THE GENERALIZATION OF BIM/IFC MODEL FOR MULTI-SCALE 3D GIS/CITYGML MODELS

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KEY WORDS: BIM, GIS, LOD.

ABSTRACT:

The development of BIM (Building Information Modeling) is important trend in different disciplines. It is not only a 3-D model for visualization. It can also exchange building models' geometry and attribute information smoothly. In order to respond to the BIM's concepts of sharing information and sustainable development, studies about integrating BIM with GIS field and follow-up applications are increasing. The integration of BIM and GIS is not only increase the data interoperability, but also save lots of time for data collection and financial resources. Hence, the conversion of BIM/IFC and GIS is an important study for the integration of these two fields. In this study, we generate different CityGML LOD models from BIM/IFC model, which includes the relationship between the coordinate systems, fields, geometries, and attributes. As the BIM model is a detailed model, we can simplify the BIM model into different LODs in CityGML. First, we use 3-D similarity transformation to convert user-defined coordinate system into world coordinate system in BIM. Then, the fields of IFC and CityGML are used to convert geometry and semantic information. For geometry property, we convert and simplify a BIM model to four different LODs in CityGML. For attribute property, we extract the information in IFC entities and link to the 3-D object in CityGML This study will convert the geometry and attribute properties from IFC model into four types of CityGML LOD models and import BIM into GIS for building development, management, and applications.

1. INTRODUCTION

1.1 Motivation and Purpose

Building Information Modeling (BIM) is an important trend in different disciplines. It has high degree of details, 3D visualization, parametric modeling and riches in semantic information, and also connect with existing spatial data and three-dimension models to supply multiple spatial information services. On the other hand, Geographic Information Systems (GIS) is the database to manage spatial information, can also supply relatively operative functions to deal with it.

Although BIM and GIS are from different fields, both of their main features are creating digital expression of real world (Zhang et al, 2009). From the perspective of buildings, BIM emphasizes the microscopic spatial information like buildings and internal structures, however, GIS highlights the macroscopic spatial information (Chou et al, 2010). In the coordinate system, BIM is the relative Cartesian coordinate system while GIS has concepts of

definition of geographic coordinates and map projection. For the model properties, BIM shall express objects completely, but GIS tends to abstract them and record by themes. Both of them emphasize the semantic information, but the biggest problem is the geometric conversion and unification of semantics (Isikdag et al., 2008).

Recently, researches about integrating two fields are increasing. It may improve the data interoperability and save times, human and financial resources. Hence, by converting two open data standards (Industry Foundation Classes (IFC) for BIM, City Geography Markup Language (CityGML) for GIS), can provide a good entrance for integrating them.

In this study, first, we generate CityGML LOD 4 (Levels of detail) model from BIM/IFC model, which includes the relationship between the coordinate systems, fields, geometries, and attributes. After conversion, we use LOD 4 model to create other LOD models (LOD 3~LOD 1). By converting two semantic models, BIM can be lead into GIS and make the foundation for subsequent applications.

1.2 Literature Review

In this study, conversion steps can be sequentially divides into coordinates, geometric, attribute and LOD conversion. However, before making the actual operation, we should first understand the definitions and structures of IFC and CityGML. Benner et al. (2005) proposed a new conceptual framework, named Quartierdaten-Managementsystem (QUASY), which can be convert into IFC models. In the research, they not only introduced the concept and structure of QUASY but also discussed the framework and entity definitions of IFC in order to ensure the object entities conversion is correct. In their result, IFC models can successfully convert into QUASY and use to display and analysis, unfortunately, this framework lack of follow-up development. On the other hand, Kolbe (2009) also introduced the concept about CityGML completely, which included system structures, modeling aspects, multi-scale representation, semantics, geometries, topologies, extensibilities and applications.

For the model conversion, Wu and Hsieh (2007) proposed the conversion of coordinates and geometric relationship between IFC and GML. In the first step of geometric conversion, we need to extract the building geometric data from IFC objects, then, calculated coordinates of objects' node points. Last, generated GML objects based on Boundary Representation (B-Rep). Both of Isikdag and Zlatanova (2009) and Chen (2010) proposed the concept about IFC models convert into CityGML multi-scale models. The former tended to describe the theory including the definition of the building objects in multi-scale and the simple relationship of conversion. The latter tended to discuss the operation such as the conversion process, correspondence between the fields etc. Cheng et al (2013) proposed the simplification of CityGML models to other LOD models. Compared to use IFC models convert to four LOD models separately, this idea could save times and change models flexibly. About this concept, we could use in our studies.

