QUALITY ASSESSMENT OF HISTORICAL BAALBEK'S 3D CITY MODEL

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ABSTRACT:

Baalbek is inscribed as a wonderful urban heritage site since 1984. This city is famous and tourist attraction due to the 5000 years of the history of the city as well as the wonderful Roman constructions such as: temples of Jupiter, Venus and Bacchus. The sanctuary was designed in a new form and built in a monumentality which was not known before. Through the (4.th – 7.th centuries) Baalbek got more Christian churches which could displace but slowly in the old cults. The Islamic empire had converted the site of temples into a great fort. According to the abovementioned historical importance, the documentation of historical Baalbek should be respected. For this purpose a 3D city model of Baalbek based on historical images is currently being created. This model supports an important document for the city. Baalbek's 3D data extracted from oriented historical photos will be considered the main input data for 3D CityGML modelling which supports different Levels of Detail (LODs) by them we can represent different data collections. In this paper we aim to know: in which LOD Baalbek data acquired can be modelled! In other words: based on the quality check of Baalbek data we want to know in which LOD Baalbek data available could be modelled. In addition, the semantic modelling of this city should be taken into account, because the geometric model does not support all information needed (e.g. classification of objects, building function, building class, names, etc.). Thus, the objects' geometry isn't the only quality concern.

1. INTRODUCTION

Baalbek is situated on the northern of the Beqaa-Plain in Lebanon. It is inscribed as a wonderful urban heritage site since 1984. This city is famous and tourist attraction due to the 5000 years of the history of the city, moreover, the wonderful Roman constructions such as: temples of Jupiter, Venus and Bacchus are witnesses of Baalbek's wonderful constructions. It could be assumed that the first settlement in Baalbek was ca. in the 3rd millennium BC (Van Ess, 1998). The sanctuary was designed in a new form and built in a monumentality which was not known before. Through the (4.th – 7.th centuries) Baalbek got more Christian churches which could displace but slowly in the old cults. In the Islamic era (635 AD) the site of temples had been converted into a great fort.

According to the abovementioned historical importance, the documentation of historical Baalbek should be taken into the account. For this purpose a 3D city model of the city is currently being created. The 3D model on one hand is an important document for the city and on other hand supports the analysis of the historical development of Baalbek's building remains from the prehistoric date until 20th century.

Historical photos of Baalbek were used to create this model. Basically, there are different historical image types of Baalbek which can be classified into: vertical, oblique and terrestrial images. It was essential to achieve a special image orientation process due to the poor properties of Baalbek's graphical materials such as: different cameras were used, no data about the cameras, different scales of images, different altitudes of flight, great image noise. In addition, the images were taken at different dates (Alamouri et al. 2008).

Baalbek's 3D data extracted from the oriented model of the photos (oriented region mosaic of Baalbek) is considered the main input data for 3D CityGML modelling. CityGML modelling supports different Levels of Detail (LOD) which are used to represent different data collections (buildings, streets, etc.). Basically, there are five LODs. LOD0 is essentially a 2.5D DTM. LOD1 is the well-known blocks model of the buildings with flat roofs structures. Additionally, LOD2 has more details about the roofs' structures. LOD3 denotes architectural models with detailed walls and roofs. The last type is LOD4 which represents interior structures of objects (see Kolbe, 2009).

Therefore, the main problem of this study is: it is not a priori clear in which LOD Baalbek's data could be modelled! In other words: the quality of Baalbek data should be checked to know in which LOD these data could be modelled. In addition, the semantic modelling of this city should be respected, because the geometric modelling does not support all information requested (e.g. building function, building class, names, etc.). Thus, the objects' geometry isn't the only quality concern.

According to (Guptill & Morrison, 1995, Joos, 1998 and Int03a, 2003), the quality parameters for geodata can be categorized into six criteria as following:

- positional/height accuracy (the accuracy of 3D coordinates)
- semantic accuracy
- completeness
- correctness
- temporal conformance
- logical consistency

The geometrical modelling in Baalbek's 3D model is considered an important step for further modelling steps (for e.g. semantic modelling). Therefore, Baalbek's data extracted should be geometrically investigated. In this context, an effective approach for the geometric evaluation of Baalbek's data set will be discussed to certain which LOD could be used.

