Interoperable Location Based Services for 3D cities on the Web using user generated content from OpenStreetMap.

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ABSTRACT: The "prosumer"-oriented GeoWeb2.0 approach of collaborative data generation where the distinction of producers and consumers of information blurs produced a new data source for urban geographic information: OpenStreetMap. This can be used in developing web-based and mobile Location-based Services such as POI-Search (spatial Yellow Pages), Routing and Maps in 2D. The Open Geospatial Consortium (OGC) has defined standards for those. On the other hand urban data management deals more and more with 3D city data. Also for that OGC has released standards such as CityGML - but in addition to that exchange format a web service for visualizing 3D city models is needed and available as a discussion paper – the Web 3D Service (W3DS). In this paper we show how these three – open user generated geodata, OpenGIS services for LBS and 3D urban models can come together in a Web Service based application to deliver rich urban 3D models and innovative applications by combining those heterogeneous sources of information in a new, but interoperable way.

1 INTRODUCTION AND MOTIATION

We can assume nowadays, that it is quite obvious that solutions for urban data management benefit from open standards. For those applications that deal obviously with spatially extended phenomena the standards of the Open Geospatial Consortium (OGC) are most relevant. This is mirrored by the trend to develop spatial data infrastructures (SDIs) from local, regional to national and international level. A most prominent example here is the EU directive INSPIRE. These SDIs provide access to an increasing variety of spatial data worldwide through exactly these OGC standards. The benefit of this approach for urban management is obvious. The question arises if this means that everything is perfect yet? Obviously this is not the case. While the concepts are striking, in practice the implementation of those SDIs is a complex and time consuming task (in particular because of the needed harmonization efforts). It covers not all relevant data and depends on issues like the willingness (and resources) of organizations to participate in such efforts - only to mention a few issues.

Only within the last few years another type of solution appeared on the Web. People collect all kinds of data in a collaborative way on the Web2.0. Well known examples include Wikipedia, Flickr or YouTube, to name only a few. In fact they are not experts, but "ordinary" Web-users that are interested in practical and easy solutions and not necessarily aware or interested in any professional specifications or formal standards. Interestingly geographic information and maps play an important role in this approach as maps/space/coordinates provide a universal framework for organizing all types of most heterogeneous content. The majority of examples for this phenomenon are so called Mashups of existing (or new) data sources with suppliers of a base maps on the Web such as Google Maps / Earth and similar. But very recently also this is changing with the increasing success and (therefore coverage and quality) of user-generated geodata as a free source. Goodchild (2007) presents an overview of these global collaborations and calls this phenomenon "Volunteered Geographic Information" (VGI). The most successful and prominent example in the domain of geographic information is the free Wiki-World map "OpenStreetMap" (Coast 2007). This is by far no longer a project that deals with streets only, but actually maps everything people are interested in (Holone et al 2007). So in some parts of the world the data is already even much more detailed than commercially available data, but in others there is still only void. The amount and quality of data is correlated with the population density, which makes it in particular especially relevant as information source within urban areas. The good thing is, that with several thousand active contributors the data base is really growing at an enormous speed. In Germany, where our first test cases were, the instances of most feature types doubled in only 4 months. In order to assess the potential of this data we started both practical realizations of Web services that use this data in a range of ways and also perform quality measurements by comparing it with commercial data sources. First we will introduce the practical examples, which use a range of OGC specifications in order to make geographic information available in an interoperable way for different kinds of applications relevant in urban data management. We show how this user-generated geodata can already be applied and how it can be used together with several OGC web services to built interesting new applications based on open data and open standards.

