AUTOMATIC LANDMARK DETECTION FOR 3D URBAN MODELS

J. Ganitseva [a], V. Coors [b]

[a] Blom Romania SRL, 3-5 I.H Radulescu St.,130010,Targoviste, Romania - julia.ganitseva@blominfo.ro
[b] University of Applied Sciences, Schellingstr. 24, 70174 Stuttgart, Germany - volker.coors@hft-stuttgart.de

Commission IV, WG IV/8

KEY WORDS: Landmark, 3D Urban Model, Quality Management

ABSTRACT:

Increasingly developing technology today allows call for a fully automated level of 3D urban model production. Customer market demands high quality realistic 3D models with consistent geometry for numerous applications including e.g. city and landscape planning, location based services and navigation support, cultural heritage, disaster management etc. Quality assessment, management and control of 3D models have become a topical problem. Landmark detection is one of the steps to simplify and automate the procedure of 3D urban model quality estimation. The quality of the complete model can be evaluated by appraisal of the quality of landmarks i.e. the most important buildings of the area. The goal of this paper is to introduce an automated procedure of landmark detection for a 3D urban model, with the purpose of automation of 3D urban models quality assessment and control.

1. INTRODUCTION

Landmark is a salient object, visually and semantically unique and easily recognizable in the urban environment. Therefore landmarks have always stayed in the area of interest among users of 3D urban models and demanded a higher quality in comparison with other 3D objects of less importance. Landmarks are widely used for navigational purposes, but in the context of the current research, landmarks are detected with the purpose of 3D model quality assessment.

Recent developments in the field of automated methods of 3D urban model production have lead to many discussions on quality assessment and control of this type of models. High quality, geometrically consistent with 3D models, can make a basis for many areas of research. Thus, having a fully automated procedure of 3D urban model production today poses a question: How to assess the quality of this three-dimensional product?

Until now, in most of the cases, the quality control has been established manually, which is a costly and time-consuming process. The purpose of this research is to suggest an approach to the quality estimation using automatic landmark detection method, which allows to identify and check “the most important buildings” of a city i.e. landmarks, and by estimating their quality, conclude on the quality of the complete 3D model.

During this research, building semantic attributes are detected and investigated using internet data extraction approach. Building visual attributes are automatically derived by analysis of feature geometry within the 3D model. Method of outlier detection for significance assessment of the building features is implemented. And, as a final stage, list of landmarks, containing salience characteristics, is obtained.

In this paper will be discussed how the method of automated landmark detection is established. First an overview about existing research into the classification and characteristic of landmarks is given. Then general concept of detecting main landmark attributes is introduced and followed up with the explanation of the procedure implementation. Evaluation of the results with an outlook to the future research concludes the paper.

2. RELATED RESEARCH WORK

In order to reach a better understanding of the concepts and fundamentals that have become a basis for this research, definition of landmark is introduced in the following section, providing a brief overview on existing classification schemes and recent developments in the field of landmark detection and recognition techniques.

Sorrows and Hirtle (1999) define landmarks as prominent, visually and/or semantically salient objects, such as monuments, buildings or other structures, which are uniquely memorable and easily recognizable in the context of surrounding environment. In this work, the definition of landmark takes into consideration only buildings.

Recognition of landmarks in the city environment is a useful and challenging task. Due to importance of landmarks for navigational purposes, several landmark classification schemes in the recent fifteen years have been proposed by different researchers (Sadeghian and Kantardzic, 2008). Steck and Mallot (1997) distinguish between global and local landmarks, where they define “global” landmark as a distant object, visible from a large area, for instance a TV tower of the city and “local” landmark, in contrast, as a salient object, visible only from a small distance, for example building at an intersection.

Lovelace et al. (1999) classify four types of landmarks for navigation purposes: “Potential choice” landmarks - located at potential turning points, “choice point” landmarks – located at the choice points, “on-route” landmarks – located along the path of travel, but not on the choice points, and “off-route” landmarks – located not directly on the path, but supplying some global orientation information. This classification schema is considered to be very useful for route directions in navigational services. However, for general quality assurance, it is not very helpful as it is always bound to a route.