Basically, the 3D feature accuracy for CityGML is described as standard deviation of the absolute 3D points (Gröger et al., 2008). In LOD1 the positional and height accuracy of 3D points should be 5m or less. In contrast, by LOD2 the positional and height precision of object points should be 2m or better. In our project, the achievable accuracy of the applicable 3D object points (namely, all object points selected) is smaller than 2m (for the position/height); therefore, it will be possible to use 3D features derived to create a 3D city model of Baalbek in LOD1 and LOD2. On the other hand, it will be possible to add thematic properties of extracted objects (e.g. building semantic properties such as: building's name, address, color, texture, etc.). This enables us to get more information about an object included and to make right decisions for further applications (e.g. archaeology, etc.).

2. RELATED WORK

In 1995 Guptill and Morrison have been described seven classes of spatial data quality: lineage, positional accuracy, attributes accuracy, completeness, logical consistency, semantic accuracy and temporal data. This description provides elements for a unified quality model.

In (Müller et al., 2003), ATKIS cadastral data was evaluated with respect to its geometric accuracy. Other quality aspects of 2D geodata were discussed (especially positional data accuracy) and presented in (Ragia & Winter, 1998). In this context, topological and geometrical differences are being calculated based on region adjacency graphs and zone skeletons created for two data sets.

An effort to comparing and evaluation different data sets (in this case: between a test data of a photogrammetric 3D building acquisition and reference data set associated with) was achieved by (Meidow & Schuster, 2005).

A quality model defining common parameters used for spatial data quality measurements of 3D city models was described in (Krämer et al., 2007). In this model a mathematical formalism was defined, which addresses the different quality parameters. A new quality control of 3D city model depending on the 3D surface matching was investigated, whereas the Euclidean distances between the verification and input data sets should be taken into the account (Acka et al, 2008).

(Dietze et al., 2007) described the applicability of the currently available metadata standards with respect to their use for city models as a relatively new kind of data type that will be part of future 3DSDIs. Basically, the definition of standards related to assessment of the spatial data quality is regarded the main aim of several standardization organizations (e.g. the Comitee Europeen de Normalisation CEN, etc.). The International Organization for Standardization/Technical Committee 211 (ISO/TC211) has addressed a set of international standards related to spatial data quality (e.g. ISO 19113, ISO 19115, etc.). In this paper we want to describe a new contribution for quality of 3D city models. This contribution is applied to data set of Baalbek 3D city model.

3. BAALBEK DATA SET

Based on the historical photos of Baalbek the intended 3D city model will be created. Basically, there are different historical image types of Baalbek which can be classified into: vertical, oblique and terrestrial images (see Figure 1).

A performance of a special image orientation process was necessary due to the poor properties of Baalbek's graphical materials such as: different cameras were used, no data about the cameras, different scales of images, different altitudes of flight, great image noise. In addition, the images were taken at different dates.

The orientation process was divided in three steps; the first one is the orientation of each image type in one block with its special properties (for example, for each type a special camera was assumed) then the bundle block adjustment was implemented. The second one is the performance of the orientation process only for the vertical and oblique photos together. The last one is that all different types of Baalbek's photos were assembled in the same block then the triangulation process was enforced (Alamouri et al .2008). Baalbek's 3D data extracted based on the oriented model of the photos (namely, the oriented region mosaic of Baalbek) is being used as the main input data for 3D CityGML modelling (Alamouri & Gruendig, 2009).