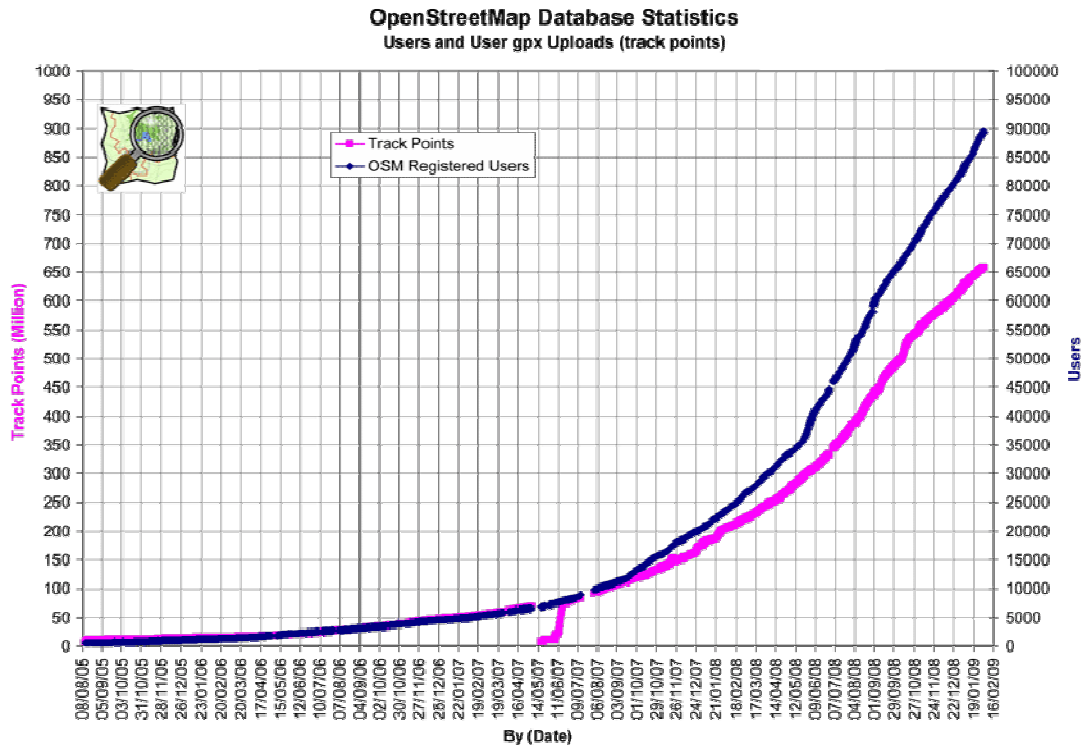

Figure 1: Growth of OpenStreetMap data and user base.*http://wiki.openstreetmap.org/wiki/Stats*

We now focus on one of the most striking and sophisticated examples of VGI - the OpenStreetMap (OSM) project. It started already in 2004 but only since mid2007 the number of users and data exploded. OSM aims at creating and collecting free vector geodata covering the whole planet. This information is provided through ordinary citizens vested with GPS-devices logging coordinates, out-of-copyright maps and aerial imagery provided by OSM-friendly companies (like Yahoo! Inc.). Increasingly existing data sources are donated to this project. Deriving from these data sources geodata is then created. At the time of writing OSM counts ~85000 registered users. Even though only a fraction actively supports data collection the amount of data is increasing at a tremendous speed. Altogether the OSM dataset currently consists of roughly 320 Mio. nodes partly constituting 30 Mio. ways. This means that from writing the last version of the abstract of this paper to the current final version more than 50 Mio. nodes were added. The number of GPS points raised only in that time from about 440 Mio. to 660 Mio. Haklay (2008) analyzed the data quality of OSM data in England. A result of this work is that contrary to first expectations quite little quality assurance is being carried out upon the OSM data – at least at that time. While he concluded that due to its lack of completeness the dataset would not (yet) be suitable for more sophisticated purposes than 'cartographic products that display central areas of cities' (p.24) even at that time the applicability for urban areas (at least in most parts of Europe) was obvious. Since then a range of cities were announced to be "completed" – whatever completeness means in that case. Typical measures were the number of streets compared to official or commercial data sets. But more detailed comparison in inner cities show for example that the OSM data is even much richer than commercial data sources such as Teleatlas or Navteq, as the OpenStreetMap community focuses very much on information relevant for pedestrians or cyclists – two domains that had been neglected by commercial companies for quite some time due to the extraordinary costs of acquiring this kind of data in a commercial fashion.

