Adapting OSM-3D to the Mobile World: Challenges and Potentials

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Abstract Location-Based-Services (LBS), such as route planning or Point-of-Interest (POI) search are well-known and their consumption is quite common on personal computers. Simultaneously, mobile devices, such as tablets or smart phones, penetrate the market and offer great potentials for sophisticated and advanced LBS. Based on the open and free OSM data, the current project OSM-3D has already demonstrated that such data can be perfectly used for the generation of a 3D virtual globe and for the provision of various 3D-LBS. Trying to merge the phenomenon of 3D-VGI with the increasingly available mobile devices, the here conducted work discusses potentials and challenges arising from a mobile OSM-3D application, and divides the challenges into platform adaptation, physical adaptation and scenario adaptation. For platform adaptation, this chapter selects one very promising technology for adapting OSM-3D to mobile devices by critically evaluating different technologies for the aimed work. For physical adaptation, the here conducted work discusses ideas for fast and apprehensible rendering of 3D objects on mobile devices. Since a good knowledge of context is essential for both physical adaptation and scenario adaptation, the presented framework also incorporates a tailored analysis of the mobile using context of OSM-3D. Thereby, this chapter provides a comprehensive framework and proposal towards a context-aware OSM-3D mobile application.

Keywords 3D geodata · Crowdsourced geodata · Mobile applications · LBS · OpenStreetMap · Volunteered geographic information · Adaptation · Context-awareness

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1 Introduction

Thanks to the technological improvement and evolution of mobile devices, such as tablets or smart phones, today's markets offer a wide variety of different so called Location-Based-Services (LBS), which incorporate the location of the user and/or deal with location information. The market and the demand for such applications are likely to increase even further, because people continuously use mobile devices more and more often. Furthermore, the majority of mobile users does not only utilize the integrated functionality, but also use broadband internet connection for the consumption of mobile services. Very impressively, according to ITU (2011), only 10 % of the world's population does not have a mobile phone signal. It seems likely that mobile devices will probably even replace ordinary personal computers, as last year (2011) already more smart-phones and tablets than personal computers have been sold (Cooper 2012). According to Arthur (2011), every fourth mobiles is a smart-phone and it seems as if the tipping point of more than 50 % can be reached in 2012. Furthermore, Google expects that by 2013 (at the latest), the number of search queries from mobile devices will exceed that from PCs (Arthur 2011). However, existing LBS basically stick to a two-dimensional representation. Yet, it has been demonstrated that 3D city models are advantageous for navigation purposes on mobile devices (Coors and Zipf 2007), and Zlatanova and Verbree (2005) also emphasize the actual need for three-dimensional information for LBS.

Regarding the data for such LBS, the last years revealed a new source of open and free to use geo-data, namely Volunteered Geographic Information (VGI). Thereby, both laymen and professionals collaboratively collect and share geo-data in a Web 2.0 community. Whereas in the early beginnings of VGI the users mainly contributed two-dimensional data, in the last few years they also started to collect 3D information, such as height information, roof geometry information etc. Such data can be utilized for the provision of comprehensive and advanced 3D LBS, such as 3D routing and navigation, Point-of-Interest (POI) searching, or simply a 3D virtual model of our globe for browsing and investigating. One of the most mature and advanced examples for the usage of 3D VGI is the OSM-3D project[1]: a virtual globe for visualizing VGI from OpenStreetMap (will be introduced later) as 3D models and providing a variety of services. Furthermore, it is fully based on the standards and drafts of the Open Geospatial Consortium (OGC), such as Web Map Service (WMS), Web3DService (W3DS) and the OpenGIS Location Services (OpenLS). The fundamental ideas, architecture details and processes of OSM-3D are described by Over et al. (2010), Goetz and Zipf (2012a, b), and some relevant details will be given in a later section of this chapter. Within OSM-3D, users can get a better working experience with map services because 3D maps can be easily read and understood by taking advantages of visual similarity with the environment (Aydin et al. 2012).

[1] www.osm-3d.org

Although modern PCs often offer better processing and rendering abilities to deal with massive 3D data, map-based services tend to be more preferred on mobile devices, because such services are mostly demanded when people are outside where a PC is unreachable. There are already several car navigation systems today, but they are mostly based on commercial thus expensive datasets. Therefore, combining OSM-3D and mobile environments raises great potentials, because well-known 3D-LBS based on crowd-sourced data will be consumable on mobile devices. Furthermore, an OSM-3D application could also be used for enriching or enhancing the current OSM data. Since users can orientate themselves and identify the environment better, they can also discover and directly correct the errors or imperfections in the OSM dataset, regarding both geometry and semantics. As an example, a person can easily validate the height of a building, the roof type or textural information, when actually standing in front of the corresponding building and comparing it to the data set in OSM-3D.

