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OpenStreetMap in 3D – Detailed Insights on the Current Situation in Germany

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Abstract

This paper investigates the generation of virtual three-dimensional city models based on collaboratively collected geographic information from the OpenStreetMap project. In particular, the suitability of OpenStreetMap (OSM) data for the generation of 3D building models is investigated. The diversity and quantity of different building attributes theoretically provides new opportunities and challenges in creating detailed virtual building models for cities. With regards on the different building attributes, the current situation in Germany is quantitatively analysed and elaborated. The complete virtual city models are made available and accessible over the Internet via specialized web services. Thereby, all these services of the presented 3D spatial data infrastructure (3D-SDI) are based on open standards or draft specifications of the open geospatial consortium (OGC). Besides three-dimensional building models, the services also contain a Digital Elevation Model (DTM) based on open data of the Spatial Radar Topography Mission (SRTM), as well as other kinds of OSM information such as Point-of-Interests. Additionally, reoccurring elements, that is elements which can be easily reproduced by duplicating a prototype and positioning it at the right position, are integrated and can be derived within the system. The service is available at www.osm-3d.de.

Keywords: 3D City Models, 3D visualization, volunteered geographic information, OpenStreetMap.

1 Introduction

Volunteered geographic information describes a relatively new phenomenon in geoinformatics. One of the most popular and most promising examples is OpenStreetMap (OSM). OSM is a community based approach aiming at collecting and sharing any kind of geographic information in a Web 2.0 platform. Regarding the quality of OSM, it has been demonstrated that - especially in urban areas - OSM is able to compete against professional data collected by official surveyors or commercial providers [1-3].

Three-dimensional virtual city models are used for various tasks related to different applications and analysis such as facility management [4], rescue operations [5], city planning [6, 7]. Thereby, the applications have different requirements regarding both visualization and information resolution. For example a simple building blocks model is suitable for visualizing a complete city with low level of details, whereas an urban planning process with public participation for a small part of a city district requires highly detailed building models.

At present, there are three different applications available which provide three-dimensional OpenStreetMap information: first the KOSMOS WorldFlier [8], second OSM3D [9], and third the OSM-3D project [10]. However, the former two examples are very limited regarding the data and visualization, whereas the latter one contains comprehensive 3D scene graphs provided by open geospatial consortium (OGC) standards and draft specifications such as a Web Map Service (WMS) or Web 3D Service (W3DS). There is also some literature available on OSM-3D [11, 12]. Focussing on the latter OSM-3D project, this paper provides a detailed perspective on the generation of 3D building models. Furthermore, a quantitative analysis on the current situation in Germany is provided.

The rest of this paper is organized as follows. There is a brief introduction to OSM, followed by an overview on the OSM-3D system architecture. Afterwards, the generation of 3D building models is investigated in more detail. The integration of prototypical models for reoccurring elements such as trees or streetlights is also described. Thereafter, the current situation in Germany, regarding different building information, is conducted. Finally, the conducted research is summarized and an outlook on future work is provided.

2 OpenStreetMap project

OpenStreetMap is one of the most promising and popular projects for VGI. With currently more than 500,000 members [13], the community bears an enormous potential of "humans acting as remote sensors" [14]. OSM aims at creating a comprehensive and free online map with global coverage. Following the collaborative Wikipedia approach, everybody can contribute, edit and improve the data of OSM. Regarding the data model, OpenStreetMap is kept as simple as possible: (1) users provide so called *nodes*, that is geo-referenced points with longitude and latitude information. (2) For the description of linestring geometries, several nodes can be combined to *ways*. Thereby, a closed way represents a polygon (e.g., a building footprint), whereas a non-closed way represents a line (e.g., a street). For the description of complex relationships or complex polygons with holes, users (3) can create *relations*.

Besides those geometries, it is possible to tag OSM features, thus to add key-value pairs. Thereby, the key describes some kind of information or information domain and the value refines this information. What information is added, is up to the contributors. Essentially, they can add any kind of information as well as an arbitrary amount of information. However, there are community-accepted tags which should be used for common map features such as streets or buildings. A list of those is available in the Watchlist [15], whereas a list of all currently used tags with exemplary values is provided at Tagwatch [16]. Figure 1 depicts a map with common OSM features, as well as the corresponding OSM key-value pairs.

Figure 1: Exemplary OSM map with corresponding tags.