2 INTEROPERABLE LOCATION BASED SERVICES IN CITIES

The most relevant OGC standard with respect to Location Based Services (LBS) is the OpenGIS Location Services specification - a series of implementation specifications for originally five core services:

- The OpenLS Directory Service is a service that provides access to an online directory (e.g., Yellow Pages) to find the location of a specific or nearest place, product or service.

- The OpenLS Location Utility Service provides a Geocoder/Reverse Geocoder; the Geocoder transforms a description of a location, such as a place name, street address or postal code, into a normalized description of the location with a point geometry

- The OpenLS Presentation (Map Portrayal) Service portrays a map made up of a base map derived from any geospatial data and a set of Abstract Data Types as overlays.

- The OpenLS Route Service determines travel routes and navigation information according to diverse criteria.
- The OpenLS Gateway Service provides positioning information of devices from wireless phone operators networds.

Combining these services (the first four) with the rich data of OpenStreetMap offers a completely new source of data for POIs. Currently our directory service based on OSM delivers POIs for the whole of Europe (and can easily be extended). Currently we have realized four of these (Location Utility Service, Presentation Service, Directory Service and Route Service). Just recently the new OpenLS Tracking Service has also been implemented. In particular the Route Service has already been successfully applied and extended within some further projects (www.ok-gis.de, www.gdi-3d.de, www.rewob.de, www.mona3d.de, www.nrw-3d.de): in particular a route service 3D (Neis et al. 2007) that works in combination with the W3DS and XNavigator client introduced here later. Further examples include a *Emergency Route Service* (ERS), an *Accessibility Analysis Service* (AAS) or *Urban Evacuation Planning* (Haase et al. 2008), to name only a few.

3 APPLYING USER GENERATED GEOGRAPHIC CONTENT FOR LBS

A first example of utilizing OSM data for a more sophisticated purpose is OpenRouteService (ORS). This is a route service operating on OSM data (Neis & Zipf 2008). It has been launched in April 2008. The initial coverage of Germany has recently been extended to the whole of Europe and even slightly beyond. It covers currently a rectangle around the European States from Island to Portugal and in the east slightly beyond the borders of Turkey and includes the western part of Russia up to Moscow. The route service has successfully been applied based on a modified version of the A*-Algorithm with OSM data consisting of more than 12 Mio street segments.