The main contribution of this chapter is the discussion and elaboration of challenges and potentials arising from the adaptation of OSM-3D to mobile devices. By evaluating different technical frameworks for the aimed work, elaborating techniques of fast and apprehensible rendering as well as analyzing the mobile using context, this chapter provides a comprehensive framework and proposal towards building a mobile OSM-3D application with context-awareness.

The rest of this chapter is organized as follows: first there is a brief overview about related work on context-aware mobile applications. Thereafter, the OpenStreetMap community is briefly described, followed by a detailed introduction to OSM-3D. Thereafter, the main part of this chapter describes the adaptation of OSM-3D to mobile devices. Dividing the challenges of such an adaptation into platform adaptation, physical adaptation and scenario adaptation, this chapter then discusses the different mobile development frameworks, fast and apprehensible rendering techniques, as well as the using context in the mobile environment. The last chapter then concludes the conducted work and provides an outlook on future research.

2 Related Work

In recent years, a number of map-based applications and services have been made available to users on mobile devices, with a particular emphasis on smart phones. Among others, many location-based services such as route planning and navigation are widely used by a diverse range of users.

Different from the relatively constant using context of the desktop environment, the using context of the mobile environment is more dynamic, diverse and therefore complicated. More specifically, the users' intention and location, the physical surroundings such as illumination or the internet connection are always changing, which will result in different user demands for the mobile services.

Therefore, researchers have performed many investigations in the mobile using context to make their mobile services context-aware.

The earliest integrated definition of context is from Abowd and Dey (1999), who define context as "*any information that can be used to characterize the situation of an entity, where an entity can be a person, place, or physical or computational object*". Based on that, many researchers have created more concrete models of context from different point of view. For example, Reichenbacher (2003) and Dransch (2005) propose models for context based on the activity theory (AT), while Nivala and Sarjakoski (2003) and Sarjakoski and Nivala (2005) study the context based on results of field tests. But they all agree that context should at least contain location, time, user, surroundings and other elements, and these elements are not independent and their significances in different using context are also varying.

To further evaluate the significance of a certain element or the geo-objects in a certain context, the concept of geographic relevance (GR) is raised by Raper (2007) in order to help information seeking in mobile environment. Actually, the concept of GR is an extension of the situational relevance (SR) with a special concern of mobility of geography. Another conceptual model for geographic relevance is given by Reichenbacher et al. (2009) based on activity theory, whereby the "distance" (spatial) is abstracted to a more semantic measurement to evaluate the relevance not only from spatial location but also the semantic distance between the user's activity and the object.

Based on the evaluation of the relevance, researchers have also investigated into the context-adaptation strategy. Zipf (2002) raises a fundamental framework towards building a smart user-centric map services; Reichenbacher (2003) summarizes the adaptable items in the geo-visualization process from categories of geo-information, user interface and visualization respectively; and Zipf (2005) further presents how to utilize the user and context models and generate an adapted mobile maps based on the well-known OGC Styled Layer Descriptor (SLD) specification, just to name a few.

However, such researches are mainly aiming at 2D mobile maps which are mostly applied in the common Location-based services (LBS). In the recent years, mobile 3D environment representations are attaining increasing interest in both academia and industry (e.g. Burigat and Chittaro 2005; Bladauf and Musialski 2010; and others), because 3D representation allows direct matching of visual cues without interpreting and mentally transforming the symbols and two-dimensional shapes of the classical 2D map to the real world environment (Nurminen 2006). Therefore, a context model together with an evaluation of geographic relevance more tailored to 3D environment should be investigated.

With respect to the 3D representation in mobile devices, a lot of challenges remain to be met. On the one hand, despite the rapid development in the last years, distinct physical restrictions of mobile devices (such as small screen size, poor processing capability and unstable internet connection) are still the bottlenecks to deal with complex and large volume of data. On the other hand, as the third dimension brings more geometric and additional semantic information, it increases the workload of the hardware, and meanwhile may impose more complexity and make the map hard to understand. To solve such issues, new techniques of rendering and data structures are required.

A number of approaches have been proposed for the aforementioned challenges. For example, Follin and Bouju (2008) and Wang et al. (2006) adapt mechanism of level of detail for real-time rendering of 3D maps on small displays, while Döllner et al. (2005) promote using non-photorealistic city model for a clearly legible visualization of the real world environment. To achieve efficient up-to-date 3D environment and services, Przybilski et al. (2005) propose to segment 3D maps into cells and designed the techniques to access and download location-specific services related to given map segment, and Nurminen (2006) develops an efficient mobile 3D city map engine to speed up the visualization of realistically textured city models in mobile devices and support the client–server network services.

