Jurnal Teknologi

Full paper

Representing 3D Model of Building From TLS Data Scanning in CityGML

R. Akmalia[a,*], H. Setan[a], Z. Majid[a], D. Suwardhi[b]

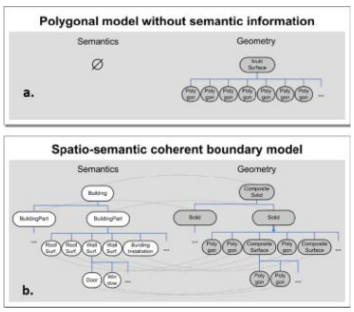
[a]*Photogrammetry and Laser Scanning Research Group, Faculty of Geoinformation and Real Estate, University of Technology Malaysia, Malaysia*
[b]*3D Model and GIS Research Group, Faculty of Earth Science and Technology, Bandung Institute of Technology, Indonesia*

[*]Corresponding author: *rizka.akmalia01@gmail.com*

Article history

Received :6 February 2014
Received in revised form :
24 July 2014
Accepted :9 October 2014

Graphical abstract



Abstract

Nowadays, 3D city models are used by the increasing number of applications. Most applications require not only geometric information but also semantic information. As a standard and tool for 3D city model, CityGML, provides a method for storing and managing both geometric and semantic information. Moreover, it also provides the multi-scale representation of 3D building model for efficient visualization. In CityGML, building models are represented in five LODs (Level of Detail), start from LOD0, LOD1, LOD2, LOD3, and LOD4. Each level has different accuracy and detail requirement for visualization. Usually, for obtaining multi-LOD of 3D building model, several data sources are integrated. For example, LiDAR data is used for generating LOD0, LOD1, and LOD2 as close-range photogrammetry data is used for generating more detailed model in LOD3 and LOD4. However, using additional data sources is increasing cost and time consuming. Since the development of TLS (Terrestrial Laser Scanner), data collection for detailed model can be conducted in a relative short time compared to photogrammetry. Point cloud generated from TLS can be used for generating the multi-LOD of building model. This paper gives an overview about the representation of 3D building model in CityGML and also method for generating multi-LOD of building from TLS data. An experiment was conducted using TLS. Following the standard in CityGML, point clouds from TLS were processed resulting 3D model of building in different level of details. Afterward, models in different LOD were converted into XML schema to be used in CityGML. From the experiment, final result shows that TLS can be used for generating 3D models of building in LOD1, LOD2, and LOD3.

Keywords: TLS, 3D Model, Building modelling, CityGML, point cloud

Abstrak

Baru-baru ini, model tiga dimensi (3D) bandar digunakan secara meluas. Banyak aplikasi memerlukan bukan hanya maklumat bentuk, tetapi juga maklumat semantik. Sebagai standar dan alat untuk model 3D Bandar, CityGML, menyediakan cara untuk menyimpan dan mengatur baik maklumat bentuk dan juga semantik. Terlebih lagi, ini juga menyediakan tampilan dalam lima tingkatan perincian (Level of Detail), mulai dari LOD0, LOD1, LOD2, LOD3, dan LOD4. Setiap tingkatan mempunyai ketelitian dan perincian yang berbeza untuk ditampilkan. Selalunya, untuk mendapatkan 3D model bangunan dalam pelbagai perincian, digunakan beberapa sumber data untuk digabungkan. Sebagai contoh, LiDAR data digunakan untuk menjana LOD0, LOD1, dan LOD2 dan data fotogrametri jarak dekat yang digunakan untuk menjana model yang lebih terperinci dalam LOD3 dan LOD4 . Walau bagaimanapun, menggunakan sumber-sumber data tambahan meningkatkan kos dan memakan masa. Sejak TLS dikembangkan, pengumpulan data untuk model terperinci boleh dijalankan dalam masa yang relatif singkat berbanding fotogrametri. Titik awan dijana daripada TLS boleh digunakan untuk menjana pelbagai LOD model bangunan. Hasilnya ialah model bangunan 3D dalam tampilan CityGML dan juga kaedah untuk menjana pelbagai LOD bangunan daripada data TLS. Satu eksperimen telah dijalankan dengan menggunakan TLS. Mengikuti standard dalam CityGML, titik awan daripada TLS diproses menghasilkan model 3D bangunan untuk perincian berbeza. Selepas itu, model yang berbeza LOD telah ditukar kepada skema XML untuk digunakan dalam CityGML. Daripada eksperimen ini, kesimpulan akhir menunjukkan bahawa TLS boleh digunakan untuk menjana model 3D bangunan di LOD1, LOD2, dan LOD3.