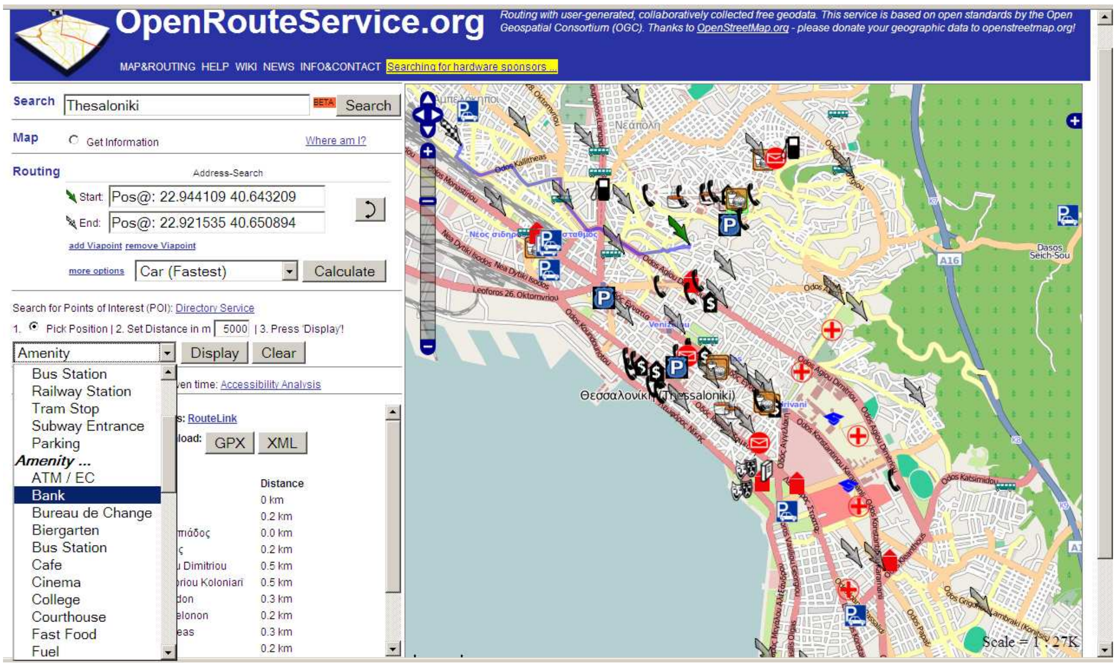

Figure 2: Using the OpenLS Directory Service as local POI search based on OpenStreetMap data in OpenRouteService.org

OpenRouteService has been the first national route planner for pedestrian or bicycle routes - making that option available even before companies like Google (which followed a few months later, but without the data richness regarding pedestrian only ways). It is the first web based service beyond web-mapping that combines free user-generated OSM data and OpenGIS standards. Currently also the WMS originally coupled with first versions of OpenRouteService.org is accessible as a dedicated service at www.osm-wms.de for Europe. The OpenLS services of OpenRouteService are also used on mobile devices, such as from the first independent navigation system for the new Google Android platform called AndNav2.

4 INTEROPERABLE 3D CITIES ON THE WEB

Within the project GDI-3D (geospatial data infrastructure 3D, http://www.gdi-3d.de) a 3D GIS and information system based on standards of the Open Geospatial Consortium (OGC) has been realized. The creation of a very detailed 3D city model of Heidelberg has been kindly supported by the local land surveying office. This model is used as a platform for testing new OGC standards and to see how they can become a part of a 3D spatial data infrastructure (Schilling et al. 2007, 2008). The OGC OpenLS Route Service mentioned above has been applied there. The route service could be extended into a 3D route service (3DRS) by collecting height values from the DTM. It was not necessary to extend or alter the OGC specifications for this (Neis & Zipf 2008).

For streaming and visualizing 3D city models on the Web the Web 3D Service (W3DS) is used. The W3DS is a draft specification (discussion paper) of the Open Geospatial Consortium –The service has been implemented together with a corresponding W3DS client called XNavigator. It offers the possibility to generate interactive 3D scenes of city models and digital elevation models(DEM) from distributed data sources in various 3D formats such as VRML or KML (X3D to follow).

Figure 3: Using the OpenLS Directory Service (local search for POIs) based on OSM data together with official city data – the case of www.heidelberg-3d.de.

It is now possible to access an OpenLS Directory Service, perform spatial queries for Points of Interest (POIs) and display them in 3D within our W3DS-Client *XNavigator*. This Java Web-Start application is downloaded and installed automatically if Java is enabled on the client computer. The first example application is Heidelberg-3D that can be accessed online at www.gdi-3d.de. The POIs have been imported from the OpenStreetMap data mentioned earlier. They contain a variety of important and interesting locations like shops, ATMs, cafes, pharmacies, bus stops, hotels, night clubs, and many more. The possible categories are unlimited and the data is being extended rapidly. The user can click on the map and search for specific types of locations within a selected radius. The result is shown as 3D labels using the OSM symbols.

Further, GIS like analysis functionalities can also be integrated into OpenGIS based service-oriented architectures through the new OGC Web Processing Service (WPS). Relevant scenarios in several domains have already been presented. This is where the question arises if those solutions can also be extended into the third dimension in order to care for specific information needs in a range of scenarios. An example is the extension of the bomb threat scenario (Stollberg & Zipf 2007) into 3D. The resulting 3D-WPS process accepts the 3D location of the bomb and the explosive force as input. The WPS calculates the security and the danger zone and generates two transparent spheres expressing the calculated areas around the bomb (Walenciak et al. 2008). The response is visualized within the W3DS client viewer (XNavigator) as shown in the figure, including also information of the other services mentioned.