3 (3D) Crowdsourced Geo-Data from OpenStreetMap

The following section briefly describes one of the most prominent, diverse and rich data sources for VGI, namely OpenStreetMap (OSM). It is divided into two subsections: a short general introduction to OSM and a specific and detailed description of OSM-3D.

3.1 The OpenStreetMap Community

Trying to use the tremendous potential arising from billions of humans acting as remote sensors, and to combine the widespread availability of GPS-enabled devices, such as smart-phones or tablets, with the trend of user-generated content (UGC), a couple of years ago the term Volunteered Geographic Information (VGI) has been described by Goodchild (2007). VGI aims at the collaborative and voluntary collection of geo-referenced data, by both laymen and professionals.

In the author's opinion, one of the most prominent and rich data source for VGI is the OpenStreetMap (OSM) project. Originally aiming at providing a free global map, the project's objective soon turned far beyond that. Today, OSM can be considered as one of the biggest free global database of different kinds of geo-data. Everybody can contribute, alter and improve the data of the OSM database. Initiated in 2004, the project currently profits from more than 500,000 registered users (OSM 2012). Within OSM, the contributors can not only provide geometries, but also additional (semantic) information about different map features by adding so called key-value pairs to an OSM feature (in OSM terminology this is called tagging). Thereby, the key describes some kind of information or information domain and the value refines this information, e.g. *building* = *yes*, *maxspeed* = *30* or *highway* = *residential*. The amount of key-value pairs is unlimited, thus users can add as much information as required.

Therefore, OSM is more than just a global map. This statement is also emphasized by the fact that more and more users collect three-dimensional data such as height information, or 3D-related information such as roof types etc.

3.2 OSM-3D

Trying to generate comprehensive 3D models based on the OSM data, the project OSM-3D has been initiated. Although, according to Goetz and Zipf (2012a, b), there is not yet much 3D-related information available, it seems to be desirable to utilize the existing data for the generation of 3D models. Even if it is not directly available in OSM, the OSM-3D project demonstrates that appealing 3D visualizations can be created from such data sets, and to enhance the quality of this visualization even in spite of the missing data is an interesting research challenge. On the one hand, this demonstrates the power and manifoldness of VGI from OSM, and on the other hand it is likely to motivate and convince the OSM members to contribute further 3D information.

More and more ideas and projects towards a three-dimensional representation of OSM data are currently under discussion and development, such as the OSM2World[2] software and the Kendzi3D plug-in (Kendzi 2011), but the OSM-3D project is one of the most promising and technically advanced projects in this context. Contrary to other approaches, OSM-3D utilizes standards and draft specifications of Open Geospatial Consortium (OGC) and dedicated (java-based) client software, aiming for global coverage in contrast to small regions. The project provides a highly detailed virtual globe which can be investigated by the user in great detail. The current client (namely XNavigator) even features atmospheric visualization effects, as well as different rendering methods (normal, wireframe etc.). Regarding the data, OSM-3D features a comprehensive number of different types of data, ranging over a Digital Terrain Model (based on SRTM), building models, Point-of-Interest (POI), streets, labels, natural areas, trees, lights and so on (Goetz and Zipf 2012b). As an exemplar, Fig. 1 depicts the three-dimensional building model of the Petronas Towers in Kuala Lumpur (left) and an exemplary perspective for Heidelberg, featuring building models, street network, trees, streetlights, natural areas etc. (right).

Also, contrary to other approaches, OSM-3D does not only provide visualization of the globe, but does also integrate different services for the users, such as integration and querying of sensor data, fog simulations and etc. Essentially, there are two useful and well known services which are very relevant for the broad public: (1) Yellow Pages query for distinct Point-of-Interests in a definable area

[2] http://osm2world.org

Fig. 1 Three-dimensional building model of the Petronas Towers in Kuala Lumpur (*left*) and an exemplary perspective for Heidelberg (*right*) in OSM-3D

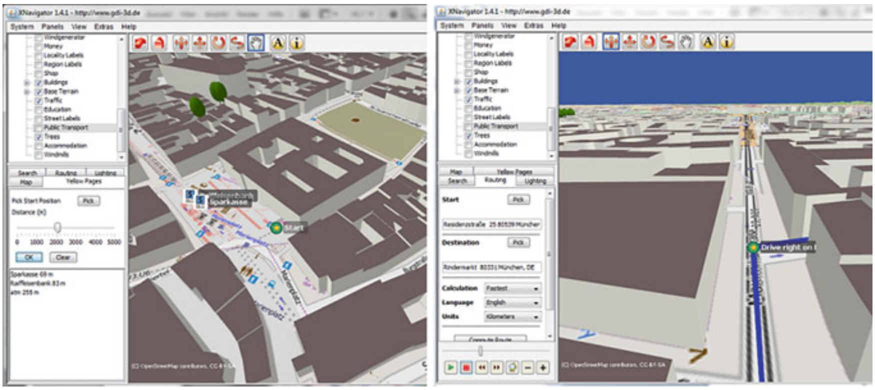

Fig. 2 Yellow Page search for an ATM (*left*) and 3D routing (*right*) in XNavigator/OSM-3D

around a distinct point and (2) three-dimensional route computation for vehicles and/or pedestrians. Figure 2 depicts an exemplary query for ATMs within 2,000 m around the Marienplatz in Munich (left) as well as an exemplary route from *Residenzstraße 25* to *Rindermarkt* in Munich (right).

