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Generation of landmarks from 3D city models and OSM data

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Abstract

In this paper a study on the generation of landmarks from 3D city models (in LOD 2) and OSM (Open Street Map) data is presented. Therefore attributes, attribute values and other characteristics which classify a building as a landmark are investigated. Further it is studied if and how these attributes can be extracted from 3D city models and OSM data. Subsequently, a landmark index dependent from the attribute values is assigned to every building to assess the suitability of a building as a landmark. Finally the concept is evaluated by comparing the landmarks generated by the landmark index with landmarks which were chosen from test persons.
Keywords: Landmarks, 3D city model, CityGML, OSM

1 Introduction

Navigation systems play a growing role in wayfinding tasks in unknown regions. Because of the widespread availability of smart phones and PDAs the need of mobile routing services also increases. Because these routing services are mainly developed for navigation systems used in cars, the information that they present tends to be inadequate for pedestrians. One reason for this problem can be found in the exclusive use of direction and distance information within the wayfinding instructions. Only few POIs (Point of Interest), for example petrol stations, are integrated. Though these POIs provide additional information, they are not a part of the wayfinding instructions themselves. However, studies from cognition psychology have shown that human beings prefer so called landmarks in routing instructions instead of directions and distance information [2, 3].

Lynch [6] was the first scientist who tried to describe landmarks and their characteristics. He defined landmarks as optical reference points and mentioned examples like buildings, signs, supermarkets or hills. According to [10] landmarks can be differentiated in visual, cognitive and structural landmarks. [9] modified this classification and replaced the cognitive by semantic landmarks. Visual landmarks are objects that are salient because of visual attributes like height or color [10]. In contrast to that, a structural landmark should feature a prominent location in the spatial environment, for example at crossroads [9]. The group of semantic landmarks focuses on the meaning of the landmark, for example the cultural or historical importance of a building [10].

For the integration of such landmarks in routing instructions for pedestrians, the landmarks have to be extracted from different sources. Within the literature different data sources, which were used for this purpose, can be found [4, 9].

In countries like Germany to a large extent 3D city models are established in the moment (mainly in LOD 2). Therefore in this work it is investigated how these 3D city models complemented by Open Street Map (OSM) data can be used for the generation of landmarks. After the identification of the attributes which may classify a building as a landmark, it is investigated how these attributes can be extracted from 3D city models and OSM data. For every building a landmark index is calculated, which gives information about the suitability of the building as a landmark. Further, the results are evaluated by comparing the landmarks generated by the landmark index with landmarks which were chosen from test persons.

2 Data Sources

2.1 3D city model

A 3D city model is a three dimensional vector dataset which includes buildings of a city. The most common information model for the representation of such 3D city models is CityGML (www.citygml.org). CityGML provides five different Levels of Detail (LoD). For this work a 3D city model of Nuremberg in CityGML format LoD 2, provided by the Bavarian Agency for Surveying and Geoinformation, was used. In the 3D city model each building consists of several polygons for the building footprint, the roof and the walls. For every building the following attributes are available:

- Bounding box;
- Roof height, position, ground level;
- Reference point roof height;
- Shape of roof;
- Function of the building (main building/annex);
- Height of the lowest building points above sea level gained from the digital terrain model;
- Absolute height of the roof above sea level;
- Relative height of the building;
- Place name or street name with house number;
- Municipality key;
- Number of floors over ground.

In the section "generation of landmarks" it is investigated if and how these attributes can be useful for the generation of landmarks.

2.2 OSM Data

"OSM is a collaborative project to create free editable maps of the world" [8]. Those maps are created with the aid of data from portable GPS devices, aerial photography and other free sources or simply from local knowledge. As OSM is captured and maintained by volunteers the completeness, consistency and accuracy of the data can vary from region to region.

In contrast to 3D city models, objects in OSM are two-dimensional. There are three basic elements to represent objects in OSM:

- Node: every node has a unique identifier with coordinates,
- Way: objects like streets are represented by lines,
- Closed way: objects like buildings are represented by polygons.

Additionally, in OSM it is possible to assign "tags" to the elements. A tag consists of an object key (e.g. k = highway) and a value (e.g. v = cars). There is a huge amount of predefined tags which, however, are not used consistently because every editor can choose his own tags. As a result, some objects are very well described (with address, function, proper noun…) while others are not described at all.

3 Landmark Attributes

Buildings that can be classified as a landmark should possess an outstanding characteristic compared to the surrounding buildings. That means they should be easy to identify for pedestrians and easy to describe within wayfinding instructions. In order to determine whether a building classifies as a landmark or not, attributes characterizing a building as a landmark have to be defined. Within the literature several attributes can be found [e.g. 9, 10]. According to [9] we divided our attributes in visual, semantic and structural attributes. Further, we investigate if these attributes can be extracted from 3D city models or from OSM data.

Visual Attributes

We identified five visual attributes, which can classify a building as a landmark: *height, proportion of height and width, façade area, façade structure and style of roof.*

Height. The height is explicitly stored in the 3D city model and can be used from this source.