2. METHODOLOGY

2.1 Overview

As shown in Figure 1, the main processes of our study contains seven parts. (1) Building BIM/IFC model by using

commercial software based on figures. (2) Transforming local coordinate system to world coordinate system by using terrain model. (3) Analyzing the field relationships between IFC and CityGML. (4) Calculating node points' coordinates by using commercial software, then, storing them in CityGML to complete geometric conversion. (5) Extracting the attribute information in IFC classes and storing them in CityGML to complete attribute conversion. (6) Integrating the geometric and attribute information to generate CityGML LOD 4 model. (7) Sequentially generating LOD models from LOD 3 to LOD 1 by simplifying LOD 4 model. About the methods of part 4 to part 7, the following sections provide the detailed descriptions.

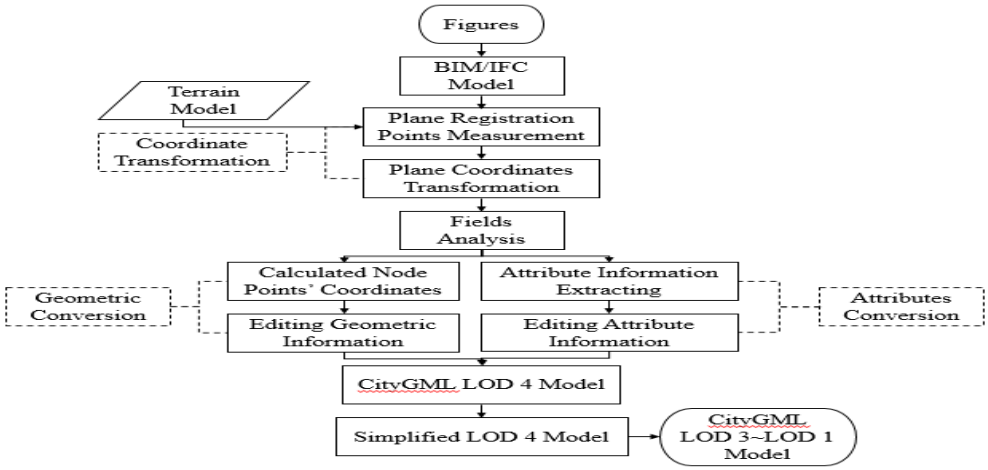


Figure 1. The flow chart of the study

2.2 Geometry & Attribute Conversion

In IFC models, objects generally presented by Swept Solid, on the other hand, the CityGML are mainly based on B-Rep. So, if we want to do the geometric conversion, we need to convert Swept Solid into B-Rep. In this study, we divides geometric conversion into calculating node points' coordinates and editing geometric information. In the first part, we use a commercial software, i.e. Safe Software's Feature Manipulation Engine (FME), to convert IFC into feature class, then, calculate node points' coordinates. The converted objects include IfcBeam, IfcColumn, IfcDoor, IfcRood, IfcSlab, IfcWallStandardCase, and IfcWindow. After the conversion, we record the coordinates in CityGML by checking on field relationships and based on B-Rep. Finally, we can complete the geometric conversion.

In the attribute conversion, the method is by extracting the attribute information in IFC classes, and then, saving in dBASE table files (.dbf). In Chen (2010), the attribute information are stored in IfcAnnotation entity for IFC and in <StringAttibute> for CityGML. Therefore, when doing the attribute conversion, we can also check on field relationships.

2.3 LOD Simplification

In the last process, we generate LOD models from LOD 3 to LOD 1 by simplifying the LOD 4 model. According to standards of LODs, each LOD models have different definitions and contain different building objects. In the LOD 1 model, usually called block models, the geometry is represented as a prismatic object with a flat top (Isikdag and

Zlatanova, 2009). The building extensions and curvature objects such as wall and roof slab should be eliminated. In the LOD 2 model, outer walls can be represented in greater detail and with multiple faces and curve geometries. The roof and building extensions such as balconies can also be represented. In the LOD 3 model, the appearances of the building can include openings such as doors and windows. Last, the LOD 4 model provides the option to represent the interior structure of the building (Isikdag and Zlatanova, 2009).