Source: [3]

3 Architecture

The system architecture of OSM-3D is distributed on four servers in total. One server (namely *brocken*) is a database server containing regularly updated two-dimensional OSM geometries with their corresponding tags. The geometries are pre-sorted in various database tables with respect to their content (e.g., buildings, naturals etc). The generation of a regularly updated OSM database is based on [17]. On a second server (namely *nebelhorn*), the processing algorithms are stored and executed. These procedures (see next section) retrieve two-dimensional OSM features from *brocken*, process them, generate three-dimensional features, and store them on a third server (namely *zimba*), which is again a database server. Both database servers are running a PostgreSQL[1] database system. The forth server (namely *rax*) contains a W3DS running on a an Apache Tomcat[2]. When requesting the service, the W3DS processes the request and provides the desired information (by retrieving data from *zimba*). For more information regarding the different processes please refer to [11, 18, 19].

The whole system and methodology of OSM-3D can be regarded as some kind of procedural city modelling approach (Cf. [20, 21]). However, it is tweaked to the specialities of unstructured and crowdsourced geodata (e.g., missing values, key-value attribution etc), because both qualities and quantities of available data in OSM differs from city to city.

4 Processing of buildings

One of the most obvious three-dimensional map features of OSM-3D are buildings. Basically, the OSM contributors only provide two dimensional footprints of the buildings, as well as different building attributes. That is, for using OSM in a three-dimensional environment, it is required to generate 3D building models based on the available information.

When generating 3D building models, the processes within OSM-3D use two-dimensional geometries, which are available on the server *brocken*. The generation of those 2D footprints is described in a different publication [17]. Additionally, different building attributes are also considered. The key *height*, as well as the key *building:height*, ought to contain information about the height of a building. If such information is not available, as an alternative, the keys *levels*, *building:levels* and *building:levels:aboveground* can be utilized for an approximation of the building height (by multiplying the amount of levels with an average level height of 3.5 meters). The key *building:min_levels* also needs to be considered because it describes the individual elevation of a building, thus the space between the ground and the building(part).

When computing building geometries, it is also interesting to generate proper roof geometries. The keys *building:roof:shape*, *building:roof:style* and *building:roof:type* contain a semantic description of the roof shape, such as pitched roof or pyramidal roof. In contrast, the key *building:roof* is supposed to contain information about the material of the roof, although it often also contains roof shape information. Similar to this key, *building:roof:material* can contain information about the roof material. Besides those keys, there are also some other relevant keys for the roof generation. *Building:roof:extent* describes the extent of the roof, thus the actual distance between the roof edge and the building facade. For describing the orientation of the roof, the key *building:roof:orientation* is applied: if the roof ridge is parallel to the longer roof side, the value is *along*; otherwise the value is *across*. The generation of roof geometries for simple building footprints, that is footprints with rectangular shape or those which only consist of 4 points, is straight forward and can be applied with adequate performance to the OSM dataset. For more complex roofs, such as those with holes or arbitrary shape, the generation of roof geometries is quite challenging. Some early results have already been gained by using procedural extrusion with Skeleton computations (Cf. [22, 23]), but until now a broad application of those algorithms for the whole OSM on the one hand is very time consuming (about factor 100) and on the other hand does not, due to special cases and exceptions, lead to satisfying results. Basically, the complete building generation process is based on the work of [12].

[1] www.postgresql.org
[2] www.apache.org

Figure 2: Pseudo code for 3D building generation

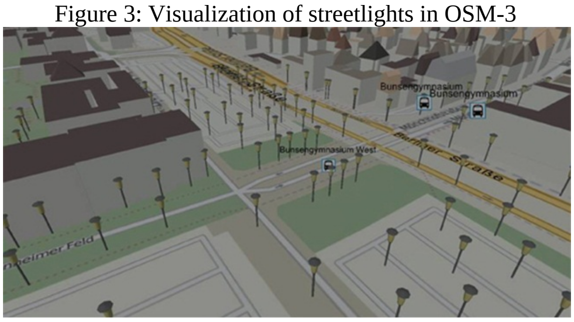
```
Algorithm create3dBuildingModel(G, A)

Input: G = 2D Geometry (Polygon) from OSM
Input: A = Attributes as OSM key-value pairs
    3dm[] <-- empty
    height <-- getHeight(A[height], A[building:height], A[levels], A[building:levels], A[building:levels:aboveground])
    roofShape <-- getRoofShape(A[building:roof:shape], A[building:roof:style], A[building:roof:type])
    roofAttr <-- getRoofType(A[building:roof:extent], A[building:roof:orientation], A[building:roof:angle], A[building:roof:height])
    roofColor <-- getRoofType(A[building:roof:colour], A[building:roof:color])
    color <-- getRoofType(A[building:colour], A[building:color], A[building:facade:colour], A[building:façade:color])
    body <-- computeBuildingBody(G, height, color)
    roof <-- computeRoof(G, roofShape, roofAttr, roofColor)
    building <-- combine(body, roof)
    triangulate(building)
Output: 3D Building as VRML (building)
```