Kata kunci: TLS, 3D model, model bangunan, CityGML, titik awan

1.0 INTRODUCTION

The increasing growth in urbanization has turned into a phenomenon and has led technology to improve the tool for managing the urban area. In order to fulfil the need of 3D model, OGC created CityGML as a standard to facilitate the various user of 3D city model. With different application, every user has their preferences of the 3D model representation.

Application such as urban planning and management, facility location, disaster management, or car-navigation systems, use a coarse 3D city model it as an essential tool to facilitate further analysis related to urban or environmental issues. Meanwhile, a detail representation of 3D city model is also needed for some applications such as architecture, design interior, or facility management. Thus, method and media to represent the data integration of all 3D data model are required.

On the other hand, the measurement tools that has the ability to generate the 3D model of building with fast and accurate is also needed. The development of LiDAR created Terrestrial Laser Scanner (TLS) as a new measurement tools that can generate 3D point cloud directly during the data scanning. Thus, a relatively fast and accurate data acquisition for 3D modeling of a city can be conducted.

However, TLS data processing is still become an issue. Point cloud generated by TLS still need to be processed to be represented in CityGML. Thus, this research is conducted to develop the methodology in the process of representing TLS data in CityGML. Outputs are building model from LOD1-LOD3 since the demand for these LODs are compulsory.

■2.0 LITERATURE REVIEW

2.1 Application of TLS for 3D city modelling

As the TLS was made with the basic concept of LiDAR, the measurement system is also similar with airborne LiDAR. The difference between TLS and airborne LiDAR is the procedure in the field [1]. There are two types of surveying method using TLS, mobile and static TLS. However, for most mapping application, static TLS has been used rapidly. While mobile TLS is mounted on the vehicle, static TLS is mounted on a tripod. It scans the object from one point as shown in Figure 1.

Figure 1 Static Terrestrial Laser Scanner

Scanning process using TLS generates point cloud representing the object in 3D coordinates. Previous works using TLS for generating 3D model of building to be used in CityGML can be found in [2], [3], and [4]. With average point spacing of 0.02 m, point cloud can be a good representation of a building model due to the high scanning resolution [2].

In order to be represented using CityGML, point clouds resulted from TLS are required to be processed to generate a solid or surface model. Process to generate 3D model from point cloud can be found in [5] and [6].

2.2 CityGML data structure and format

CityGML is a standard to store and manage 3D urban spatial data infrastructure. In CityGML, sharing and exchanging 3D data can be done effectively. It represents semantic, geometric, topology, and also appearance for virtual 3D city model [7]. Figure 2 shows the difference of CityGML concept that representing model using spatio-semantic with CAD concept that only represent the geometry of model.

