2002): User-Adaptive Maps for Location-Based Services (LBS) for Tourism. Proceedings of the 9th Int. Conf. for Information and Communication Technologies in Tourism, ENTER 2002, Innsbruck, Austria. Springer, Berlin/Heidelberg.

Zipf, A.; Aras, H. (2002): Proactive Exploitation of the Spatial Context in LBS – through Interoperable Integration of GIS-Services with an Multi Agent System. AGILE 2002. Int. Conf. on Geographic Information System (MAS).

Zipf, A.; Jöst, M. (2006). Implementing adaptive mobile GI services based on ontologies: Examples from pedestrian navigation support. In: Computers, environment and urban systems, p.15.

Zipf, A.; Richter, K.-F. (2002): Using Focus Maps to Ease Map Reading. In: Künstliche Intelligenz (KI), 4 (2), pp. 35-37.