Sorrows and Hirtle (1999) proposed three categories of landmarks: visual, cognitive and structural. Visual landmarks are buildings with salient visual characteristics, that have prominent unique features in strong contrast with the environment e.g. Eiffel Tower in Paris. Cognitive landmarks are the ones which are semantically meaningful because of their cultural, social or historical significance e.g. museums, theatres, commercial centres. Structural landmarks are buildings which are memorable due to their spatial location e.g. buildings at intersections, bus stations, objects around city squares (Grabler et al., 2008).

In 2002, based on Sorrows and Hirtle categorization, the new methodology of building peculiarity identification was offered by Raubal and Winter (Sadeghian and Kantardzic, 2008). Their model of landmark saliency includes four measures regarding visual attraction: facade area, shape, colour and visibility. Semantic attraction includes cultural and historical importance of an object and explicit marks i.e. signs in front of the building that specify its semantics. And finally, level of structural attraction is measured by analysing the spatial locations such as buildings at intersection and close to the boundaries of the roads (Raubal and Winter, 2002).

3. CONCEPT

The following section summarizes the process of an automatic landmark detection and recognition.

The concept of this research is based on Raubal and Winter landmark categorization, briefly described in section 2. The process includes the analysis of building visual and semantic attraction based on attributes such as building height, area of façade, shape factor, shape deviation, complexity, dynamic and static factor. The more outstanding in comparison with the neighbourhood the attributes of the building are, the more likely for this building is to be a landmark. The way to automatically derive building attributes and measure the level of their saliency will be explained in detail in the upcoming parts of this section.

3.1 Sample Dataset

Development and implementation of the landmark extraction procedure is introduced using CityGML model of Stuttgart city centre with the area of 4 square kilometres and 5523 building models. To clarify the concept of an automatic extraction of the building attributes, the way of interaction with the 3D urban model has to be explained first.

The city model is stored in a MySQL database using the java based framework City Administration Toolkit (CAT3D) developed at HFT Stuttgart (Knapp, Bogdahn, Coors, 2007)

Figure 1 describes the way a 3D urban model is defined within the database using a CAT3D schema. 3D building features are stored in the layer, which is defined by ID, Name, Minimum bounding rectangle and reference coordinate system (SRS). Building (feature3d) within the database, together with some other attributes, has an ID, Name, Representative Coordinates and reference to the Coordinate System. Each feature is described by its geometry (geom), which is stored as 2d geometry or a faceset using a sequence of points, defined by their indexes. Depending on the model, it can represent various types of building elements, such as walls, roofs, ground plan etc.

The CityGML model, used as the test dataset, is defined by OGC CityGML specifications as LOD2 geometry, where outer facades of the building are a simply connected geometry without the holes, thematically defined by the BoundarySurface and classified as WallSurface, RoofSurface and GroundSurface (Gröger et al, 2008).

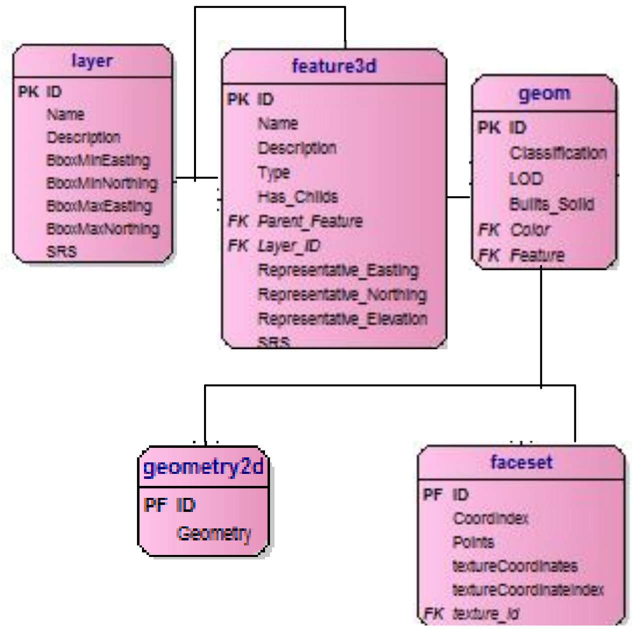


Figure 1. CAT3D UML Diagram

3.2 Workflow

The concept methodology schema, introduced in Figure 2, gives an overview of the process workflow, presenting step by step the procedure of data extraction and analysis. The workflow is divided into following steps:

1. Import of the 3D model into MySQL Database, defined by CAT3D schema;
2. Detection of the building visual characteristics, by retrieval of the building attributes from the database;
3. Detection of semantically meaningful buildings, within the area of Stuttgart, by use of information on points of interest extracted from the internet;
4. Outlier detection for building visual attributes within its neighborhood;
5. Compilation of the list of landmarks, based on outlier detection results;

Each of the steps introduced in the workflow is performed fully automatically and combined together to compile a procedure of an automatic landmark extraction from a 3D urban model.

3.3 Landmark Visual Characteristics

According to Raubal and Winter (2002), visual landmarks have prominent visual characteristics in strong contrast with the surrounding environment. This type of objects is easily recognizable and therefore, they stay in the area of high interest. Visual characteristics of the buildings are obtained by extraction and interpretation of geometry information within the 3D urban model.

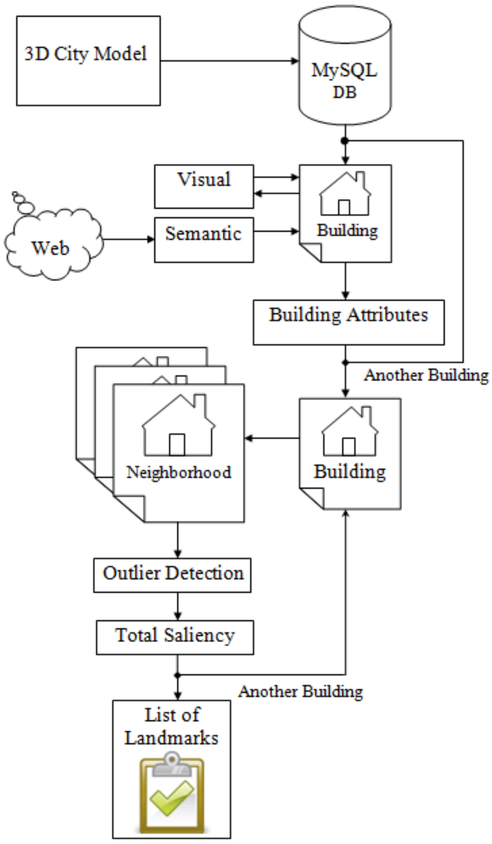


Figure 2. Concept Methodology schema for an automatic Landmark Detection Procedure

Height

Height of the building is an important attribute. Significantly high buildings are noticeable from far away, therefore it is an essential attribute to detect. Height is detected by calculating the height of building AABB (axis aligned bounding box) as follows:

$$h = |maxEl - minEl| \tag{1}$$

where h = height of the building,
$maxEl$ = elevation of the building bounding box maximum coordinate
$minEl$ = elevation of the building bounding box minimum coordinate

Facade Area

Facade area is a distinctive building attribute for determining its contrast with the environment. People tend to notice buildings with facade areas that considerably exceed or rather deviate from traditional rectangular form (Raubal and Winter, 2002). Facade Total area is an area of all building facades including area of the roof. Assuming that building facades could be rather complicated and not necessary plane surfaces, method of Polygon 2D projection on a plane developed by Snyder & Barr, 1987 is integrated, in order to obtain the area, in the detection procedure.

Shape deviation

Many buildings have a standard, rectangular shape. The more it deviates from the standard, the more salient it becomes as a landmark (Grabler et al., 2008). Shape deviation is a difference between actual building volume and volume of the building OBB (oriented bounding box). In order to obtain shape deviation, we need to acquire two values: Volume of the building OBB and Volume of the building itself. OBB has a shape of rectangular prism. Its volume V is calculated using the following formula:

$$V = B * h \tag{2}$$

Where B = area of the base
h = height:

To solve the problem of the building volume calculation for a 3D object of any shape, a TetGen development of Delaunay tetrahedralization implemented by Hang Si (2006) is used. This implementation allows to split an object into tetrahedrons and, by calculating volumes for each of them, to obtain the total volume Vb of the 3D object, as follows:

$$V_b = \sum_{i=1}^{n} \left(\frac{1}{6} * |det\,(a-b, b-c, c-d)| \right)_i \tag{3}$$

where a tetrahedron is defined by vertexes $a = (a_1, a_2, a_3)$, $b = (b_1, b_2, b_3)$, $c = (c_1, c_2, c_3)$, and $d = (d_1, d_2, d_3)$. This method of the volume calculation is very sensitive to the correctness of the building geometry, which should fulfil the restriction requirements of Piecewise Linear Complex.

Geometry Complexity

Shape Deviation method alternative - also called geometry complexity - comes from the assumption that the more face sets building has, the more complicated is building geometry. Therefore, number of face sets is calculated for each building. Due to the fact that even a simple close to rectangular form of the building, in some of the cases, can be represented with many face sets, the geometry complexity is taken into account only when shape deviation of the building cannot be detected.

Shape factor

Narrow and high buildings, such as skyscrapers, are in strong contrast and will have a high shape factor within the neighbourhood of low and long buildings. Shape factor is calculated using following formula:

$$F = \frac{h \times 2}{w + d} \tag{4}$$

Where F = building shape factor;
h = height of the building;
w = width of the building OBB;
d = depth of the building OBB;

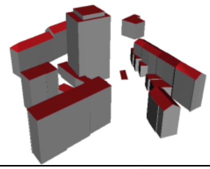
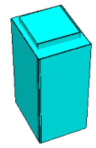
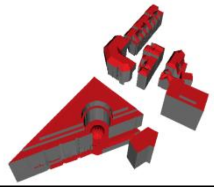
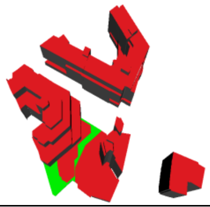
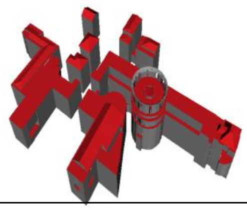
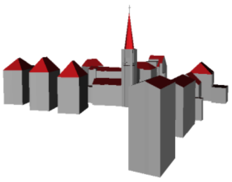
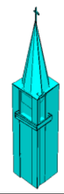
Neighbourhood	Detected Building	Outlier Attribute
		Height: 49,08 m
		Facade Area: 33 235 m^2
		Deviation: 6.76
		Num. of Faces : 1976
		Shape Factor: 6.97

Table 1. Detected visual outlier attributes

Visual Saliency Calculation

The values of significance for each visual attribute of the building are calculated using Dixon's Q –Test (Efstathiou, 2010) for one extreme observation for a neighbourhood within the radius of 50m.

Dixon's Q-Test allows to investigate if one observation from the dataset possesses an extreme value compared to its neighbourhood. Q-Test is based on the assumption of a normal (Gaussian) distribution of the data set and accept or reject the observation as an outlier with 95% confidence and 5% significance in the frames of current research work. Dixon's Q-test is applied as follows: For each of the building visual attributes, the observation values N of its local neighbourhood are arranged in the ascending order ($x_1 < x_2 < . . . < x_N$). The statistic experimental Q-value (Q_{exp}) is calculated. This is a ratio defined as the difference between the suspect value (x_S) and its nearest (x_{S-1}) neighbour, divided by the range of the values. Thus, for testing x_S, as a possible outlier, Q_{exp} derived as follows:

$$Q_{exp} = \frac{x_S - x_{S-1}}{x_n - x_1} \tag{5}$$

The obtained Q_{exp} value is compared to a critical Q-value (Q_{crit}) found in tables of extended critical values developed by Verma & Quiroz-Ruiz 2006, for a 95% level of confidence. If $Q_{exp} > Q_{crit}$, then the suspect value can be characterized as an outlier and get the value of significance = 1, if not, the suspect value is rejected as an outlier and significance = 0 (Efstathiou, 2010). In case the suspect do not have enough neighbors to compare significance = 0 because the spatial location (structural saliency) was not analyzed in the frames of this research work. Some results for detected building visual outlier attributes are shown in Table 1.