The Yellow Page service functions as follows: the user can pick an arbitrary location in the 3D environment and define the search radius for the POI search. Thereafter, the user defines what kind of POI should be searched, such as hotel, motel, coffee shop, ATM etc. The service then performs the POI search and visualizes all possible POIs in the 3D scene. Meanwhile, the three-dimensional route computation functions as follows: a user can define an arbitrary start and destination point, either by entering the corresponding address or location in the corresponding forms (currently only for Europe), or by picking the desired location in the 3D scene. In the former case, a Geo-coder decodes the address into longitude and latitude information, whereby in the latter case the geo-coordinates are directly retrieved from the scene. There are furthermore different options available for the route computation, such as *shortest route*, *fastest route*, *pedestrian* or *bicycle*. After computing the route (which is done by an OGC Open Location Service, OpenLS), the route—if available—is visualized in 3D in the scene. Routing instructions, such as turns, are additionally depicted as icons with text. The user can then individually explore the route from any desired location, or use the fly-mode, which will automatically pre-ride the route.

4 Adaptation to Mobile Devices

OSM-3D is currently only consumable via personal computers, either via the Java application XNavigator or the webpage with a Java plug-in. However, especially for the previously described services, an application for OSM-3D on mobile devices is very desirable. Having such an application, the user will be allowed to compute and consume three-dimensional routes as well as perform Yellow Page POI searches while actually being on-site. Of course, by integrating the user's current location (via GPS etc.), those services could be perfectly tailored to the user's context. However, in order to bring it to the mobile world, we are facing a series of challenges. This section therefore aims at emphasizing the arising challenges and offering some possible solutions for adapting OSM-3D to mobile devices.

4.1 Challenges Towards Bringing OSM-3D to Mobile Devices

In this subsection, we will elaborate the numerous challenges we are facing when trying to adapt the OSM-3D to the mobile devices. In general, these adaptation challenges can be divided into three aspects, i.e.: platform adaptation, physical adaptation and scenario adaptation, as depicted in Fig. 3.

For the platform adaptation, the challenges are more technical and mainly caused by the differences between computer platform and mobile platform. Typical challenges in this aspect include:

- A dedicated development framework for mobile app, because Java, the framework adopted in the current desktop client of OSM-3D (XNavigator), is resource consumable and not directly suitable for the mobile platform;
- Eligible 3D graphics techniques tailored to the mobile devices, because the 3D techniques adopted in the current client is Java3D together with VRML (but also e.g. KML, X3D are supported by convertors), which are out-of-date and not supported in modern mobile device.

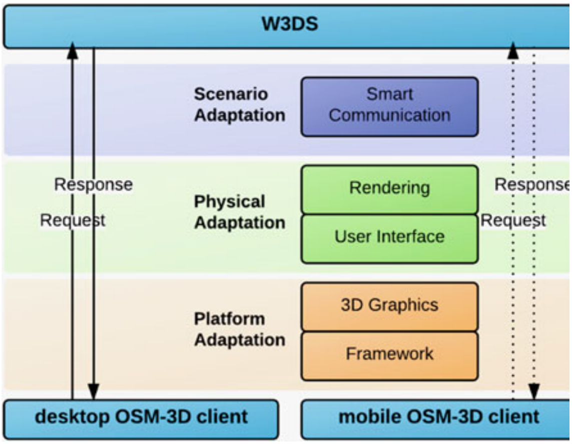

Fig. 3 Challenges raised by different platform and different context

Within this chapter, we will focus on the first challenge in the second sub-section of this chapter; that is, to compare a series of mobile development framework and offer a promising solution.

For the physical adaptation, the challenges are mainly imposed by the physical restrictions/characteristics of mobile devices, such as their smaller display sizes, poorer processing capabilities, unstable internet connections, and also their special way of interaction. Typical challenges in this aspect include:

- A new user interface specifically designed for mobile screens, because otherwise too dense information on small screens will make the map very hard to read. The different way of interaction should also be taken into consideration when designing a new user interface;
- Fast and apprehensible rendering, because on the one hand, the future users would demand the service to be fast and apprehensible as they would typically follow other tasks (such as walking or driving) rather than just focusing on their devices and reading maps; on the other hand, the processing capability of mobile devices are limited while the OSM-3D tends to contain complex geometries and large data volume.