Focussing more on the appearance of a building, various keys contain information about the building's colours as well as materials. By investigating the keys building:roof:colour, building:facade:colour and building:cladding it is furthermore possible to create a realistic colour appearance for the building models. Regarding the latter mentioned keys, British English spelling as well as American English spelling must be considered. Figure 2 contains a very basic and brief description of the applied algorithm for the generation of 3D building models from OSM, written as pseudo code.

5 Integration of reoccuring 3D features

Aiming at the creation of a comprehensive data source, the OSM community also collects information about reoccurring elements such as trees, or streetlights. These elements are all mapped as single nodes and tagged accordingly.

Figure 3: Visualization of streetlights in OSM-3



Source: Own screenshot of OSM-3D

Such elements are indeed unique (regarding their appearance) however they are all somehow similar. Trying to use this data and to create a more realistic virtual perspective on the real world, OSM-3D utilized this data and integrated reoccurring 3D features.

When processing the OSM data, all tress and streetlights are stored in a database table with their point-geometry. Additionally, the feature is annotated as being a tree or light. OSM-3D does not integrate a 3D VRML model for each tree or light, because this would require too much storage. Instead, the system provides a prototype (a sample) for a tree and a light. When requesting 3D scenes from the system, every light (and tree) point is referenced to its prototype and a copy of the model is placed at the corresponding location. This is a quite fast and storage saving method for integrating various models for trees and lights. Figure 3 depicts an exemplary view on an area where obviously many streetlights are mapped in OSM.

6 Quantitative analysis on the current situation in Germany

When OSM has been started 2007, contributors mainly provided information about streets. However, soon they also contributed building information – especially building footprints. Regarding the whole OSM planet file, recently the amount of buildings even surpassed the amount of streets. Considering Germany, there are currently nearly 5.5 million building footprints available. Compared to the real number of 17.8 million buildings, about 30% of all buildings in Germany are covered within OSM. However, every week the OSM members contribute about 200,000 new building footprints in the German area[3], thus the cleavage is decreasing. A complete coverage seems not likely in the near future, but similar coverage rates as for streets (currently about 90% [3]) sound reasonable within the period of one to two years.

Besides building footprints, users also contribute 3D- and semantic information about buildings. Table 1 contains a detailed analysis on the usage of different building attributes. The analysis reveals that users indeed provide building footprints, but they do not provide additional information on a large scale. Solely information about the amount of levels or about the height is a bit more often available, but still just about 0.5 % of all buildings is tagged accordingly. Also it is

[3] According to our internal database

interesting to see that the contributors still use the key *building:height*, although it has been defined as obsolete [24]. Regarding the keys with colour information (e.g. *building:roof:colour*) the values in Table 1 are accumulated, so both British English and American English spelling are considered and combined in one row.

Table 1: Quantitative analysis on OSM building information in Germany (*5,461,059* buildings in total)

Amount of buildings with	Absolute	Relative
height	4,965	0.0909 %
building:height	25,056	0.4588 %
levels	911	0.0167 %
building:levels	37,956	0.6950 %
building:levels:aboveground	2,061	0.0377 %
building:levels:belowground	616	0.0133 %
building:min_levels	158	0.0029 %
building:roof	12,440	0.2278 %
building:roof:shape	5,122	0.0938 %
building:roof:type	342	0.0063 %
building:roof:style	0	0.0000 %
building:roof:extent	3	0.0001 %
building:roof:orientation	2,302	0.0422 %
building:roof:height	644	0.0118 %
building:roof:angle	605	0.0111 %
building:roof:colour	2,251	0.0412 %
building:roof:material	158	0.0029 %
building:material	9	0.0002 %
building:cladding	355	0.0065 %
building:façade:colour	59	0.0011 %
building:colour	1,635	0.0299 %
building:architecture	586	0.0107 %
building:source	923	0.0169 %