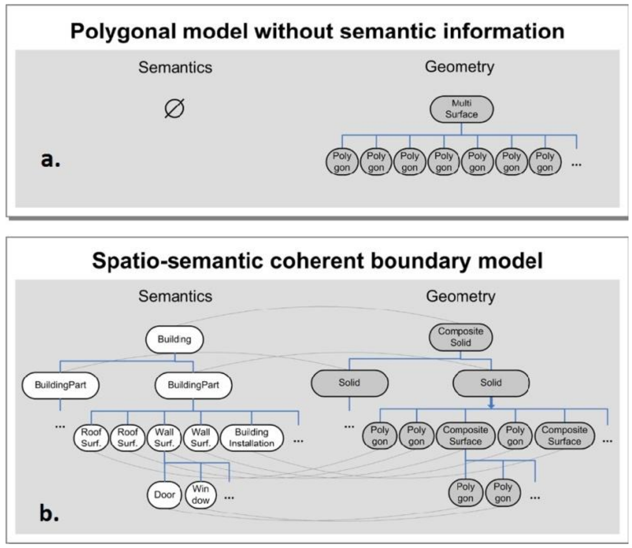


Figure 2 Model representation (a) without semantic (b) with spatio-semantic **[8]**

CityGML information are stored and exchanged by GML schema and stored as a XML file. Further reading about CityGML schema and data structure can be found in [9], [10], and [7].

CityGML consists of core module and thematic extension module for every application. CityGML core module defines the basic concept and components of the CityGML data model. It is a universal concept for all extensions modules. As it is a dependency for any extension modules, XML schema file of the core module is imported by each XML schema file defining any one of thirteen provided thematic extension modules.

Building is the example of thematic extension modules. In CityGML, building model can be represented in five level-of-details (LOD), start from LOD0 to LOD4. Every LOD has different scale of detail and also accuracy. However, the LOD0 is only for building footprint. Lower LOD represents lower detail of model that can be useful for some applications need coarse model for a large area such as landscape planning. The highest LOD is LOD 4 visualizing the interior of building. Features that can be represented in each LOD are already defined in Figure 3 [11] shows the different representation of building in every LOD.

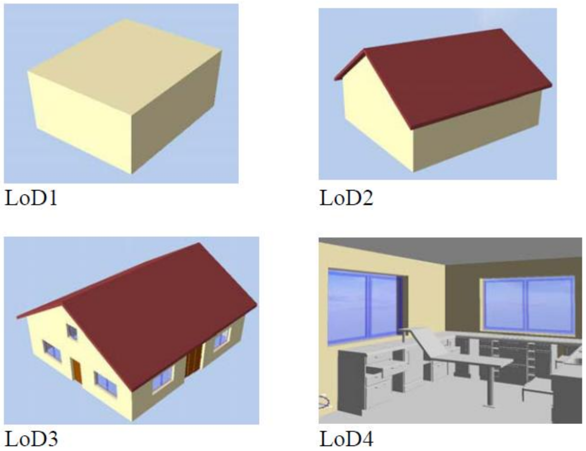


Figure 3 Four Different LODs [11]

■3.0 METHODOLOGY

Process to visualize the TLS data in CityGML is proposed in methodology as described in Figure 4.

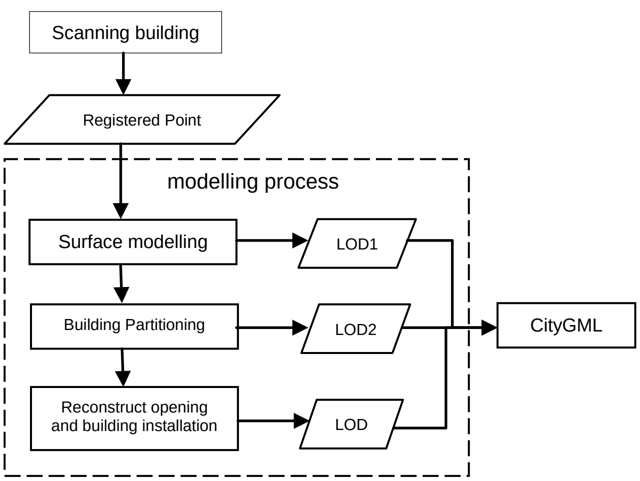


Figure 4 Methodology

TLS generates point clouds directly in 3D coordinate. For building, scanning process can be conducted from several stations in order to cover all building surfaces. Registration process is required to combine all point clouds from several scan stations into one coordinate system. Result from this process is a registered point cloud.

