DEVELOPING A FRAMEWORK FOR MALAYSIAN 3D SDI

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ABSTRACT:

This paper discusses the making of three-dimensional geospatial data infrastructure (3D GDI) for Malaysia. The main component of the initiative is 3D city models with CityGML as the standard for data modelling, transfer and exchange. Various aspects of 3D city modelling especially on the construction of the models and texturing of facades via dynamic pulse function are described. The generated models then are utilized in the network. More and more geospatial users deal with three-dimensional (3D) data such as buildings, plants, vegetation, street furniture (including bridges), etc. for various GIS applications within urban environment. One of the applications is 3D modelling for city, i.e. 3D city modelling. The modelling involves various aspects, e.g. texturing, semantic, and spatial database. This paper discusses these three aspects with the introduction of a simple but novel method of texturing of building facades for 3D city models, i.e. synthetic texturing by dynamic pulse function. High quality texturing, semantic modelling for 3D database within CityServer3D environment will form major discussion of this paper. The paper also describes how CityGML can be utilized for semantic modelling of the 3D buildings and also highlights the building blocks of the proposed a "near-future" Malaysian 3D SDI, i.e. 3D city models. It is a "big picture" of the whole idea for the 3D SDI framework for Putrajaya area and eventually for a country-wide area.

1. INTRODUCTION

Due to improved tools for the design and acquisition of 3D models, to the wider acceptance of 3D technology, and 3D spatial databases the creation and management of urban information spaces representing entire cities in the virtual world is feasible nowadays. The urban information space is not limited to 3D building geometry but includes building semantics as well providing necessary information for urban planning, construction and management. However, sharing information between professionals from various disciplines and non-professional users such as citizens affected by planning proposals is a big challenge for the future. Currently, traditional disciplines such as architecture, civil engineering and GIS create classic information "islands" with different focus. Usually GIS is used to represent the current status of a whole city for administrative purposes. In contrast, planning and construction professionals focus on the future shape and status of a relatively small part city or just individual buildings in very high detailed. In general, three categories of urban geo-information can be distinguished:

- GIS: two-dimensional maps, digital terrain model, 3D buildings with simple geometry of the entire city,
- CAD: detailed building models including interior,
- BIM: building information model including information about structure and usage of individual buildings and their interior up to urban quarters.

Due to the historical development of domain-specific applications, systems and formats, the different data sources are not interoperable per se. Döllner and Hagedorn (2007) have shown an integration of these data on visualization level using a service-based 3D viewer based on the OGC Web Service Initiative 4 (OWS-4). However, new challenges such as disaster management, sustainable development, and energy-efficiency do not only require an integration on visualization level, but an integration and convergence on data model level to enable intelligent data processing on city scale level.

This paper describes a framework for 3D geospatial data infrastructure based on OGC Standards in Malaysia. As test area, the Putrajaya area was chosen. The area is known as Malaysian capital of government administrative centre. It houses almost all federal government agencies including King's palace and Prime Minister's office. Other buildings such as private houses, flats, and convention centre are also in the area. In all, the area is occupied with thousands of buildings. However, the intended project only covers buildings along the major street, called Putrajaya "Boulevard" approximately more than 20 major buildings. Fig. 1 shows the map of the study area (i.e. Putrajaya, Malaysia).

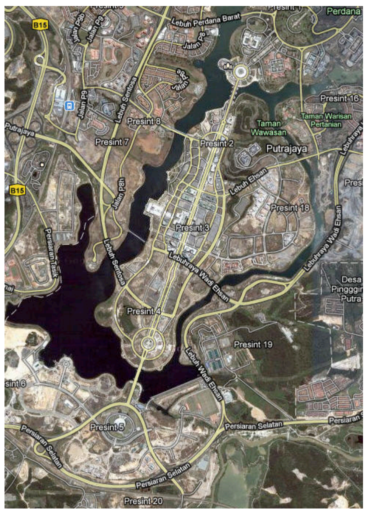

Figure 1. The study area of Putrajaya, Malaysia (from Google Earth).

The remaining of this paper, Section 2 discusses the various techniques for the 3D city modeling. Section 3 describes the dynamic pulse function, and Section 4 discusses the CityGML and 3D SDI. Finally, the conclusion of and further works are highlighted in Section 5.
The paper must be compiled in one column for the Title and Abstract and in two columns for all subsequent text. All text should be single-spaced unless otherwise stated herein. Left and right justified typing is preferred.