The first challenge in the physical adaptation is more a design issue, while the fast and apprehensible rendering is both technical and theoretical. Within this chapter, we will focus on the second challenge and discuss it in the third sub-section.

For the scenario adaptation, the challenges are imposed by the moving scenarios. When the service is on use, the using context (including the location, time, user's intention, network condition, etc.) keeps changing because the users are always moving. The major challenge in this aspect therefore is:

- A smart OSM-3D client that can have smart communications with users on smart devices. With context-aware communications, the users can get better help from the service more efficiently; therefore the usability of the service can be largely enhanced.

To achieve the smart context-aware communications, a thorough knowledge of context is required. Moreover, the understanding of context is also vital to the aforementioned rendering issue. To achieve fast and apprehensible rendering, we have to eliminate many geographic information objects (GIOs) without losing the most essential and crucial ones. But whether a GIO is essential or not depends heavily on the context. Therefore, it is clear that a good knowledge of the mobile using context is essential for both challenges of rendering and smart communication. Consequently, we will perform an analysis on the mobile using context in the fourth sub-section of this chapter.

4.2 Selection of Technical Frameworks

One of the most resounding themes in terms of mobile application developments in the past two years is the debate of building a native app or a mobile web app (Warren 2011). Nowadays, millions of native apps are sold on the app stores. Although those native apps enrich the functionalities and facilitate the use of mobile devices, the numerous mobile operation systems (including iOS, Android, BlackBerry OS, Windows Phone, Symbian etc.), each with their own developing kit, bring rather a big trouble to developers for developing and maintaining their applications. To offer a certain service to users, developers have to rewrite the code for each operating system. Such a drawback is one of the reasons why web apps are now gaining popularity, since a website can be accessed via browsers (basically regardless of the underlying operating system or device).

The advancement of HTML5 even intensifies the trend. Although the full specification has not been published by W3C[3] and WHATWG,[4] it has already brought a tremendous storm not only to the desktop website but also to the development of mobile applications. In terms of 3D world, the combination of HTML5 and WebGL (together with a lot of more advanced WebGL-based libraries and SDKs such as X3DOM, three.js, OpenWebGlobe, etc.) is gaining popularity in offering 3D scenes and 3D services without any cumbersome plug-ins. In the recent years, several frameworks for developing a HMTL5-based web apps have emerged, and the most popular ones among them including *Sencha Touch,*[5] *JQuery Mobile,*[6] *JQtouch*[7] and so on.

However, native apps are not supposed to be extinct ever since, as it still has some proprietary merits over web apps. For example, web apps are not designed to have full access to the native device APIs, such as GPS, compass etc.

[3] http://www.w3.org/

[4] http://www.whatwg.org/

[5] http://www.sencha.com/

[6] http://jquerymobile.com/

[7] http://www.jqtouch.com/

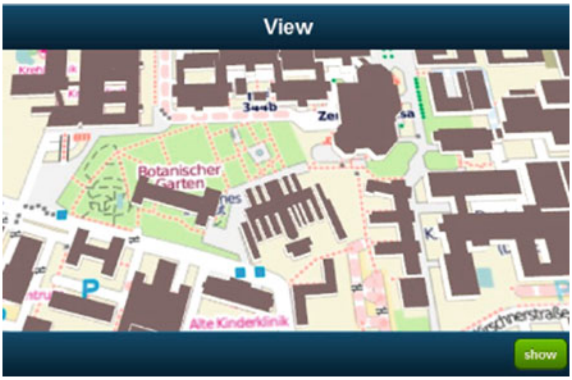

Fig. 4 A simple web app that utilizes HTML 5 and WebGL to visualize a single 3D building scene received from W3DS (within the framework of *Sencha Touch* + *PhoneGap* of Android version)

Nevertheless, having access to APIs of those sensors can be regarded as crucial for the development of powerful but safe mobile apps. Besides, native apps tend to have better graphics and a smooth user experience due to the interface with the device (Weber 2011).

Thereby, for bringing OSM-3D to the mobile world, a possible method is combining the characteristics and advantages of both kinds of frameworks. It should on the one hand be both user- and developer-friendly; on the other hand provide all envisioned features. There also emerge some frameworks aiming at such kind of apps, that is, hybrid apps. Specifically, they are developed using web developing technology such as HTML, Javascript and CSS like any web apps, but will work on local machine and have full access to sensors like any native apps. *PhoneGap*[8] and *Titanium*[9] are the most popular frameworks among them. Taking *PhoneGap* as an example, it serves as a wrapper of web apps for the browser. The apps appear as if they are native ones because they can be directly started by an icon-touching, but inside they are HTML/Javascript apps. Consequently, it shares the advantages of both kinds of apps. Here we propose a combination of *Sencha Touch* and *PhoneGap* as the developing framework for mobile OSM-3D.