Modelling process is divided into three steps. First step is to generate block model for LOD1. Point cloud should be imported to modelling software first. Second step is to generate roof and wall as main parts of building following the requirement for LOD2. Lastly, for generating LOD3, building installations including all openings such as windows and doors are needed to be reconstructed. Afterward, all models should be converted to XML files in order to be represented in CityGML.

Models represented in CityGML are from surface and solid models created in modelling process. Since CityGML can manage geometry and also semantic information, attributes for surface models are required to be added during modelling process. Some layers should be created to recognize building features. For example, in LOD3, building features such as stairs, windows, and doors should be managed in different layers. Thus, when models are converted to XML files, information saved in layers can be recognized as semantic information.

■4.0 IMPLEMENTATION

The implementation of proposed methodology was conducted using Leica C10 TLS. The object was a residential house inside UTM Skudai Campus as shown in Figure 5.

Figure 5 Residential Building inside UTM Skudai Campus

4.1 Scanning Process

The whole building was scanned from 5 scan stations. After registration process, data cleaning and filtering point cloud were also done in order to reduce noise during scanning. All point cloud processing were done using Cyclone 7.3, commercial software from Leica. Afterward, the point cloud was exported to SketchUp for modelling process. Figure 6 shows the result from point cloud.

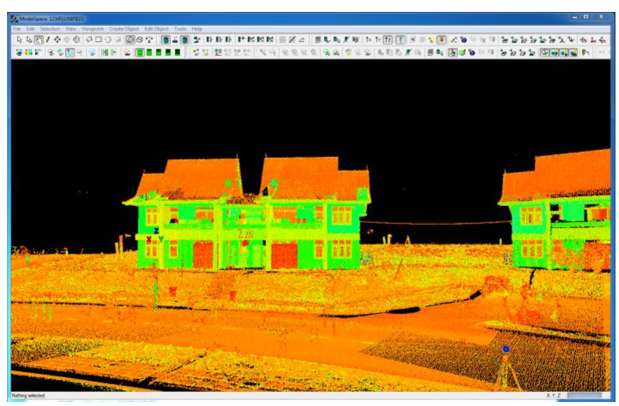


Figure 6 Point cloud of building

4.2 3D Modelling Process

Modelling process was started with creating LOD1 in SketchUp. Figure 7 shows the point cloud overlapped with the block model in LOD1. Following the requirement, height of the block model was the lowest point of the roof and width of the block model was the footprint of building.

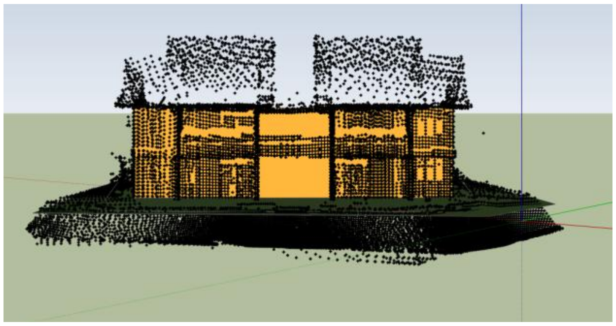


Figure 7 Modelling LOD1

To generate LOD2, model from LOD1 was developed. The main function of LOD2 is to differentiate the building structures such as walls and roofs. Figure 8 shows the model in LOD2.