3.4 Landmark Semantic Characteristics

Semantically meaningful buildings possess historical and/or cultural attraction. For example the central train station is very well known object in any city not only due to its strong visual characteristics but also because of its practical purpose. Churches, museums, libraries, hotels, commercial centres and many more other objects in the urban environment are known and belong to the area of high interest. Various web pages and internet applications offer thousands of information on city most attractive tourist places, business centres, hotels and restaurant. Currently, only web page http://places.falk.de is used as a source of semantic extraction.

In order to get information about Stuttgart points of interest, source code analysis of the mentioned above web page is performed. JavaScript and HTML based code is easily understandable and allows to retrieve necessary information such as POI coordinates, title etc. in an automated manner. Using Java environment and Java.net package following building attributes has been automatically detected and analyzed:

1. *Name*- extracted directly from the source code: `"title": "Neues Schloss Stuttgart";`
2. *Coordinates*- (latitude and longitude) extracted directly from the source code: `"geocode": "geox": "9.180470", "geoy": "48.778099";`
3. *Description*- extracted directly from the source code: `"content": "Beschreibung\nDie frühere Residenz der württembergischen Könige, im Spätbarock errichtet, beherrscht heute den Stadtkern. Vor dem Schloss erstreckt ...;`
4. *Average Rating*- extracted directly from the source code by counting number of star avg on, with width of 100% adding one point and 50% adding 0.5 points (within this example average POI rating is 2.5) :

```
<div class="star avg on"><a style="width:100%;"
<div class="star avg on"><a style="width:100%;"
<div class="star avg on"><a style="width:50%;"
<div class="star avg"><a style="width:100%;"
<div class="star avg"><a style="width:100%;"
```

5. *Maximum Rating value*- from previous example and for all points of interest equal to five;
6. *Number of People Rated* = 4 in this example, extracted directly from the source code:

```
<span id="rating-num-votes-43193"> 4 </span> Bewertungen);
```

7. *Rating Ratio* = Average Rating/ Maximum Rating value;

8. Weighted Rating Ratio= Rating Ratio * Number of People Rated;

Static attribute

Static attribute, also described as building category, defines if building might possess any cultural or historical attractiveness. For example, finding key words like 'theatre', 'hospital' or 'university' in the name and description of POI would put it into the 'cultural' category, and words like castle or museum would put it into the 'historical' category. Key words were developed using OGC standards for building Class Type and Function Type. If none of that key word is found, POI category is set to undefined. Value of Saliency for this attribute is assigned as follows: Historical meaning = 1; Cultural meaning = 1; Undefined category = 0;

Dynamic attribute

Dynamic attribute, or building popularity among the visitors, takes into account rating values of the building. The value of dynamic salience has been calculated as follows: *Dynamic Saliency = Weighted Rating Ratio/Maximum Number of People Rated;*

Semantic Saliency Calculation

Buildings that possess a historical meaning are considered to be more important, but they are rarely rated by the users. On the other side, cultural places, especially restaurants and hotels, are more often rated. Therefore, calculations of the value of *Total Saliency* have the following logic:

If POI is detected as historical, *Semantic Saliency = Static Saliency;*

If POI is detected as cultural, *Semantic Saliency = (Dynamic Saliency + Static Saliency)/2;*

If POI is undefined, *Semantic Saliency = Dynamic Saliency;*

POI Type	Measure-ment	Value	Max People Rated	Saliency	Total Saliency
Cultural	Weighted Ratio	7.6	11	7.6/11 =0.69	(0.69+1) /2 = **0.85**
	Cultural	true		1	
Historical	Weighted Ratio	7.6	11	-	**1**
	Historical	true		1	
Undefined	Weighted Ratio	7.6	11	7.6/11 =0.69	**0.69**
	Undefined	true		-	

Table 2. Semantic Saliency calculation for Cultural/Historical/Undefined POI type

Saliency calculation for a 3 hypothetical POI shown in Table 2, gives an example of how the value of total semantic significance is calculated for each extracted POI.