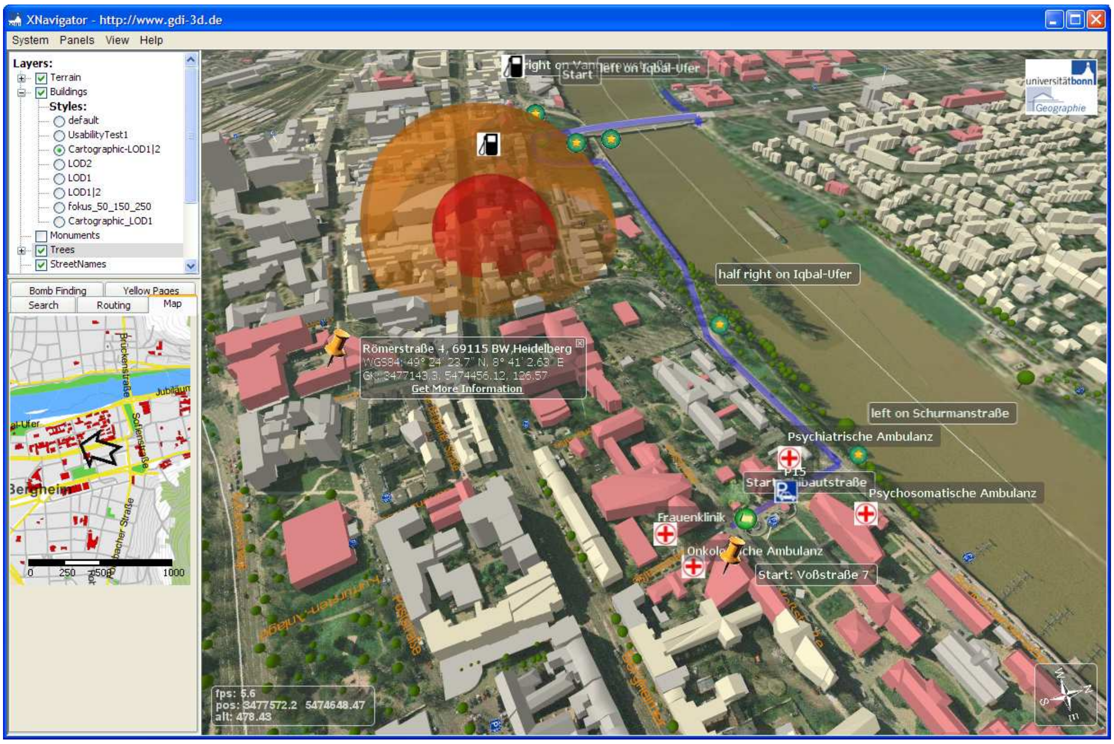

Figure 4: The screenshot of the XNavigator W3DS client shows buildings streamed from the W3DS, styled according to building type using 3D Symbology Encoding (SLD-3D). Hospitals and gas stations are delivered by the OpenLS directory service based on OpenStreetMap data. The calculated route around the avoid area is provided by the 3D Emergency Route Service. The result of a geo-coder query for an address, and a WMS map are also displayed.

Figure 5 and 6 shows examples of OSM road and land use data that has been combined with a SRTM 3 arc-seconds (ca. 90m) terrain model.