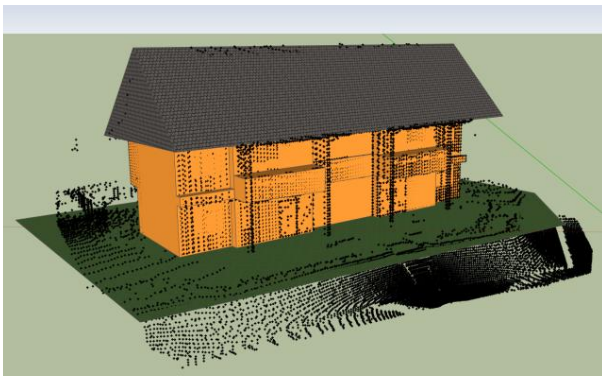


Figure 8 Modelling LOD2

In order to generate LOD3, the roof in LOD2 was developed to reconstruct the real structure. Wall surface was developed to generate the detail structure and building features such as balconies and also openings such as windows and doors.
Figure shows the model in LOD3.

Figure 9 Modelling LOD3

4.3 Visualizing in CityGML

Surface models were converted into GML files using CityGML plug-in in SketchUp software. To follow the CityGML file structure, in the modelling step, some layers were created as the attribute to give semantic information. Figure 10 shows the source code of XML file for representing LOD1. Since only block model represented in LOD1, coordinates of building model were saved below the *MultiSurface* section without any building parts were created and included.

```
<core:cityObjectMember>
 - <bldg:Building gml:id="_lod1_BD.1">
   - <bldg:lod1MultiSurface>
     - <gml:MultiSurface>
       - <gml:surfaceMember>
         - <gml:Polygon gml:id="_lod1_BD.1_PG.1">
           - <gml:exterior>
             - <gml:LinearRing gml:id="_lod1_BD.1_PG.1_LR.1">
                 <gml:posList srsDimension="3"> -9.0019879509834
                   9.00198795098341 7.99444531653823 5.9683
                   5.32070415421027 5.968307 -24.9602477734
                   9.00198795098341 7.99444531653823 0.0812
                   0.081253 </gml:posList>
               </gml:LinearRing>
             </gml:exterior>
           </gml:Polygon>
         </gml:surfaceMember>
```

Figure 10 Source code for LOD1

For LOD2, two layers were made to differentiate roof and wall. Figure 11 shows the source code for LOD2. *WallSurface* and *RoofSurface* were created below the *BuildingPart* section.

```
        - <bldg:WallSurface gml:id="_lod2_BD.1_WallSurface_49">
            + <bldg:lod2MultiSurface>
          </bldg:WallSurface>
        </bldg:boundedBy>
      - <bldg:boundedBy>
        - <bldg:RoofSurface gml:id="_lod2_BD.1_RoofSurface_1">
            + <bldg:lod2MultiSurface>
          </bldg:RoofSurface>
        </bldg:boundedBy>
      + <bldg:boundedBy>
      + <bldg:boundedBy>
      + <bldg:boundedBy>
      + <bldg:boundedBy>
    </bldg:Building>
  </core:cityObjectMember>
- <app:appearanceMember>
  - <app:Appearance>
    - <app:surfaceDataMember>
      - <app:ParameterizedTexture>
```

Figure 11 Source code for LOD2

Meanwhile, in LOD3, all building features were made. Openings were created below the WallSurface section. Attributes for building features, such as materials, were also included in LOD3. Figure 12 shows the source code for LOD3.

```
<app:appearanceMember>
 - <app:Appearance>
   - <app:surfaceDataMember>
     - <app:ParameterizedTexture>
         <app:imageURI>/textures/Metal_Aluminum_Anodized.jp
         <app:wrapMode>wrap</app:wrapMode>
       + <app:target uri="#_lod3_BD.10_PG.1">
       + <app:target uri="#_lod3_BD.11_PG.1">
       </app:ParameterizedTexture>
     </app:surfaceDataMember>
   - <app:surfaceDataMember>
     - <app:ParameterizedTexture>
         <app:imageURI>/textures/Translucent_Glass_Corrugate
         <app:wrapMode>wrap</app:wrapMode>
```

Figure 12 Source code for LOD3

As the result, XML files of LOD1, LOD2, and also LOD3 were opened in LandXplorer, an open source software to open

CityGML files. Figure 13 shows the LOD 1, LOD2, and LOD3 visualized in LandXplorer.