2. 3D CITY MODELLING

3D city modeling defines methods for modeling various types of 3D objects within the city such as buildings, terrain, road network, facades and roofs textures, streets furniture such as traffic light, trees, and etc. Recently, high performance and efficient computers along with powerful 3D hardware graphics systems are available in the market, thus, 3D GIS application such as 3D city modeling and 3D realistic navigation systems are in demand by various GIS users. A lot of efforts are being taken and investigated by researchers to improve some aspects of the modeling such as texturing. Inventions in 3D city modeling is obvious, for instance, the procedural method along with L-system used for 3D virtual city model of Manhattan with nearly 26000 buildings (Parish and Müller, 2001). Procedural modeling of buildings is used for modeling the Petronas twin towers of Kuala Lumpur, Malaysia and other similar landmarks with repeating polyhedrons in a building of different sizes (Müller et al. 2006). Rule-driven procedure approach is used for large scale virtual 3D city models (Wang and Hua, 2006). 3D navigation system for virtual reality based on 3D game engine utilized manual synthetic texturing and photo realistic 3D modeling in simulating navigation for UTM campus, Malaysia (Sharkawi et al. 2008). Mobile navigation system using 3D city model based on synthetic texturing with limited number of layers for walls, windows and door textures (at most three layers) on the façade which can be run on any Java based cellphones (Coors and Zipf, 2007), Mobile navigation system using 3D city model based on synthetic texturing and pulse function with unlimited number of layers for window and door textures on the façade which is using XML schema for keeping the parameters of layers and runs it by Java graphics to generate the façade as described by Bogdahn and Coors (2009) and also by Alizadehashrafi et al (2009). Others such as mobile location aware messaging application for 3D navigation system on Nokia 6630 and N92 which run using VRML file on m-Loma using global positioning system (Nurminen 2006a), (Nurminen 2006b), (Nurminen and Helin, 2005) and (Nurminen, 2007). Conventional photogrammetric method using terrestrial laser scanning and geo-referenced images on the façade produce models with large image size and also time consuming (Schulze–Horsel, 2007). Surveying equipment such as Total stations like Topcon GPT-7000i series with a built-in 1.3 mega pixel digital camera used for geo-referencing the images on scanned area and using applications such as Image-Master to generate the 3D model and map the image on the geometry in a very short period of time. 3D modeling techniques with rapid and easy that produce high quality image and small image size are the main concerned in 3D city modeling. Our novel method is called synthetic texturing by dynamic pulse function is described in Section 3. This method is utilized for generating high quality texture for the proposed 3D city models of the Putrajaya area.

3. DYNAMIC PULSE FUNCTION

Pulse function is a method to put/not to put the texture on an intersection of two axis's X [0-1], Y [0-1] on a given background. Contrary to mathematic [0, 0] is on the upper left corner the same as starting point of picture elements (pixel) on computer screen. After generating the pulse function for any unlimited number of layers, the logical value of zero or false in the intersection of XY axes, represents that the texture must not be mapped and one or true means it must be mapped on the given background.

3.1 Rectification and projective transformation

Photo exposure process either conventional or metric cameras, the parallel lines in reality will not be parallel in the photo. The lines meet each other at points, called vanishing points. The equations called projective transformation can define the relation between the film or digital sensor plane and the recording plane of a building's facade. Nearly all texturing applications use projective transformation to rectify the picture of façade or remove the projective distortion of the picture. We need to rectify the picture and crop the façade in order to generate the dynamic pulse function with respect to the size of rectified image. This picture can be used for measuring the parameters of dynamic pulse function for windows and doors with respect to upper left corner of the rectified façade.

Figure 2. Four points must be selected in a plane with known coordinates where each point provides 2 independent equations (1.1 and 2.1)

$$x' = \frac{x'_1}{x'_3} = \frac{h_{11}x + h_{12}y + h_{13}}{h_{31}x + h_{32}y + h_{33}} \quad (1.1)$$

$$x'\left(h_{31}x + h_{32}y + h_{33}\right) = h_{11}x + h_{12}y + h_{13} \quad (1.2)$$

$$y' = \frac{x'_2}{x'_3} = \frac{h_{21}x + h_{22}y + h_{23}}{h_{31}x + h_{32}y + h_{33}} \quad (2.1)$$

$$y'\left(h_{31}x + h_{32}y + h_{33}\right) = h_{21}x + h_{22}y + h_{23} \quad (2.2)$$