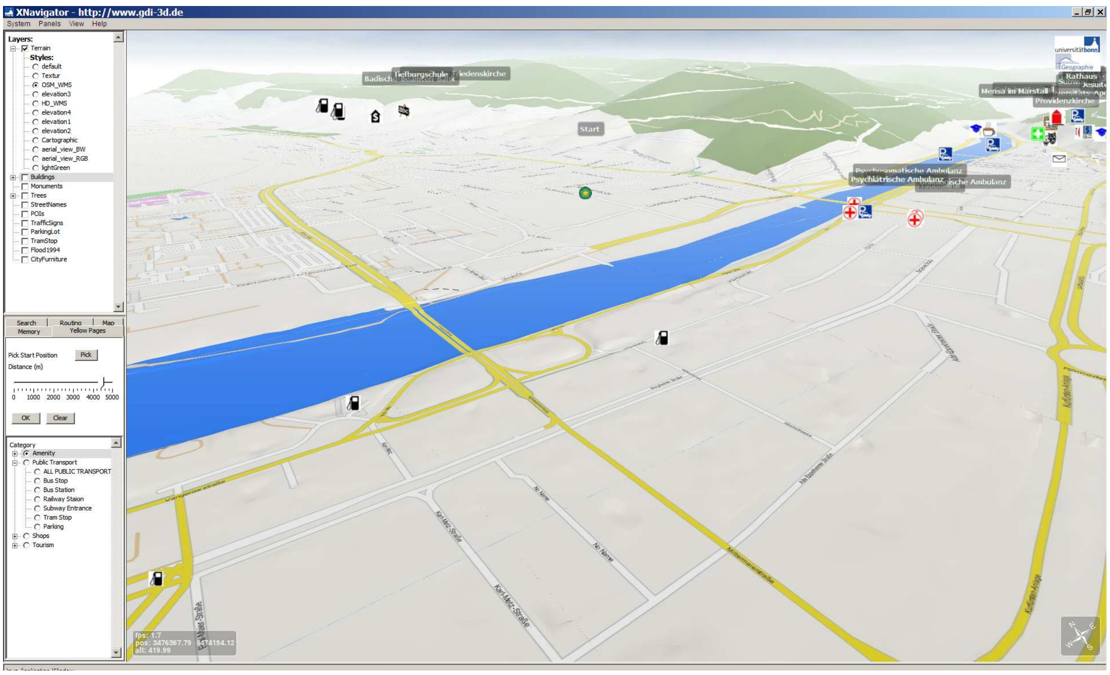

Figure 5. Local POI search (yellow pages) in XNavigator based on open data (OSM) and the OpenLS Directory Service with a WMS texture derived from OSM data mapped on the official high resolution DEM of Heidelberg – Heidelberg-3D available online at www.gdi-3d.de.

The buildings are generated in that case from official sources (Department of Surveying, City of Heidelberg), but other data partly also comes from user generated content such as Open-StreetMap, as explained above in the case of the POIs. But this is not the only possibility to use the user-generated data source OpenStreetMap for 3D city models. It can further act as cartographic base layer in 3D. We have demonstrated this using both open source SRTM DEMs and official high resolution DEMs (5 meters) and using the OSM data as texture layer as well as through vector based triangulation into the resulting TIN. The range of different algorithms and concepts needed for the latter approach have been explained in Schilling et al. (2007, 2008, 2009). Here we can show that these work well also with huge masses of user generated data on a national scale providing GI information services that work from national to very local scales within an urban neighbourhood.