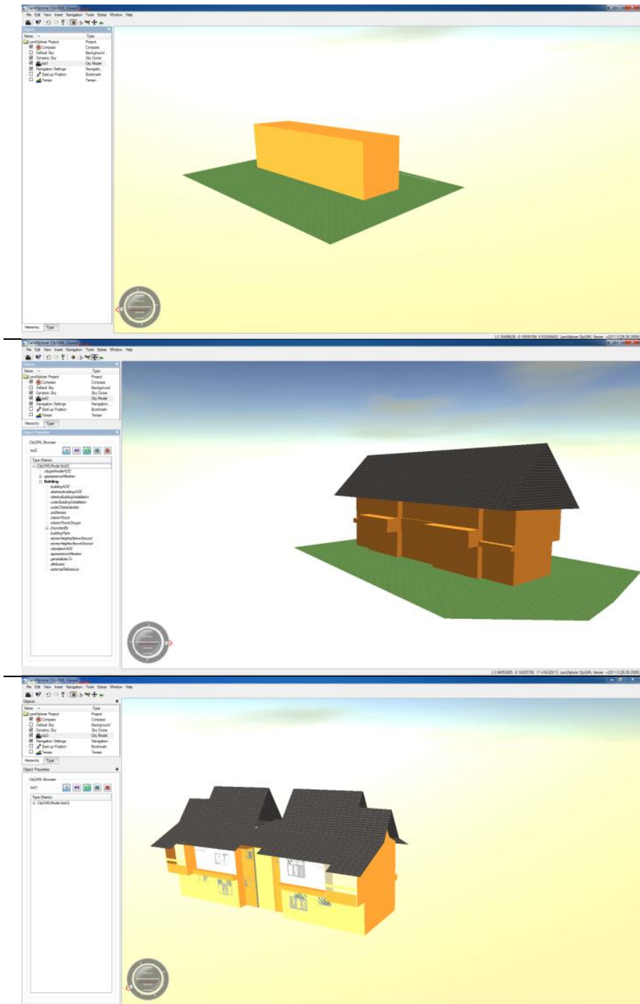


Figure 13 Representation of CityGML files using LandXplorer

5.0 ANALYSIS AND DISCUSSION

Result from TLS scanning is point clouds. In order to visualize the data in CityGML, beside point cloud processing, modelling process is also required to generate surface or solid model. However, the process for modelling from point cloud still cannot be done automatically. In this case, manual method to generate surface model was done.

Open source software such as SketchUp and LandXplorer are helpful to do the process. Plug-ins for SketchUp can be used to import point cloud and also export the surface model into XML files. Although, the process was not fully automatic since the attribute of the building parts were still input manually by creating layers for each building parts in the modelling process. For further study, the fully automatic modelling from point cloud should be done due to effectiveness in processing for large data sets of point clouds.

6.0 CONCLUSION

CityGML, as the standard of 3D city modelling, is already managed for building visualization in different LODs. The most detail models are represented in LOD4 since interior of buildings are also included. However, for building facade, details represented in LOD3 and LOD4 are the same.

As a measurement tools, TLS can represents 3D objects in details. It is a reliable measurement tools to be used for data acquisition of 3D city modelling. One set data scanning of building facade can be used to generate LOD1, LOD2, and LOD3 for CityGML. Thus, no additional tool is required to generate multi-LOD of building for CityGML. In order to visualize the TLS data, there are steps to be conducted start from point cloud processing, 3D modelling, and also converting 3D modelling to GML files.

Acknowledgements

The authors would like to express their sincere appreciation to Universiti Teknologi Malaysia and the Ministry of Higher Education (MoHE) of Malaysia for the FRGS grant (04H92) given to this research project.

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