The following eight equations resulted from rearranging the equations 1.2 and 2.2. Solving these equations will provide eight homographic constants. With the coordinates of the two images known the transformation is done to change the image to the reference image and to get the front-to-parallel view of the image.

$$\begin{bmatrix} x'_1 \\ y'_1 \\ x'_2 \\ y'_2 \\ x'_3 \\ y'_3 \\ x'_4 \\ y'_4 \end{bmatrix} = \begin{bmatrix} x_1 & y_1 & 1 & 0 & 0 & 0 & -x'_1x_1 & -x'_1y_1 \\ 0 & 0 & 0 & x_1 & y_1 & 1 & -y'_1x_1 & -y'_1y_1 \\ x_2 & y_2 & 1 & 0 & 0 & 0 & -x'_2x_2 & -x'_2y_2 \\ 0 & 0 & 0 & x_2 & y_2 & 1 & -y'_2x_2 & -y'_2y_2 \\ x_3 & y_3 & 1 & 0 & 0 & 0 & -x'_3x_3 & -x'_3y_3 \\ 0 & 0 & 0 & x_3 & y_3 & 1 & -y'_3x_3 & -y'_3y_3 \\ x_4 & y_4 & 1 & 0 & 0 & 0 & -x'_4x_4 & -x'_4y_4 \\ 0 & 0 & 0 & x_4 & y_4 & 1 & -y'_4x_4 & -y'_4y_4 \end{bmatrix} \begin{bmatrix} h_{11} \\ h_{12} \\ h_{13} \\ h_{21} \\ h_{22} \\ h_{23} \\ h_{31} \\ h_{32} \end{bmatrix} \quad (3)$$

$$X' = X.H$$

$$(X-1).X' = (X-1).X.H \quad \text{thus,} \quad X-1\,X' = H \quad (4)$$

In this case, the building's façade is considered flat and without deep geometries of windows and doors. Insignificant deformation can be seen on the final rectified image especially on the area which is closer to exposure position. The observation-measurements of at least four control points (predefined and topographically measured) on the image will lead to a solution of the unknown parameters that is connecting every point of the facade onto its digital image. Photo editing software such as Adobe Photoshop can be used for projective transformation and removing perspective effect of the camera.

A group of windows which are exactly in the same rows, columns, size, shape and vertical or horizontal distances can be assumed as one layer. By observing each facade and its rectified image we can make decision on number of layers for the windows. For example in Figure 2: we have 3 layers just for the windows and one layer for the background. First of all we have to generate the dynamic pulse function with respect to the width and height of rectified façade. After generating the frame of output image file, we have to measure the geometries of components with respect to the upper left corner of the rectified picture and enter the parameters to the program. Using java graphics, we can generate the facade with a very high quality and small data size. (See figure 2. The generated facade is 25KB and the rectified facade including leaning geometries and shadow is ~ 1.45MB taken by 3.2Mega Pixel Sony Ericsson K800i Mobile Phone)

3.2 The algorithm

Parameters such as size of windows and doors and position of them with respect to upper left corner of the rectified façade, the name and path of texture files are needed for running the program. The algorithm consists of two parts; one of them is programmed in JavaScript that can be run in Internet Explorer (IE). The user enters the parameters and ActiveXObjects of Microsoft windows is used to write the XML file on the hard disk drive. The second part is using the generated XML file as input and generates the final output image file using java graphics. The texture files are extracted and cropped from pictures as perpendicular as possible from windows and doors. It can increase the quality of the 3D model. Reasonable differences can be seen in the size and quality of rectified image and the output image file produced by our method.

3.3 SketchUp Pro 8

There are many methods for measuring and analyzing the parameters of 3D building's façade e.g. by using SketchUp Pro 8. Detail elaboration of how to use the package for generating wireframe of buildings can be found in Alizadehashrafi, et al (2009). The following figures show some of the snapshots of the steps taken for generating the texture with the dynamic pulse function. The method seems able to provide an accuracy of plus-minus 2 to 3 meters of the real buildings heights.

Figure 3. Aligning the XY axes for modeling, texturing and generating the wireframe.

Alizadehashrafi et al (2009) also described the CityGML conversion from SketchUp software in detailed.

Any kind of semantic data can be added to the CityGML file with respect to requested information such as age, volume, name, appearance, etc. The textures were mapped on the corresponding "lightweight" geometry and then visualized in VRML. The 3D models in VRML format are imported to the 3DMAX application and rendered with the related textures. Finally the 3DS file format is exported from the 3DMAX and then imported to the SketchUp application. The CityGML plug ins are installed in SketchUp to export XML schema file in CityGML format.