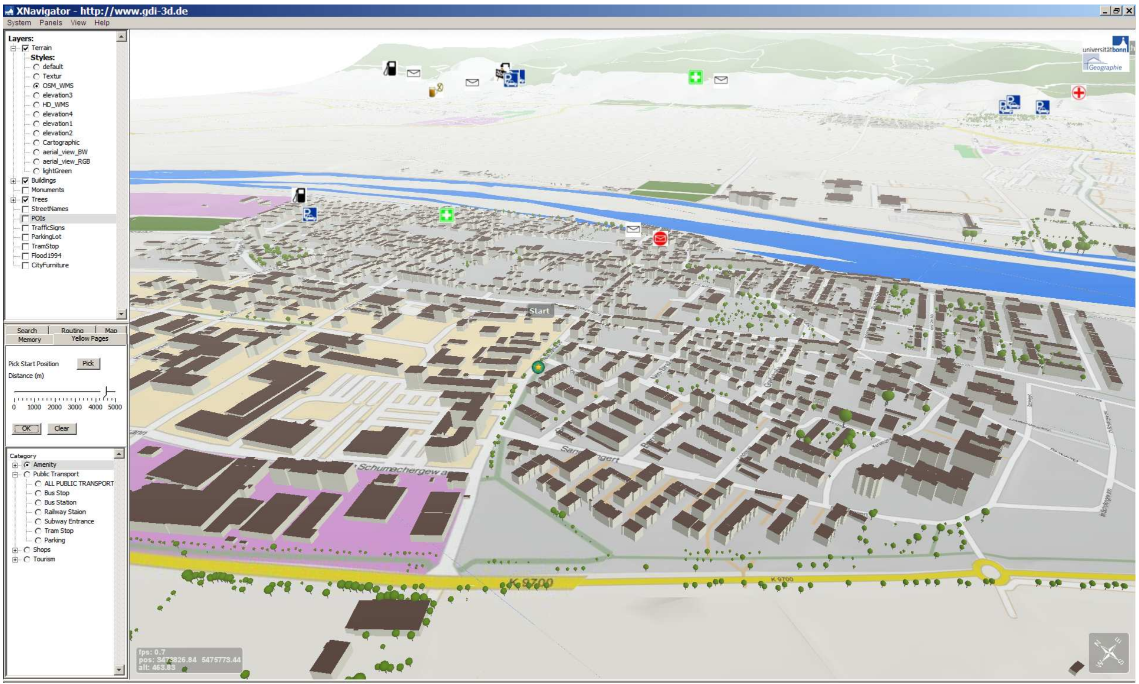

Figure 6: Web 3D service based on free user generated data (OSM) for landuse and POIs. Buildings and DEM heights added from the Bureau of Surveying – POI search realized using the OpenLS Directory Service.

But the potential of the free OSM data is even much larger - in particular for urban areas. OSM contributers start to map also building footprints. These can be used in a similar way to generate 3D city modes. These can be integrated into the 3d spatial data infrastructure technology of GDI-3D in a very similar way. This has been realized for the whole of Germany leading to a standards-based 3D web service for Germany using OSM data in combination with the free SRTM digital elevation model (Neubauer et al. 2009). The preprocessing for this task war extremely computing intense and required more than 1300 CPU hours on a computer cluster (Over et al. 2009 submitted). Examples are depicted in figure 7 an 8. These show the first versions of the Germany wide Web 3D service realized completely on free OpenStreetMap data and SRTM DEM.

5 SUMMARY AND OUTLOOK

In this paper it could be shown that today's considerable suite of OGC specifications (or draft specifications) is quite rich in order to develop interesting LBS and web-based GI applications for 3D cities. Of course there are still open issues, in particular when it comes to more fine grained visualization rules for 3d maps (Neubauer & Zipf 2007) as well as thematic mapping, where the current SLD/SE approach is too limited and needs extensions (Dietze & Zipf 2007). Further it could be demonstrated that the concepts, algorithms and software components that were originally developed for the test case of a single medium city (Heidelberg with ~140.000 people and ~40.000 buildings) does scale very well to really large regions (whole countries) with a lot of cities covered through the services of GDI-3D.de. The number of buildings in OpenStreetMap is still limited to a few 100.000, but at least in big cities also buildings are being mapped more and more.

Figure 7: Web 3D Service for Germany based on open data (OSM) and SRTM DEM. Landuse, buildings and POIs generated from OpenStreeMap. The range of OpenLS services available from GDI-3D.de is available also in this application de offering OSM data in distinct ways from the integrated client XNavigator. Example: Munich.