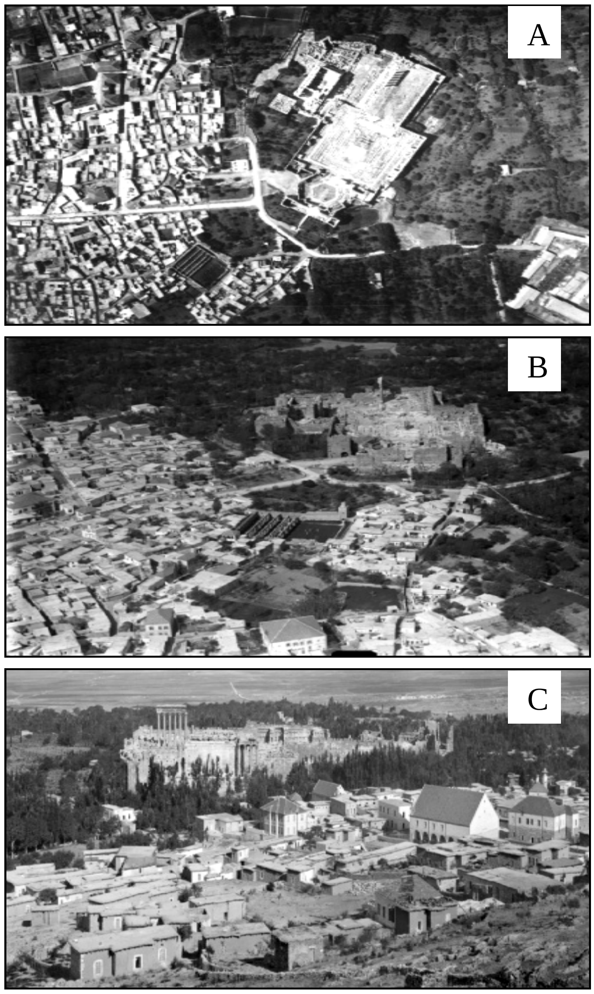

Fig. 1: Historic imagery of Baalbek. (A): a section of a historical vertical image taken in the year 1937, which includes the temples area; (B): an oblique photo taken in the year 1939; (C): a terrestrial photo in 1904. (Images copyright © Francais du Proche Orient IFPO - Damascus).

4. QUALITY MODEL

4.1. Quality parameters

To express the quality parameters in detail, the following terms should be respected:

- *Conceptual Reality (CR)*: according to (DEU, 1998), the conceptual reality is the user's understanding of the real world (user's idea about the real world). In practice, it may be a part of the real world which to be modelled (Fig. 2.a).
- *Digital Data Modelling (DDM)*: it describes a digital data set of elements included in *CR* that means it is the digital presentation of *CR*'s objects (Fig 2.b).

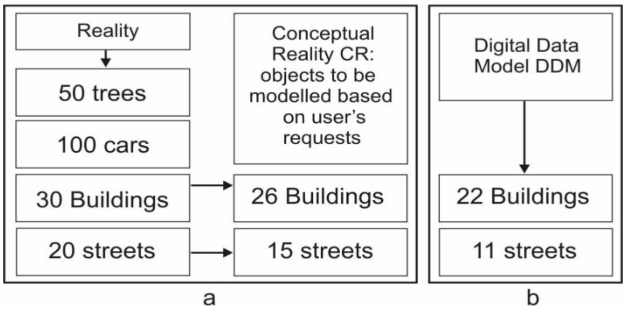

Fig. 2: Differences between *CR* and *DDM*; if there are e.g. 30 buildings as well as 20 streets in real world, due to user's requirement: it may be only 26 buildings and 15 streets which to be modelled (a), by a digital presentation only 22 buildings and 11 streets are presented; remaining parts were not captured due to errors by data extraction or object recognitions (b).

According to (Guptill & Morrison, 1995, Joos, 1998 and Int03a, 2003) the quality parameters can be categorized into six criteria:

- *Positional accuracy (geometry)*: geometry check of all objects included in *CR* and *DDM*
- *Semantic accuracy*: objects' classes and attributes must be correct and valid (in general, objects' classes and functions should be same in *CR* and *DDM*)
- *Completeness*: objects are complete if an object in *CR* has only a coupled object in *DDM*
- *Correctness*: each feature in *CR* and its coupled object in *DDM* have attributes which have the same valid value.
- *Temporal conformance*: it consists of accuracy of time measurement, date of update, update frequency and temporal validity.
- *Logical consistency*: logical rules should be same for all objects (for e.g.: all line strings must be closed, all points must be 3D, etc.).

4.2. Baalbek data quality

In this paper, a quality evaluation of Baalbek data is carried out separately for planimetry and height. This is due to the different accuracies that are obtained during photogrammetric 3D point measurements for the XY and Z coordinates. We propose a method for identification of differences between independently acquired data sets. This geometric evaluation of Baalbek data is essential due to the assumption that the geometrical modelling in Baalbek's 3D model is considered an important step for further modelling steps (e.g. semantic modelling).

4.2.1. Positional accuracy

The proposed method for a geometric 2D data check reveals to which extent the applicable extracted object points are accurate. It depends on the calculation of displacements related to some object points selected. Since to the selected object points form a polygon, it could be accepted that the suggested method can give information about the 2D data quality for the whole area within the polygon. The principle of the abovementioned method can be described in following steps:

- **Step I**: a section of the oriented model of Baalbek's mosaic was determined by a polygon (PT[1]) generated based on a few control points (CPs) measured by tachymeter (in this case five CPs were used). Three criteria should be respected in selection of control points; the first is that the CPs were not used in orientation process to keep statistically independency in the deformation calculation of CPs used. Second, CPs should be spread all over the studied area. Finally, it is important that the polygon should be created with a convex form which is, in general, more accessible in further mathematical processes (it allows for interpolation).
- **Step II**: aforementioned CPs were also measured based on the region mosaic of Baalbek; which means a new polygon (PM[2]) was generated (Figure 3.a).
- **Step III**: based on the overlapping between the both polygons PT and PM the displacements (Δ_i) of CPs selected can be calculated as following (Figure 3.b):

$$\Delta_i = \sqrt{(X_t - X_m)^2 + (Y_t - Y_m)^2} \qquad (1)$$

where: i: 1, 2 … 5
X_t, Y_t: coordinates of the CPs measured using Tachymeter
X_m, Y_m: coordinates of CPs measured using Baalbek mosaic

Figure (3.a): An illustration of the polygon PM (red line)

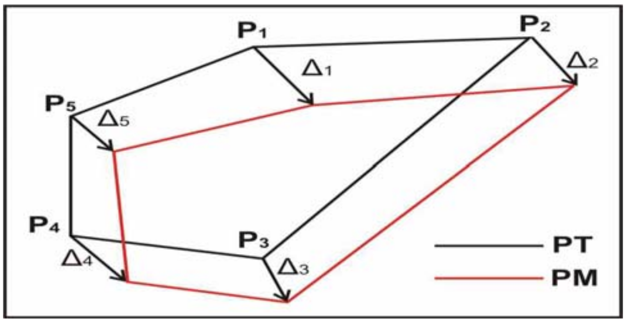

Figure (3.b): The overlapping between the both polygons (PT and PM)

[1] **PT**: **P**olygon based on points measured using **T**achymeter
[2] **PM**: **P**olygon based on points measured using Baalbek's **M**osaic

The positional deformations calculated depending on CPs used are approximately in the range [0.12 - 0.38] m (Figure 4).

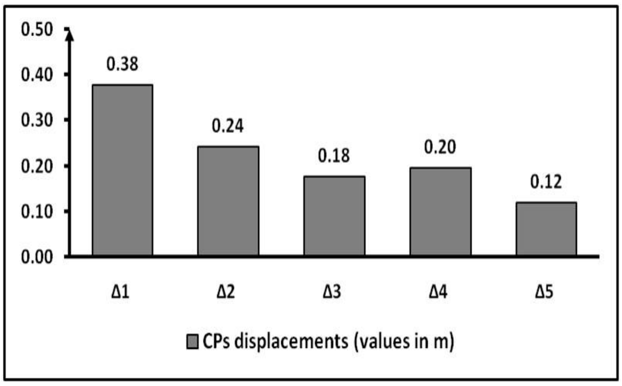

Figure 4: Displacement values of CPs selected

4.2.2. Height accuracy

The geometrical analysis of the heights is done in an analogous way which is described in the evaluation of positional quality of Baalbek data. The height differences associated with the most of CPs chosen are in the range [0.45-1.13] m.

5. RESULT INTERPRETATION

According to (Gröger et al., 2008), the 3D feature accuracy for CityGML is described as standard deviation of the absolute 3D point coordinates. In LOD1 the positional and height accuracy of the 3D points must be 5m or less. In contrast, by LOD2 the positional and height precision of object points must be 2m or better. In our project, the achievable accuracy of the applicable 3D object points is smaller than 2m (for the position/height).

Consequently, it will be possible to use Baalbek's 3D features derived to create a 3D city model of Baalbek in LOD1 and LOD2. An overview of Baalbek's 3D model (in LOD1) is shown in the Figure (5).

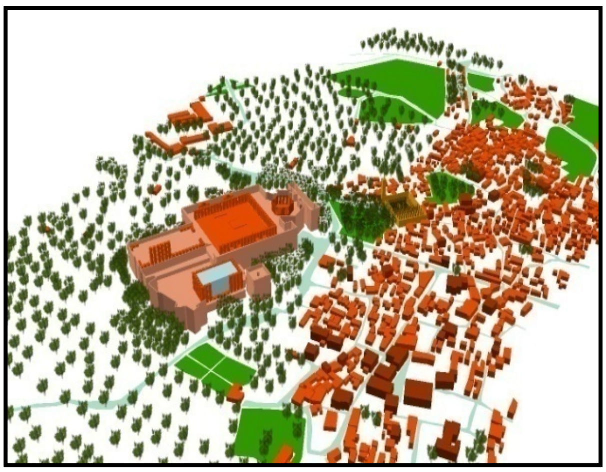

Figure 5: An overview of the 3D model of the historic Baalbek in LOD1; the temples area as well as buildings (in this LOD as blocks), streets, vegetation, etc. are shown. These entities were modelled using different tools (e.g. Erdas Imagine, ArcMap, Arc Scene, etc.).