Figure 4 depicts a 3D scene received from W3DS within the combined framework of *Sencha Touch* and *PhoneGap*, which also demonstrates the feasibility of the combination of HTML5 and WebGL on mobile devices.

4.3 Fast and Apprehensible Rendering

Concerning the rendering of OSM-3D on mobile devices, special algorithms and techniques must be employed to the simplify/generalize the 3D scene, as the display space cannot accommodate too many details due to its limited size and

8 http://phonegap.com

9 http://www.appcelerator.com/products/titanium-mobile-application-development/

Fig. 5 3D focus map with focus on area around the route

resolution. Otherwise the high density of geometrical and semantical information will make it impossible to recognize important aspects of the 3D objects. Meanwhile, generalized 3D scene with less data volumes can be transmitted over the internet and processed by the device more efficiently. Furthermore, generalized 3D scene with a special focus on the region/target that is currently of interest to the user can draw user's attention directly towards the needed information and reduce user's workload of interpretation, thus make the map more apprehensible.

The concept of *Focus Maps* for 2D mobile maps is raised by Zipf and Richter (2002) to reduce the data volume thereby to ensure the rendering speed and emphasizes the relevant information. Two major factors are involved to attracting users' attention: generalization and color. That is, the regions/targets of user's interest will be shown with more details as well as in a more noticeable color; whilst the rest of the map will be displayed with fewer details and in an e.g. grayish color. In this way, maps will have less data volume and can be interpreted by users very easily. Neis and Zipf (2008) has extended such concept into the third dimension and realized 3D focus maps with landmarks for (mobile) web based on a series of OGC standards (OpenLS, OGC SLD and etc.), as shown in Fig. 5.

A possible extension to what is already available in the existing 3D focus map would be using 3D template models of POIs according to the specific LOD and context. Such templates with various LODs can, on the one hand, contribute to map comprehending process because they can attract the users' attention and be interpreted easily; on the other hand, be handled easily by the mobile client because the templates of POI objects are a small database.

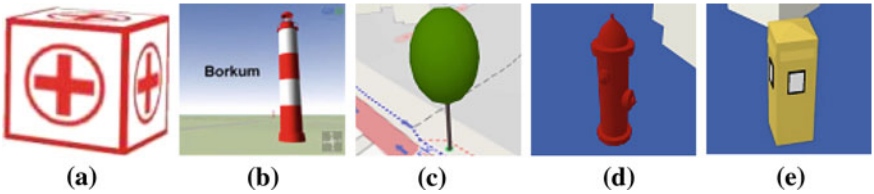

Fig. 6 3D templates. **a** hospital. **b** Light house. **c** Trees. **d** Fire hydrant (new). **e** Post box (new)

Currently in our OSM-3D database, we already have several 3D template models including 3D POI models[10] such as restaurant, hospital and 3D facility models[11] like light house, wind generator, wind mill, trees and so on. Recently new 3D models for post boxes and fire hydrants are also created in our database repository, as shown in Fig. 6. Furthermore, we are trying to take this a step further by building up a free 3D model repository called OpenBuildingsModels (OBM) which can be linked to the OSM database (Uden and Zipf 2012). It will not only include 3D building models as the name has suggested, but also other geographic objects such as street furniture. With the OBM, the models and templates in the OSM-3D world will largely be enriched and make the service more effectively and efficiently.

Other methodologies can also be applied to mobile OSM-3D, such as non-photorealistic visualization. Non-photorealistic rendering (*NPR*) techniques intentionally disregard the idea of images close to reality and present 3D city models in a comic-strip like style rendered by computers (e.g. Döllner et al. 2005). In this way, cost in time and resource can be reduced. Meanwhile, user's understanding towards the map will not be interrupted (or in some situations can turn even better) because studies have shown that human image interpretation is influenced by factors that have little to do with realism (Plesa and Cartwright 2008). However, so far a standard for 3D non-photorealistic models is still missing, let alone a standard process to generate 3D non-photorealistic models. Consequently, dedicated work is required to generate and visualize non-photorealistic models tailored to OSM-3D.

Layer selection is also a simple but effective approach. Considering the context of mobile usage for OSM-3D, layers such as DTMs may not be as important as street labels or buildings in most situations, therefore it can be displayed in low level of details or sometimes even be neglected. And in most cases, 3D street labels are more essential for navigation purpose, while 3D building models are more efficient for orientation. However, we have not yet performed enough tests to give a complete list of situations when a certain layer should be selected or not, since it depends heavily on a series of factors within the using context and their correlations. Nevertheless, it is among of our future schedules.