What started with mapping a few important landmarks became now to nearly complete city districts. Also the richness of POIs mapped is increasing and while a comparison with commercial POI data regarding the quality and quantity of this type of information is just in the process of being conducted right now the long term potential seems quite promising. Of course quality management keeps the main problem of such kind of efforts, but that was also true for Wikipedia from the beginning – and Wikipedia became eventually a quite relevant source of information. OSM uses the same concepts, but a crucial distinction is the needed number of contributers not only in total but per area in order to provide a satisfactory coverage of the data provided by OSM. As explained above in particular big cities benefit from the very probable correlation with population density. Currently the OSM community is most active in Germany and the country of its origin – the UK of GB, but other countries are catching up. The combination of interoperable services originally designed for LBS applications (location based services) and 3D leads to a convergence of different interesting spatial technologies. Mobile navigation system start to become 3D, too. While even the first commercial version appear for car navigation 3D mobile navigation support for pedestrians remains a challenge and research activity (e.g. MoNa3D.de - Mobile Navigation with 3D city models project).. Even the current – always growing – set of OGC web standards – if used in a creative way – can provide first solutions for improved user experience (e.g. Neis & Zipf 2008b). The services explained here based on both open standards and user-generated data lay an interesting framework for such applications. Further screenshots and videos and the online service itself will be available.fro www.gdi-3d.de.

Figure 8: Web 3D Service for Germany based on user generated geodata (OSM) and SRTM. Landuse, buildings and POIs generated from OpenStreetMap. The range of OpenLS services available from GDI-3D.de offering OSM data in distinct ways is available also in this application from the integrated client XNavigator. Example: Düsseldorf.

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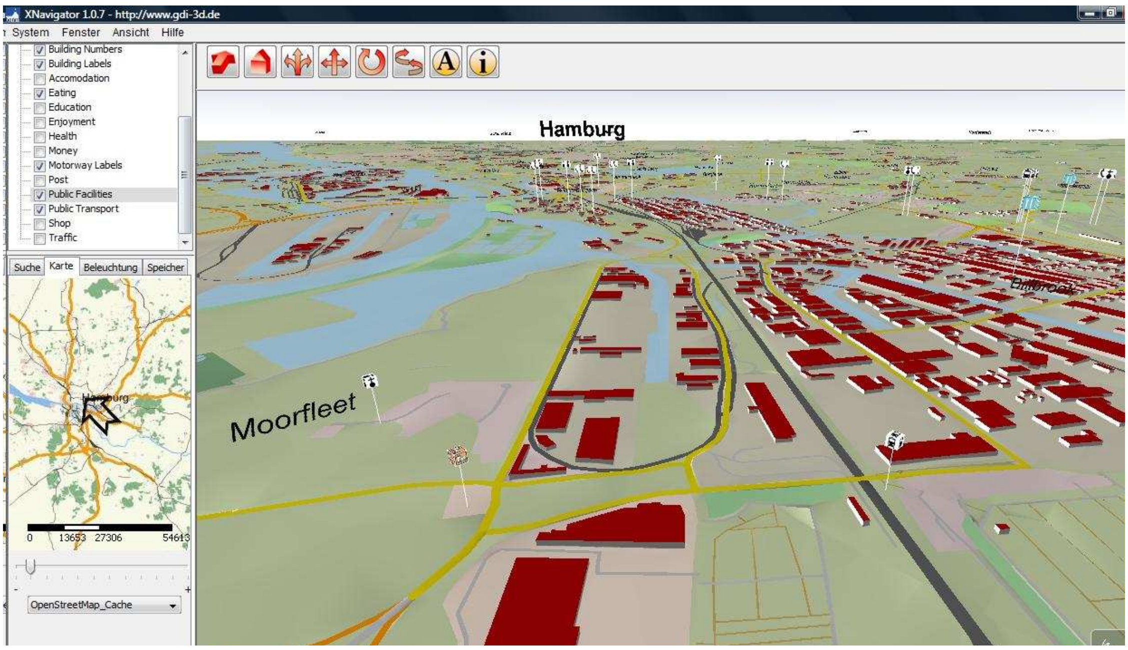

Figure 9: Web 3D Service for Germany based on user generated geodata (OSM). Example: Hamburg.

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