3.5 Total Saliency Calculation

After detecting the values of significance for each attribute of semantic and visual attraction, the total saliency can be calculated for every building by obtaining the mean value from building attributes (see Table 3).

Measure	Attribute	Value	Saliency	Total Saliency
Visual	Height	46.11	1	(1+1+1+0+ +0.53)/5= **0.706**
	Façade Area	26092.8	1	
	Shape Deviation	0	1	
	Complexity	368		
	Shape Factor	0.5	0	
Semantic	Static	cultural	0.53	
	Dynamic	0.06		

Table 3. Calculation of Building Total Saliency

4. IMPLEMENTATION

This section briefly describes the java implementation for an automatic landmark extraction. As it has already been mentioned above, the landmark detection procedure is performed in several steps. Implementation consists of a number of functions, such as 3D model import into the DB, extraction of building visual and semantic attributes, detection of outliers and output list of landmarks.

Implementation is structured into five different packages according to the functionality of the classes (see Figure 3). *DataQuery package*, with the QueryTest class, using CAT3D enables the import of the model into the database. Landmark Detection procedure is executed within the main class of *Main pac*kage, which, step by step, invokes other classes for detection of visual and semantic attributes.

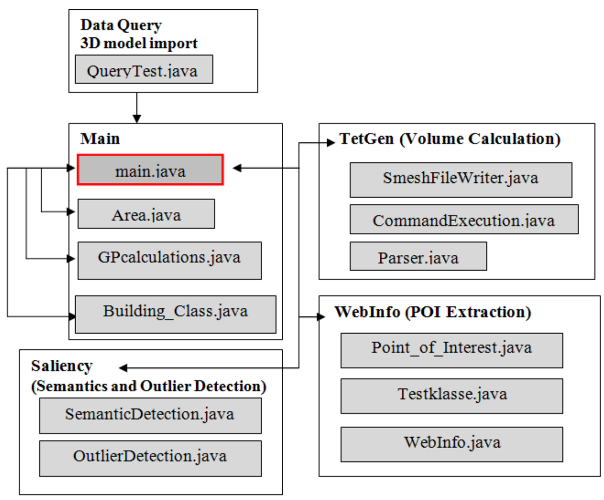


Figure 3. Packages and Classes of test implementation for automatic landmark detection

Package TetGen enables calculation of building volumes, as a part of obtaining building visual characteristics. *Package WebInfo* engages the processes of POI extraction from the internet, interpretation of the information needed and calculation of Semantic Salience of POI. And finally, *Saliency Package* enables overlays of POI, extracted from internet, with the 3D buildings, and performs the procedure of an outlier detection method for the building visual attributes. Method of total saliency calculation and output list of landmarks with the evaluation of the building visual and semantic attributes, detected value of saliency and reference coordinates of the landmarks are implemented in the classes of main package

5. EVALUATION OF THE RESULTS

Using previously described methods, 652 Landmarks are automatically extracted from the 3D urban model with 5523 buildings.

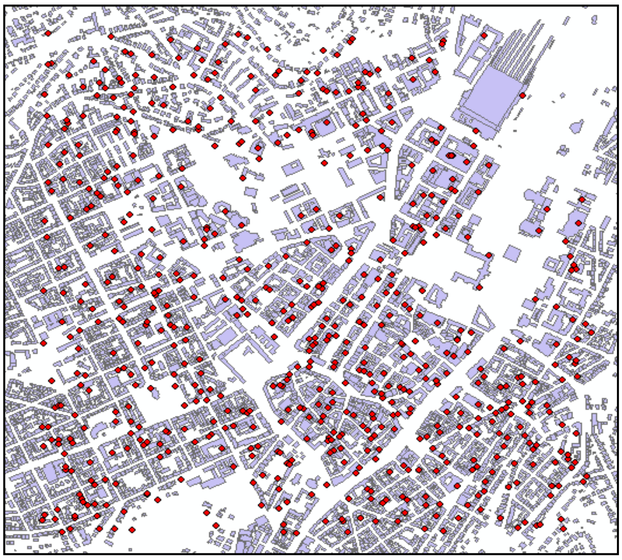


Figure 4. Results of Automatic Landmark Detection

Figure 4 shows the complete list of detected landmarks, where buildings are marked using the representative coordinates, extracted from the 3D model database. Total Saliency of the Landmarks varies from 0.8 to 0.008, depending on the number of building attributes detected as outliers. So the more outlier attributes the building possesses, the higher the value of the Total Saliency is and the more significant it is as an outlier.