It will be possible to develop Baalbek model created in LOD1 to LOD2. This means that thematic properties of extracted objects (e.g. building semantic properties such as: building's name, address, color, texture, etc.) could be added. This enables us to provide more information about objects modelled as well as to make right decisions for further applications (e.g. applications in archaeology, etc.).

The Figure (6.a) shows a close view of the 3D model (in CityGML LOD2) of some parts of the both temples: Jupiter and Bacchus. Entities are not only reconstructed in geometrical sense, but they are also classified into certain classes (e.g. walls, columns, etc.) and they contain thematic attributes (name, textures, etc.). The possibility to add semantic data of an object or a part of object (e.g. building or part of building) is performed in this case using a semantic editor (c.f. Figure 6.b)

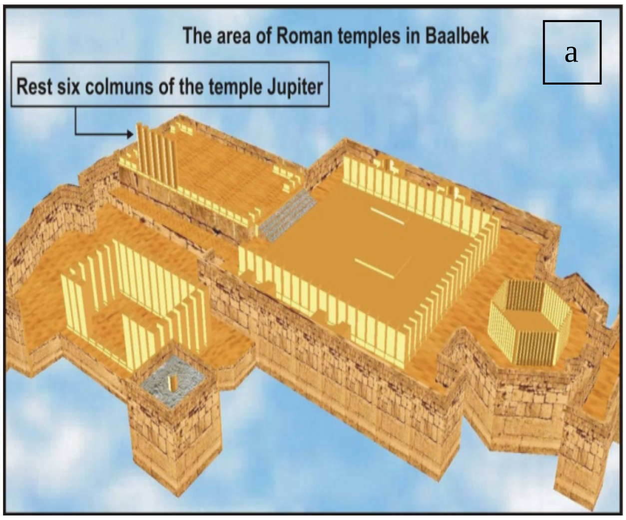

Figure (6.a): An illustration of 3D geometric and semantic model (in LOD2) of some parts of the temples: Jupiter and Bacchus. The main tools used in this case are "FME Universal Translator and the software Aristoteles 3D".

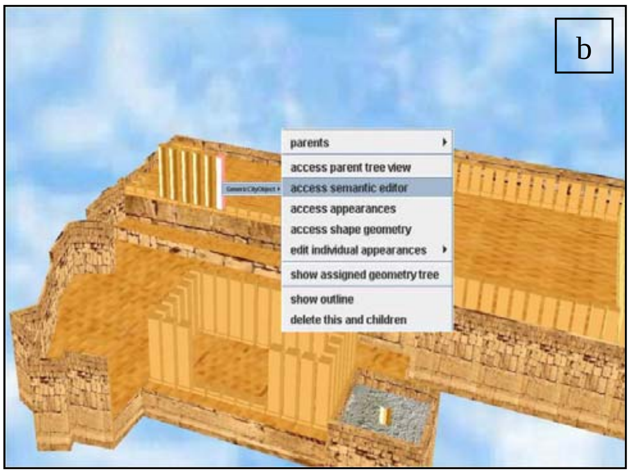

Figure (6.b): The possibility to add thematic information using a semantic editor (screen)

Basically, geometric quality has an indirect impact on semantic quality, because it affects the possible achievable CityGML LOD which determines also the semantic resolution. In addition, the resolution of Baalbek's historical photos has direct impact on the achievable semantic quality due to the images resolution affects the determination and 3D reconstruction of separate objects like parts of buildings (e.g. balconies, etc.).

6. CONCLUSION

Baalbek is an important urban heritage site sine 1984 due to the 5000 years of history. Therefore, the documentation of historic Baalbek should be taken into the account. For this purpose a 3D city model of the historic Baalbek based on historical images is currently being created. An effective approach was investigated to check the quality of Baalbek's data available. The principle of quality control depends on the calculation of displacement values associated with a few selected object points (in this case, five control points) included in the studied area. According to the implementation specification of the CityGML (Gröger et al., 2008), Baalbek's 3D features derived can be used to create a 3D city model of Baalbek in LOD1 and LOD2.

Basically the displacement values were calculated only for the vertices specifying the polygon. In next steps, we aim at the calculation of the deformation of each point included in the assigned polygon in the studied area. In this context, a raster grid should be determined and its vertexes' deformation should be taken into the account. Moreover, it will be investigated whether displacement values of raster points included in the determined polygon are smaller than the maximum deformation calculated.

7. ACKNOWLEDGMENT

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