As shown in Figure 2, the processes of simplifying is eliminated objects which not include in LOD models.

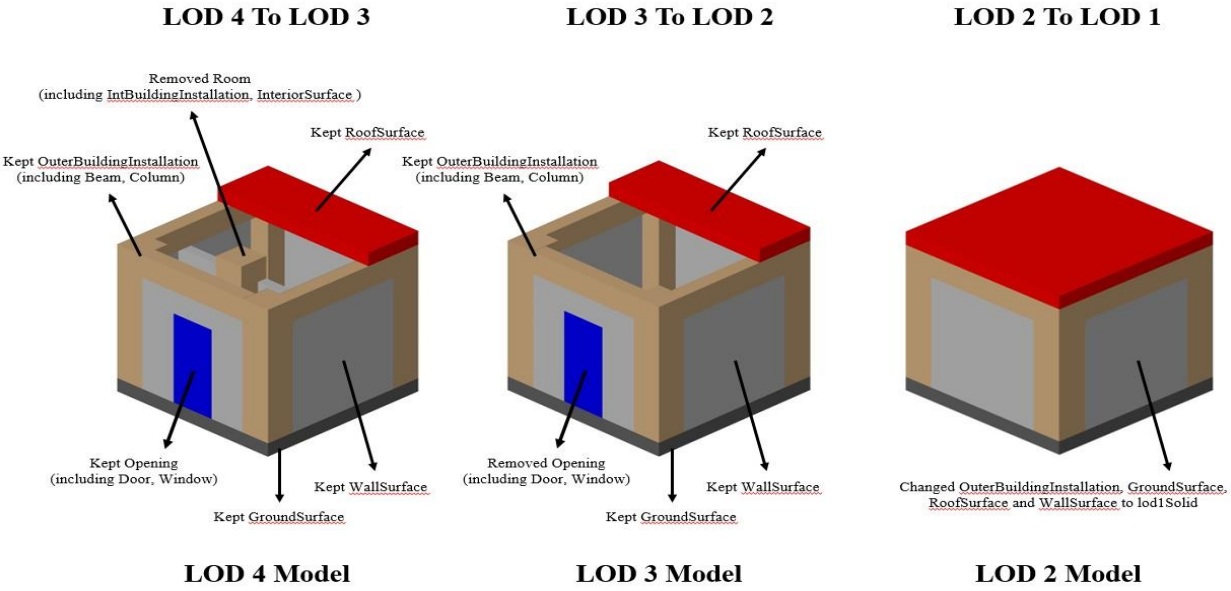


Figure 2. Detail of LODs simplifying

3. RESULTS AND DISCUSSION

3.1 Experimental Data

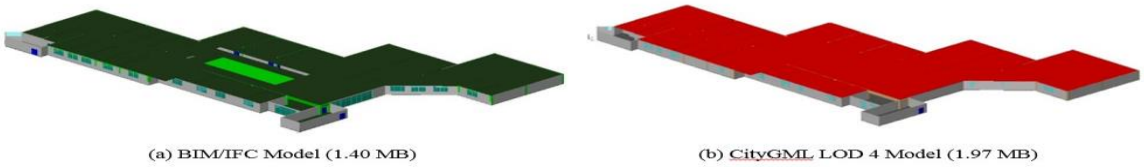
In our study, the BIM/IFC model is the first floor of NCTU Second Engineering Building, and the experimental data includes the architectural figures of the building and the terrain model, which are used to rebuild the BIM/IFC model and measure the registration points in the coordinate transformation, respectively.

3.2 Experimental Results

In our research, the results can divide to two parts. First will demonstration the CityGML LOD 4 model which is converting from BIM/IFC model. In the second part, we display the results of simplifying between different LODs in CityGML.