[10] http://wiki.openstreetmap.org/wiki/OSM-3D#Points_of_Interest

[11] http://wiki.openstreetmap.org/wiki/OSM-3D#Technical_Facilities

To further enhance the intelligence of the software and accelerate the rendering in the mobile OSM-3D, we also plan to adopt pull-service (implicit requests) and pre-cashing strategy. For example, when the user tries to find way to a certain location, this might suggest that the user would go there later. In this case, the service will not only send a request for route planning (explicit request), but also keep asking for more 3D data along the route (implicit request) when the resource is free of use (which indicates the user might be walking). A sufficient knowledge of the context is vital for effective pull-service; otherwise such kind of service would be dangerous because it may extract and deliver wrong information at wrong time.

4.4 Context Model and Context Adaptation

Nivala and Sarjakoski (2003) have demonstrated that embedding context awareness into the mobile application could increase the usability of mobile map services. Meanwhile, we also have demonstrated in the earlier sub-sections that a thorough understanding of mobile using context is essential not only for achieving context-awareness, but also for realizing fast and apprehensible rendering. To achieve a mobile OSM-3D that can have smart communications with users as well as render the 3D scenes in a fast and apprehensible way, the elements of context have to be investigated and their impacts to the usability have to be evaluated. Then the adaptation strategy can be designed based on the evaluation.

As a Location-Based service, the location information is always the most fundamental factor, because users normally care more about the information around their current location. As a map-based service, the users' intension is also a significant factor to decide what kind of information should be retrieved and how should it be displayed. For example, von Hunolstein and Zipf (2003) have argued the importance of providing task/intention-oriented functionality and visualization for mobile tourist navigation. As a graphic user interface (GUI) for geo-information, the user's preference and the physical condition of the devices should be specially considered. It seems an obvious compromise to reduce details of 3D scenes for fast processing and rendering due to the limited communication bandwidth and low capability of processor in mobile devices.

The elements of context is more than the abovementioned. Figure 7 depicts the fundamental elements of OSM-3D context. As shown in the figure, we divided context into three categories: (1) User, which basically contains the most dominant elements in the context such as the users' intentions, location, preference, and etc.; (2) Technology, which contains elements that usually act as restrictions, such as display size, capability, internet connection, and so on; and (3) Surroundings, which contains elements that can used to further optimize the service, such as illumination, season, time, and so forth.

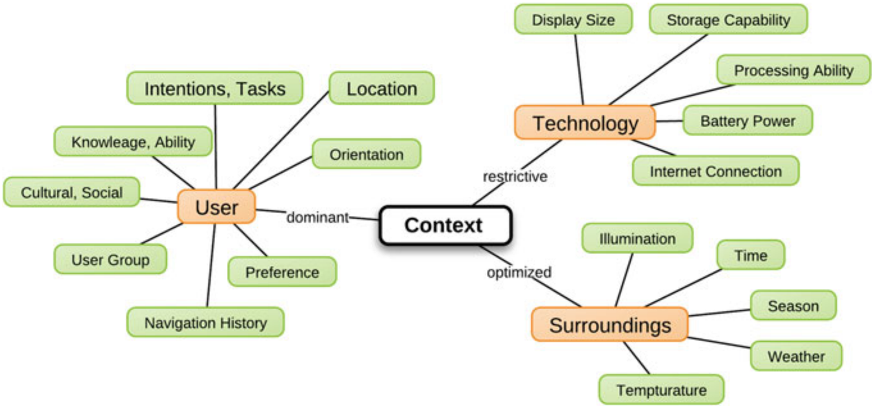

Fig. 7 Some potential elements of context for mobile OSM-3D

Table 1 explains how these elements can affect the appearance of the 3D scene. It describes what items in the mobile 3D scenes can be adapted, and offers some scenario examples or notes as well. It is not yet exhaustive and final, but can be regarded as a start for further discussions.

However, the adaptation situations are more complicated than what have been listed on the table. Take the "color" item in the table as an example. The color is mainly adapted to the users' intention when it is used to highlight the most relevant GIOs thereby ease the reading of 3D scenes (see Focus Maps). But in case of colorblind users, the color schema should also further adapted to the users' group or preference. The surrounding elements such as illumination could also change the color schema because some highlighting colors (e.g.: bright yellow) cannot be observed easily under high intensity of light. Furthermore, adaptation items such as information amount, LOD and generalization are tightly interlinked, and more research on their interdependencies is needed.

Also, those elements in Fig. 7 that do not appear in Table 1, such as navigation history, can also contribute a lot to a context-aware service. For example, if the evaluation of the GPS signal reveals that the user's present location represents a city the user has never been to before (not exist in the navigation history), this might indicates that the user is traveling, thus a possible adaptation would be to retrieve and display more detailed information for 3D POIs, such as central transport stations, hotels or tourist attractions, in the mobile application. Such information could then be furthermore adapted to the present time (day or night) as well as season (summer or winter).