In order to obtain a better impression on efficiency of the method, area of HFT Stuttgart is closely analyzed for detected Landmarks and their value of saliency (see Figure 5). It can be seen that building 1 (BID3010) and building 4 (BID2182) of the HFT are detected with the high value of total salience. The parking lot (BID2017) next to the building 2 is detected as a semantic object “Schlesinger bar” but the value of total salience is low – 0.02, because no other visual attributes of the building possess outlier characteristics. Additionally, for visual attribute outliers of total façade area and shape complexity, “Haus der Wirtschafts” (BID5329) is detected as a landmark with the total saliency of 0.4.

6. CONCLUSIONS AND FUTURE WORK

The result of this work is a valid automated procedure of Landmark Detection of 3D urban model developed in the java environment, using the example of CityGML model of Stuttgart.

During the process, building visual and semantic attributes are detected and analyzed for the outlier characteristics. Results are evaluated and the output list of Landmarks with assessment of building significance and detected attribute values is obtained.

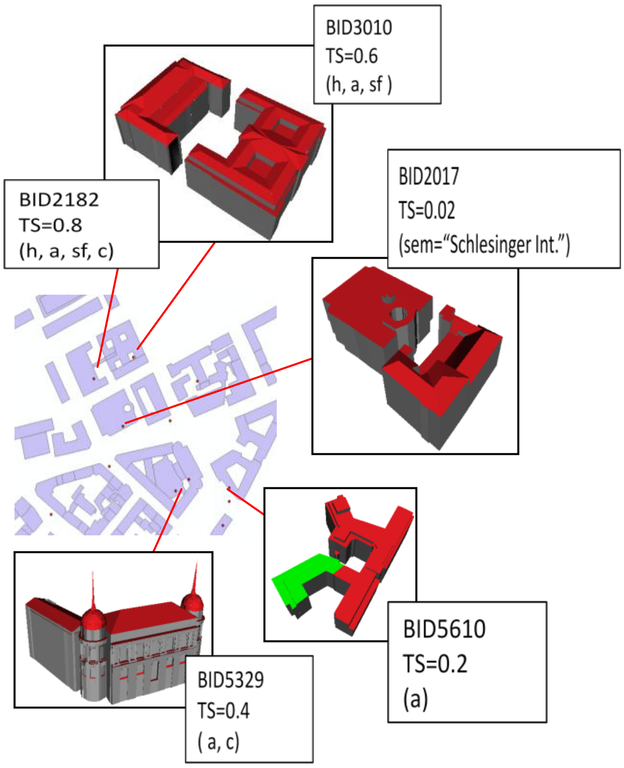


Figure 5. Landmarks Detected within the area of HFT Stuttgart, where *TS* –Total Significance; *sem*-semantic; *h*-height; *a* – façade area; *sf* – shape factor; *d*-shape deviation; *c*- complexity detected as an outlier attribute

Analysis of the results shows that the automated process of landmark detection highly depends on the quality of 3D model, with regards to its logical consistency and quality of the model geometry. Detection of the building visual attributes strongly depends on the quality of the building geometry. Therefore, algorithms to improve the 3D urban models geometry quality should be developed and implemented. 3D models should be logically consistent and building parts should be associated with the buildings to which they belong. This type of model inconsistency can lead to detection of false landmarks, due to which reason not a complete building, but only a building part is evaluated. Nevertheless it can be said that automated methods, developed for detection of building visual attributes, give good results in terms of correctness and efficiency.

Referring to detection of building semantic attributes, it is also concluded that the quality of data, extracted from the online resources, plays a major role in the procedure of landmark detection. During this research only one online resource is used for detection of building semantics, but in order to improve the results and make them more reliable several online resources should be evaluated.