Ratio of height and width. Objects, which have unusual ratios of height and width are for example skyscrapers or long and low buildings. In this work the relative height of the building, stored in the 3D city model, is used. The width can be derived from the bounding box of the object which is available in the 3D city model.

Façade Area. People tend to notice objects whose façade areas are larger or smaller in comparison with the façade areas of the surrounding objects. The façade area for every wall of the building is explicitly stored in the 3D city model.

Façade structure. Buildings with even façades are more difficult to recognize than objects with unregularly façades with bay windows, for example. For every wall the number of façade elements is stored within the 3D city model. This number gives information about the structure of the façade. A low number indicates a common façade, a high number an unregularly façade.

Style of Roof. An individual style of roof is also an outstanding attribute. The style of roof is also stored in the 3D city model.

Semantic Attributes

We introduced two semantic attributes, which can classify a building as a landmark: *function of the building* and *proper noun*.

Function of the building. Buildings with special functions are for example churches, supermarkets or hospitals. The function of a building is stored in both the 3D city model and OSM data. While in the 3D city model only the function of the building of main or adjacent buildings are included, OSM differentiates between many functions, like for example churches, supermarkets or hospitals. Therefore the OSM data are used for the extraction of the building function.

Proper noun. Buildings with cultural or historical importance often stand out due to proper nouns, like for example the "Frauenkirche" or the "Deutsches Museum" in Munich. Proper nouns are included in the OSM data and are therefore used from this source.

Structural Attributes

In the group of structural attributes we considered: *distance to route* and *number of adjacent routes.*

Number of adjacent routes. A street network consists of nodes and edges. Nodes are intersections like street intersections or squares [9]. Landmarks which are located at nodes are more important than landmarks located at edges. The number of routes can be extracted from OSM data by applying a buffer to the respective buildings [4].

Number of adjacent buildings. The second structural attribute is the number of adjacent buildings. Freestanding buildings are easier to identify and to describe than buildings with many neighbors (e.g. terraced houses). The number of adjacent buildings can be extracted from both 3D city model and OSM data.

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4 Concept for the generation of landmarks

The concept for the generation of landmarks consists of three steps:

1. Extraction of the values for the above defined attributes for every building;
2. Derivation of a so called *landmark index* for every building;
3. Extraction of the landmarks.

Extraction of the values for the defined attributes

For every building the values for the defined attributes are extracted from the 3D city model and OSM data, respectively. To combine OSM and the 3D city model data the coordinates for the building footprints, which are available in both datasets, are compared. As shown in figure 1 there are buildings in the 3D city model without counterpart in OSM (see figure 1 upper left corner). Therefore the 3D city model is used as primary data set and the OSM data as supplementary data source.

Figure 1: buildings available in OSM only (yellow), available in the the 3D city model only (blue) and in both data sets (brown).

Derivation of the landmark index

In this section we develop the so called landmark index (LMI) and describe the way how it is calculated. The LMI is derived from the values for the defined attributes. If an attribute value of a building is salient or differs from the attribute values of the surrounding buildings, the building is assigned the significance “1” for this attribute. If the value is neither different nor salient the building is assigned the significance “0”. Table 1 shows which conditions must be fulfilled to assign a significance of 1 to the building for each attribute.

For the comparison of the visual attributes of a building with the visual attributes of its surrounding buildings the size of the observed area has to be chosen. Thereby it has to be considered that this area is neither too small nor too large. In this paper the buildings within a radius of 100 m are considered.

Table 1: Significances.

Attribute	Significance = 1
Visual Attributes	
Ratio of height and width	If > 5
Height	See text below
Façade Area	
Façade Structure	
Style of roof	If no flat or pitched roof (because they are dominant)
Semantic Attributes	
Function of building	If available
Proper noun	
Structural Attributes	
Number of adjacent routes	If > 1
Adjacent buildings	If freestanding

Another important step regarding the visual attributes is the definition of threshold values at which the attribute value of a building differs significantly from the attribute values of the surrounding buildings. Therefore thresholds are defined (which were gained by experiments, which are not explained here, due to the limited size of the paper):

- Height: significant, if the value is twice as high as the average height within the observed area;
- Façade Area: significant, if the façade area is three times bigger than the average façade area within the observed area;
- Façade Structure: significant, if the number of façade elements is maximum within the observed area.

If a building possesses a value for the semantic attributes, *proper noun* and/or *building function*, a significance value of 1 is assigned to it for this attribute. For the *number of adjacent routes* an environment has to be defined in which the routes are counted. In this case an environment of 10 m is chosen. If there is more than one route within this environment a significance value of 1 is assigned to the building. Freestanding buildings, where the *number of adjacent buildings* is zero, also get the significance value 1.