4. CITYGML AND 3D SDI

The framework attempts to utilize the available Open Geospatial Consortium (OGC) Web services such as Web3D Service. Features that have been implemented by Basanow et al (2007) seem very appropriate with some modification to suite with the local requirements, example of the features such as CSW, WMS, WFS, WCS, WPS, OpenSL, etc.

4.1 Semantic modeling and CityServer3D

Nagel et al (2009) discusses several aspects of CityGML including the characteristics of the language. CityGML is a standardized information model which puts focus not only on the objects' geometry but also on their semantics, topology, and appearance. Key features of CityGML are:

- Objects may comprise coexisting geometric representations for different levels of detail (LOD concept).
- Topological relations between objects are realized by links between identical geometries (XLink concept).
- Variable complexity in the structuring of geometry and semantics – preferably coherent structures (spatio-semantic coherence, see Stadler and Kolbe, 2007).
- Aggregation hierarchies on the part of both geometry and semantics support complex object structures (hierarchical structuring).

The most important aspect of CityGML is the import/export tools to add/get semantic data to/from the 3D city server. The 3D city server is normally based on Oracle database and SQL queries can be used as import/export tools (illustrated in the following example - CityGML for KBS Building, Putrajaya, Malaysia). Semantic data such as owners, names, year of construction, building function types, URL, etc could be added to the database content. These data can be useful for instance, for city planners and building designers.

```
<cityObjectMember>
<Building gml:id="KBS">
<gml:name>KBS</gml:name>
<externalReference>
<informationSystem>http://www.utm.my/fksg/</inf
ormationSystem>
</externalReference>
<function>1072</function>
<yearOfConstruction>2003</yearOfConstruction>
<stringAttrib>
 name="BuildingOwner">
<value>Putrajaya Holding</value>
</stringAttrib>
<lod3MultiSurface>
<gml:MultiSurface>
<gml:surfaceMember>
```

Semantic describes an object with its attributes (Name, Date of Built, Owner, Value, etc.) and builds segments of it (wall, roof, window, door, etc). As a user, one can get the specific information out of the 3D model and this can be used in various applications. Semantic modeling is one of the advantages of CityGML.

CityGML is a common information model for the representation of 3D urban objects. It defines the classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantical and appearance properties, example, for city planning - "Show me all buildings higher than 20m".

The following figures, (i.e. 4, 5, 6) show the integration of buildings CAD data for the development of 3D city model in LoD3 and LoD4 of the area and managed within CityServer3D environment, and snapshot of LoD3 building modeled in the server respectively.

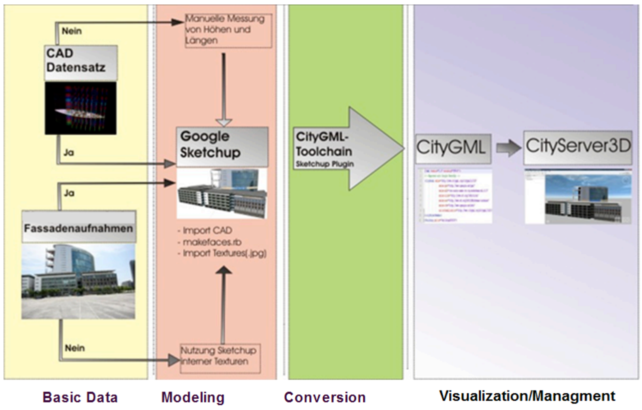

Figure 4. The data, modeling, conversion and data management workflow.