In general, both the context model and the adaptation strategy are challenging work and we will put more studying efforts on them in our future work.

Table 1 Exemplary selected items of a mobile 3D scene that could be adapted to the elements of context for OSM-3D

Category	Adaptable Items	Most Relevant Elements	Notes / Scenario examples
Scene features (What information to be visualized)	Layer selection	intentions, user group	e.g.: many users may not care about the topographic layer, while it is crucial to the professional orienteer or the disabled.
	Boundary box	location	Users are more interested in the information around their current location.
	Priorities of GIOs	intentions	e.g.: fire hydrants will be especially important for fire emergency.
	Level of detail (LOD)	intentions, location	e.g.: different LOD is required for different intentions; also as there is not a fixed scale in 3D scenes, the LOD may also vary with the distance from the user.
Scene style (How the information be visualized)	Generalization	intensions, processing ability, internet connections	Very important for fast rendering, and specific algorithms should be developed according to users' intention and physical restrictions.
	Perspective	orientation, preference	e.g.: pedestrian (walking) view, bird eyes view, etc.
	Dimension	intention, preference	e.g.: 3D POIs are more useful when the LOD is high. As the LODget lower, the POIs can appear in 2D or even as points.
	Color	intention	e.g.: the usage in Focus maps.
	Layout	screen size, preference	e.g.: tablets can have a different way of layout from smart phones, because they have bigger screen.
	Interaction	preference	e.g.: a single touch-move event could mean pan or rotate, depending on the user's preference.
	Symbol styles	preference	Switch between predefined styles according to user's preference.
	Language	preference	Display the map in the language that the user prefers.
	Text style	User group, preference	e.g.: change the size for the old group; display the street labelson the street or as a billboard box,etc.

5 Conclusion and Future Work

Due to the large scale availability of mobile devices, the demand for mobile applications increases. Especially Location-Based-Services, such as route planning, navigation or Point-of-Interest search, are well-known on personal computers and the users demand the adaptation of such services to mobile devices. Having such mobile applications can increase the quality of life for the users, without the need of actually sitting in front of a computer. Essentially three-dimensional applications, which provide a more realistic perspective and orientation to the users, are desirable. Trying to decrease the costs of such applications, it is furthermore advisable to use open and free geo-data, instead of proprietary and licensed data. Based on OSM data and several Open Geospatial Consortium (OGC) standards and draft specifications, OSM-3D provides a highly detailed virtual globe with various 3D data/models and offers utilizable functionalities including Yellow Page query and 3D routing service. By combining the proficient 3D map service and the agile mobile platform, users can get a better and more brisk map service. Meanwhile, as an OSM-based service, the adapted mobile OSM-3D is also promising to enrich OSM dataset and enhance its quality. However, the non-negligible gap that lies between PC world and mobile world calls for adaptation.

After the short introduction on the increasing demand for 3D-LBS on mobile devices, a brief overview about related work has been conducted. Following, a brief overview about the OpenStreetMap community has been provided, because OSM is one of the most prominent and manifold sources for different kinds of open geo-data. Closely related to OSM, the OSM-3D project has been described in detail. Since the main aim of this chapter is to describe a framework towards the adaptation of OSM-3D to mobile devices, this OSM-3D introduction is a very important part. Focusing on the aimed adaptation, the challenges have been elaborated in three aspects, i.e.: platform adaptation, physical adaptation and scenario adaptation. For the platform adaptation, a critical discussion and final selection of a technical framework for achieving the goal has been provided. For physical adaptation, techniques for fast and apprehensible rendering of 3D features have been discussed, including an extension to the current 3D Focus Maps and several other possible solutions. Since the understanding of context is fundamental for both physical adaptation and scenario adaptation, a context model for adaptation together with the adaptable items in mobile 3D scenes have been discussed and tailored to OSM-3D.

In line with adapting OSM-3D on mobile devices, generalization of the 3D information would be the most significant task towards fast and comprehensive rendering, and a thorough knowledge of the changing context is the most fundamental above all. In the future, we will put efforts on elaborating more detailed a context model and the corresponding adaptation strategy, and conducting investigations on visual cognitions to develop reasonable algorithms of generalization, thereby gain good performance and usability. With all the efforts, we aim to be able to present the users a platform-independent mobile OSM-3D with good performance in both rendering and interaction, thereby offer them effective and efficient location-based 3D map services. In general, a standard-based, platform-independent, context-aware visualization of 3D content on mobile devices is an important, but challenging task, and will be an integral part of our future research efforts.

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