Structural analysis, e.g. detection of buildings at intersections and around the city plazas, should be implemented in the procedure together with visibility analysis. This type of landmarks is more important in terms of 3D urban model quality demands, because they stay in the bigger area of interest than buildings inside the neighbourhood, which are not visible from the roads.

Concluding the results of the current research work, it can be said that developed procedure is an efficient method of landmark detection, which is interoperable with several 3D data types. Developed implementation delivers list of landmarks with the values of their visual and semantic attributes, together with detected level of saliency for each attribute and total saliency evaluation for the landmark.

7. ACKNOWLEDGMENT

We would like to thank Linde vande Velde and Sven Coppens from TeleAtlas for fruitful discussions on the topic and for posing the problem, Jürgen Bogdahn for providing the CAT3D framework used in this research and the city of Stuttgart for providing the 3D urban model data.

8. BIBLIOGRAPHY

Cambridge University Press (2008). Cambridge advanced learner's dictionary 3rd edition. Cambridge Dictionary. http://dictionary.cambridge.org/define.asp?key=44569&dict=CALD&topic=buildings-in-general (accessed 17 Jan. 2010)

Efstathiou, C. (2010). Dixon's Q-test: Detection of a single outlier. http://www.chem.uoa.gr/applets/AppletQtest/Text_Qtest2.htm (accessed 28 Feb. 2010)

Grabler, F., Agrawala, M., Sumner, R., and Pauly, M. (2008). Automatic generation of tourist maps. In: International Conference on Computer Graphics and Interactive Techniques, ACM SIGGRAPH 2008, Los Angeles, California, U.S.

Gröger, G., Kolbe, T., Cyerwinski, A., Nagel, C (2008). OpenGIS® City Geography Markup Language (CityGML) Encoding Standard. Open Geospatial Consortium Inc. Version 1.0.0

Hang Si (2006). TetGen a Quality Tetrahedral Mesh Generator and Three-Dimensional Delaunay Triangulator. Verison 1.4. Users Manual. http://tetgen.berlios.de/ (accessed 18 Feb. 2010)

Knapp, S., Bogdahn, J., Coors, V. (2007). Improve public participation in planning processes by using web-based 3D-models for communication platforms. In: M. Schrenk, V. Popovich, J. Benediktreal (Eds.), CORP 007 Proceedings / Tagungsband Vienna, May 20-23 2007.

Lovelace, K., Hegarty, M., and Montello, D. (1999). Elements of good route directions in familiar and unfamiliar environments. In: C. Freksa and D. Mark (Eds.), Spatial information theory: Cognitive and computational foundation of geographic information science (pp. 65-82).

Raubal, M. and Winter, S. (2002). Enriching wayfinding instructions with local landmarks. In: M. Egenhofer and D. Marks (Eds.), Geographic Information Science, Lecture Notes in Computer Science (vol. 2478, pp. 243-259).

Sadeghian, P. and Kantardzic, M. (2008). The new generation of automatic landmark detection systems: challenges and guidelines. In: Spatial Cognition & Computation,(vol. 8: 3, pp 252—287).

Sorrows, M. And Hirtle, S. (1999). The nature of landmark for real and electronic spaces. In: C. Freksa and D. Mark (Eds.), Spatial Information Theory, International Conference COSIT´99 (vol. 1661, pp 37-50).

Steck, S. and Mallot, H. (1997). The role of global and local landmarks in environment navigation. In: Technical Report No. 63, Max-Plank-Institute für biologische Kybernetic, Tübingen, Germany.

Snyder, J. and Barr, A. (1987). Ray Tracing Complex Models Containing Surface Tessellations, ACM Comp Graphics 21.

Verma, S., Quiroz-Ruiz, A. (2006). Critical values for six Dixon tests for outliers in normal samples up to sizes 100, and applications in science and engineering. In: Revista Mexicana de Ciencias Geológicas, v. 23, num 2, (pp. 133-161).

Winter, S., Raubal, M. and Nothegger, C. (2004). Focalizing measures of salience for route directions. In: L. Meng, A. Zipf, & T. Reichenbacher (Eds.), Map-based mobile services—Theories, methods and design implementations (pp. 127–142).