Source: Internal OSM database (10th January 2012)

7 Conclusions and future work

Within this paper, a project for generating and providing 3D models based on OSM data, namely OSM-3D, has been described. After a short introduction to 3D models and the OSM community, the system architecture has been described. Afterwards, a detailed perspective on the generation of 3D building models has been provided. Thereafter, the integration of reoccurring 3D models has been discussed by using the example of integrating a 3D model for streetlights. Following, a detailed quantitative analysis on the current situation in Germany has been conducted, whereby the focus was on building related information. Finally, the research findings are summarized and discussed. Figure 4 shows an exemplary view on the city of Munich in OSM-3D. It depicts quite a lot of buildings; some of them area also enriched with roof information. Additionally in the far back, the DTM is roughly visualized.

With the quantitative analysis of the current dataset, it became apparent that OSM contributors mainly provide building footprints. All kinds of other building information is hardly available. That is, when generating 3D models from OSM, an algorithm should consider those values (if available), but also include some heuristics for the generation of more appealing and realistic city models. However, the generation of LoD1 city models (i.e., building blocks) is feasible from OSM data, and even LoD2 is possible for some buildings. Such city models can be utilized for applications which do not need a high level of detail, but a wide range of data on city level, such as environmental simulations [4], noise mapping or city planning [6, 7]. Furthermore, such models can be utilized for global earth browsers, comparable to commercial applications such as Google Earth[4].

For the future it is desired to integrate even more OSM features and attributes. Especially the consideration of different available building attributes will allow for the creation of even more detailed building models. Also the usage of such keys needs to be promoted inside the community. As the analysis reveals, it is likely that in the next 12 – 18 months nearly all building footprints in Germany will be available in OpenStreetMap. In contrast, it also became obvious that other building attributes are yet hardly available in Germany, thus their usage needs to be further promoted, aiming at the creation of more realistic 3D models.

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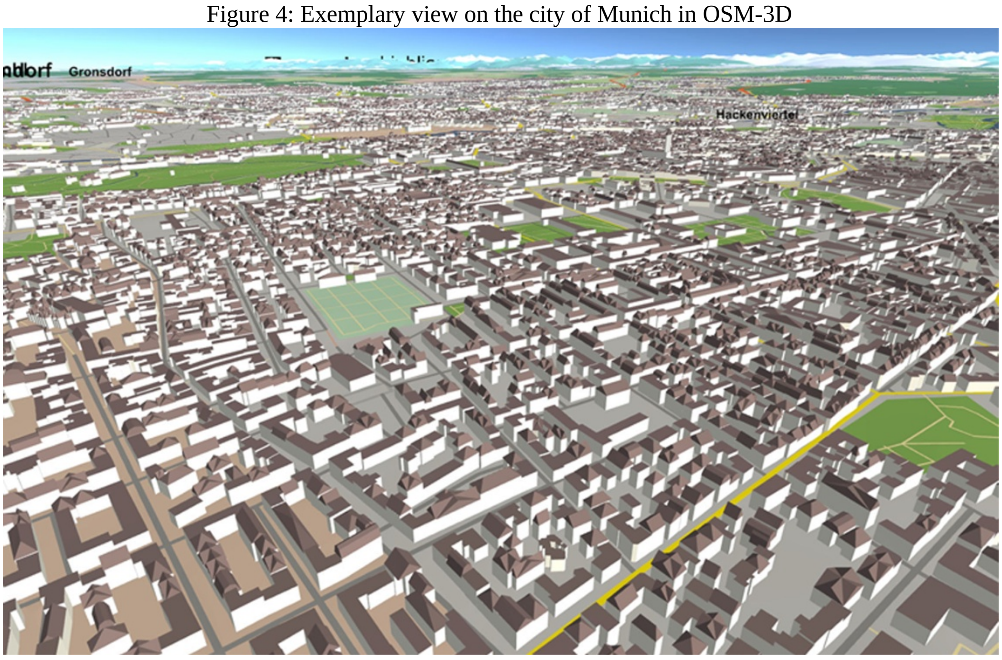
Figure 4: Exemplary view on the city of Munich in OSM-3D



Source: Own screenshot of OSM-3D

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