After the determination of the significances for all individual attributes the LMI is obtained. Therefore the significances for each individual attribute are added and divided by the number of attributes (see formula 1):

$$LMI = \frac{\sum_{i=1}^{n} Attribute\ significance_i}{n} \quad (1)$$

$$n: number\ of\ Attributes$$

If the LMI of a building exceeds a predefined threshold it is classified as a landmark. Additionally to that because of geometrical issues the height, the ratio of height and width and the façade area are given a higher weight than the other

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attributes. Therefore if one of these attribute of a building is significant according to the above mentioned definitions, it is classified as a landmark regardless of the other attributes' values.

Extraction of the landmarks

In the third and last step of the concept for the generation of landmarks those buildings are extracted which are suitable as landmarks. The 3D city model of Nuremberg contains altogether 7014 buildings. To extract landmarks from the dataset a LMI > 0.5 is used. That is, a building classifies as a landmark if 5 of the 9 attributes are significant. Consequently 98 buildings are classified as a landmark. Additionally a building gets a LMI of 1 if one of the attributes height, ratio of height and width or façade area is significant. Like that another 217 landmarks were identified. Thereof 80 buildings were chosen because of their height, 62 because of their ratio of height and width and 138 because of their façade area. Like that 315 landmarks were chosen in total (see figure 2).

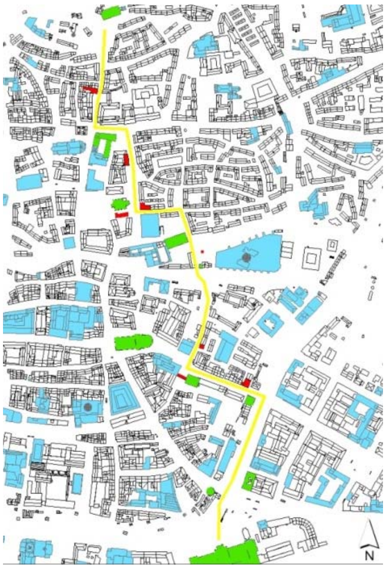
Figure 2: Generated landmarks in 3D city model.

5 Evaluation

To evaluate the extracted landmarks a test route is chosen. The route runs from the railway station of Nuremberg to the castle (see figure 3).

To evaluate the results test persons were asked to provide possibly suitable landmarks for the selected route. In figure 3 the landmarks generated with the LMI are shown in blue. The landmarks selected by test persons are shown in green. The landmarks chosen by test persons but not generated with the LMI are shown red. Landmarks generated by the LMI and identified by test persons were buildings like the main station, churches, towers of the city wall, as well as buildings with interesting façade areas (e.g. with pointed gables, turrets or glazed façade areas), salient styles of roof or outstanding ratios of height and width. 8 buildings were chosen as a landmark only by test persons but were not generated by the LMI. These objects are chosen from test persons because their number of adjacent buildings (null), their distance to route, their function or because of unique attributes (e.g. building cross-overs).

Figure 3: Test route and landmarks in 3D city model.



It is striking that freestanding buildings are often not identified as landmarks by the LMI although they are available in the 3D city model (see figure 4, tower). One reason for this is that "the number of adjacent buildings" is the only significant attribute which is considered for these buildings within the LMI.

Figure 4: Not identified freestanding tower in 3D city model.

Other buildings, which were not identified by the LMI as landmarks are building cross-overs (see figure 5). To identify also such free hanging buildings new attributes have to be introduced and the LMI has to be adjusted in future work.

Figure 5: Not identified free hanging building in 3D city model.

The tests also showed that persons often used objects or attributes to describe the route, which are neither available in

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3D city model nor in OSM data. For example control panels or small walls.

Further, 15 % of the wayfinding instructions were based on semantics, for example “Der Beck”. Such semantics are included in OSM with the attributes function of the building and proper noun. Unfortunately in our test area none of such buildings were available and therefore did not play an important role in the landmark extraction process.

Further, the tests showed that façade structures where used within wayfinding instructions, which are also not included in the available city model.

6 Conclusion and Future Work

The study introduced in this paper clearly shows that the usage of a 3D city models in LOD 2 in combination with OSM data for the generation of landmarks for pedestrian navigation is rather limited.

One limitation of the proposed approach are the data which are neither available in 3D city model LOD 2 nor in OSM data. Therefore it should be investigated how these data can be extracted from additional data sources (e. g. city maps for semantics [9]) or crowd initiatives aiming on that should be initiated.

Furthermore, the evaluation showed that persons in some cases choose landmarks to describe the route, which were not generated by using the LMI as it was proposed in this work. Thus, it should be investigated in future research which additional attributes should be considered and how the LMI can be adjusted to generate the missing landmarks from 3D city models or from OSM data.

Nevertheless, with this approach in quite a number of cases landmarks were extracted with the LMI, which were confirmed by the test persons. That means, the approach introduced can be used as a base and has to be extended using the outcome of this paper. Further, in future work parameters like direction of movement, line of sight of the pedestrian and turn directions have to be considered also. For that purpose existing work like for example [1, 5, 7] can be adapted and adjusted.

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