Figure 5. Some of the LoD3 buildings in Putrajaya visualized in CityServer3D

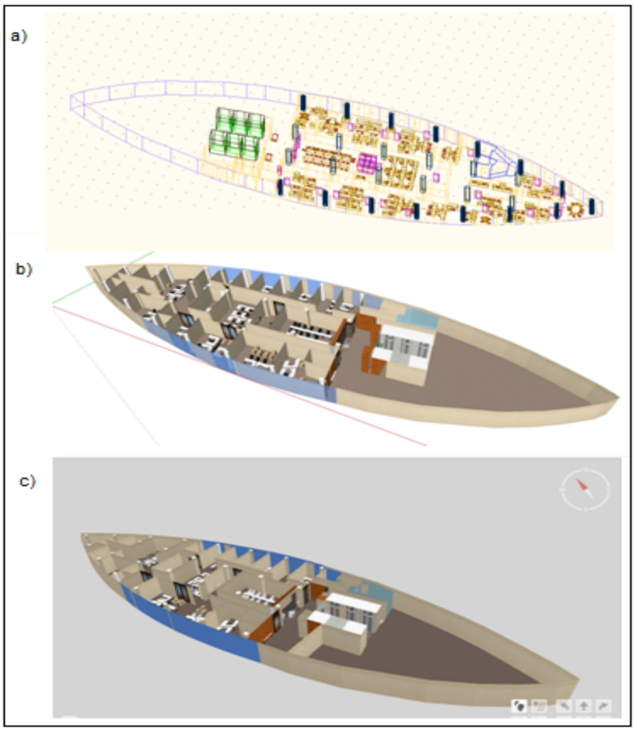

Figure 6. Modeling of the LoD4, the interior of MaCGDI's headquarters office within CityServer3D.

4.2 3D spatial data infrastructure

To achieve the integration of those spatial data, applications and services, a 3D geospatial data infrastructure has to be built in order to connect the existing information "islands". The core component of this data infrastructure is a domain specific ontology that specifies the knowledge stored in the overall city information model. CityGML (Gröger et al. 2008) is a candidate for such ontology. It was accepted as an OGC standard for the representation, storage and exchange of virtual 3D city and landscape models. CityGML is based on a rich, general purpose information model in addition to geometry and appearance information. For specific domain areas, CityGML also provides an extension mechanism to enrich the data with identifiable features under preservation of semantic interoperability. This extension mechanism is essential to make use of CityGML in various other applications such as flood simulation (Schulte and Coors, 2008) and energy management. From BIM, the industrial foundation classes (IFC) developed by the International Alliance for Interoperability (IAI 2007) is a well defined data model for data interchange of building information models. The definition of a mapping of both CityGML and IFC is a future challenge that would result into a city information model at all levels from city-wide models to high detailed building information model.
The second challenge towards a 3D geospatial data infrastructure is the definition of standard interfaces to access distributed data sources. These interfaces will enable individual access to the relevant information sources for a specific task. The OGC working group 3D Information Management (3DIM) is developing such interfaces to support a framework of data interoperability for the lifecycle of building and infrastructure investment: planning, design, construction, operation, and decommissioning. Web service specifications for visualizing 3D city and landscape models are needed. These are available as discussion papers – e.g. the Web 3D Service (W3DS), see Schilling and Kolbe (2010).

The Malaysian 3D SDI aims to provide 3D information to many users within the existing Malaysian Geospatial Data Infrastructure (MyGDI) framework. This MyGDI is basically contains various 2D spatial data and layers. Our current research project with the Malaysian Centre for Geospatial Data Infrastructure (MaCGDI) could be part of "bigger picture" of the proposed 3D SDI or the SDI roadmap that eventually to serve the community with appropriate interface especially applications like navigation, urban planning, police simulation, building management, homeland security, and others. Figure 7 illustrates the proposed 3D SDI for the Putrajaya area, Malaysia.

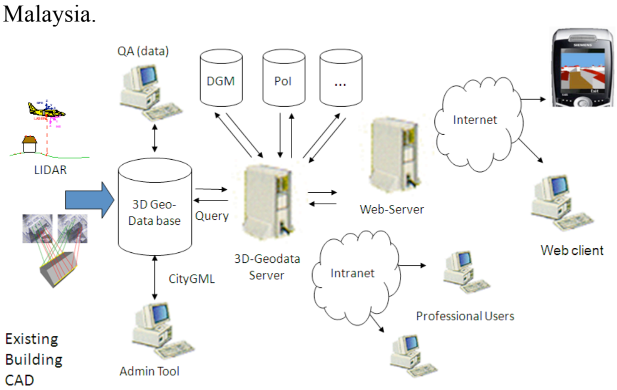

Figure 7. The conceptual view of the 3D SDI of Putrajaya city.

5. CONCLUSION AND FURTHER WORKS

In this paper we had described different techniques of generating 3D city models. Our approach of generating 3D city models is based on the available CAD data, it is one of the cheapest since no new data collection for buildings were involved. This is possible because all owners of the buildings were obliged to submit all digital data to one central agency that managed the city, i.e. the Putrajaya city council. We intend to develop a 3D SDI framework for the area based on the major 3D data that we have generated for the area - 3D city models. We also plan to develop an interface for the intended services with OGC standards as being developed by other cities. At the moment we are working with the MaCGDI, i.e. the central agency for GIS data infrastructure in Malaysia and in the process of extending the work for the nation-wide 3D SDI.

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