3.2.1 Result of transforming BIM/IFC model into CityGML LOD 4 model: The framework of conversion is based on proposed method. The results are shown in Figure 3. The Figure 3(a) is the BIM/IFC model which was rebuilt by Revit 2014, and the figure 3(b) is the CityGML LOD 4 model which had been converted. According to the results, we can see that our method can successfully convert

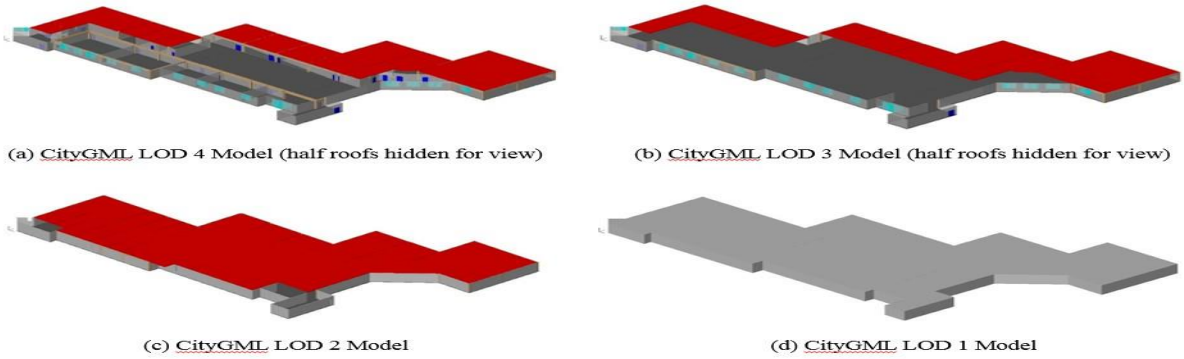
BIM/IFC model into CityGML model. However, there still have some problems such as it is hard to display the detail appearances of doors and windows. Moreover, the file size of CityGML model is much larger than BIM/IFC model. This is because the CityGML model is used B-Rep to generate objects



(a) BIM/IFC Model (1.40 MB) (b) CityGML LOD 4 Model (1.97 MB)

Figure 3. Results of BIM/IFC Model and CityGML Model

3.2.2 Results of simplifying between different LODs in CityGML models: The second demonstration is the results of simplifying between different LODs in CityGML. The results are shown in Figure 4. The Figures 4(a) to (d) are represented the models from LOD 3 to LOD 1, respectively. These models are simplified from previous LOD 4 model. As the results, we can also successfully generate different LODs models by using our methods. On the other hand, the file size of different LODs models and the relative statistics are shown in Table 1. In Table 1, we can see that the file size decreased with the simplifying works Especially in LOD 1 model, it can reduce nearly 98.6% data volumes from LOD 4 model.



(a) CityGML LOD 4 Model (half roofs hidden for view) (b) CityGML LOD 3 Model (half roofs hidden for view)

(c) CityGML LOD 2 Model (d) CityGML LOD 1 Model

Figure 4. Results of Simplifying Between Different LODs in CityGML

Table 1. The Statistics of Different LODs Models' File Sizes

Levels of Detail	LOD 4	LOD 3	LOD 2	LOD 1
File Size	1.97 MB	1.17 MB	1.06 MB	27.4 KB
Percentage of Reducing (%)	Based on LOD 4	40.61%	46.19%	98.64%

4. CONCLUSION

In this study, we generated CityGML LOD 4 model from BIM/IFC model, which includes the relationship between the coordinate systems, fields, geometries, and attributes. After conversion, we also simplified the LOD 4 model to generate different LODs models. In the results, we can see that the proposed methods successfully converted BIM/IFC model into CityGML model and simplified it into different LODs models. In the conversion part,

although CityGML model displays almost as same as BIM/IFC model, the representation of detail appearances in door and windows are the serious problem. It is because both appearances have lots of node points and we don't have the fully automatic conversion program to deal with them. Therefore it is hard to convert them now. In the simplifying part, we can generate different LODs models. However, the problem is the same as the former part, if we can simplify models fully automatics, it will be more efficient. The future works about our study is to finish the fully automatic program, with the completion of this program, we can do both conversion and simplifying more efficient.

ACKNOWLEDGEMENTS

This research was partially supported by the Ministry of Interior of Taiwan under the project number SYC1030127. The authors also like to thank the Taiwan Railways Administration for providing the test data sets.

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