LOD 1 - 3D CityModel for Implementing SmartCity Concept

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ABSTRACT
Smartcity refers to uses of information communication and internet of things technology for managing and monitoring urban dynamics and assets through interactive and visual platform in support of sustainable city developments. Maps and spatial information are commonly used as an interface of various smart city platforms to capture, model, and spatially represent the assets and dynamics of the city. Integration of 3D models and relevant urban data for enabling spatial query will be the focus of this paper. This paper investigates the applicability of 3DCityDB as a data store for integrating cadaster, utilities, infrastructures, and 3D buildings for providing urban land monitoring of urban tourist areas. 3D building models are generated from OpenStreetMap and aerial photographs are represented as CityGML. RDF and Linked data are used to integrate the collections of 2D/3D geometry and attributes from government and cloud sources into a structured and meaningful data model that can be linked with external information from internet. The results are demonstrated through the execution of spatial queries to 3DCityDB used as a data store.

CCS Concepts
• Human-centered Computing → Human-Computer Interaction (HCI) → Interaction Paradigm → Web-based interaction •Applied Computing → Service-Oriented Architecture

Keyword
CityGML, 3DCityDB, SmartCity, Cloud

1. INTRODUCTION
SmartCity refers to uses of information communication and internet of things technology for managing and monitoring urban dynamics and assets through interactive and visual platform in support of sustainable city developments. Recently, the concept of smart cities emerged in the international context [1], [2], with the term "smart" refers to cities able to solve urban issues including mobility and environment. Data management is essential in implementing smart city concept and applications. A good data model for smart cities must encompass a set of comprehensive set of data from multiple domains, such as land and 3D building models, public transportation, urban infrastructure and environments.

Maps and spatial information are commonly used as an interface of various smart city platforms to capture, model, and spatially represent the assets and dynamics of the city. One of urban assets that are vital for visualization are buildings and infrastructures in the city. For many applications and purposes, 3D Models of buildings in the city have been primarily used for visualization and analysis tasks [3]. These 3D models would be more meaningful for smart city applications when it can be combined with related relational data regarding urban environments such as attributes on heat, energy, planning zones, routes, and transportation. Integration of 3D geospatial models and participatory sensing through mobile phones in smart city applications becomes essential to maximize the potential of integration of crowd and government data.

First of all, 3D models need to be represented using a standard 3D data model. CityGML emerges as influential 3D data model standards amidst others (e.g. IFC). CityGML has widely been recognized for its capabilities to accommodate needs to store and represent of geometry, topology, and semantics properties of 3D geospatial features [4][5], [6]. Simple to advanced Level of Detail (from LOD 1 to LOD 4) can also be implemented using CityGML [6]–[11], although expensive computation cost would be required for higher LODs [4].

Creating geometry and semantic consistency in CityGML modelling have been well known challenges to be solved [12]–[14][15]. In order to be used for further urban data integration and query, geometry and semantics of CityGML need to be stored and linked with relevant urban data. For this purpose, geometry and semantics of CityGML can be stored into 3DCityDB [16] as relational database [17].

This paper investigates a probable development of 3D city models as a base for best affordable city management in order to support smartcity concept especially Smart Mobility and Smart Planning, where the 3D models are generated from OpenStreetMap and Aerial photo and integrated with cadaster and web urban data. One challenging task to achieve is how to store and visualize 3D models in the context of property management and spatial planning. In this paper, the focus will be given to the use of OSM data as data source for developing LOD 1 of CityGML. Considering the availability and rapid growth of OSM urban data, the solution will match to the needs for development of rapid tools to support minimum requirements for 3D visualization and analysis in order to support smart city applications [18].

2. LITERATURE REVIEW
2.1. CityGML Format
CityGML is a OpenGeospatialConsortium (OGC) standardized format for virtual 3D city model storage and exchange. It extends the GML version 3 standards, and is able to represents 3D city

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objects such as buildings, road networks, bridges, vegetations, etc [19]. CityGML had been implemented to provide visualization of simple to complex 3D virtual city such as in [20]. CityGML focuses on establishing standardized, sematic 3D data and thus differs from other 3D format which focuses on visualization. CityGML is a modular standard which consists of several thematic modules to represents 3D elements in virtual city. These so called top-level features define the capabilities of CityGML to store multiple objects3D features.

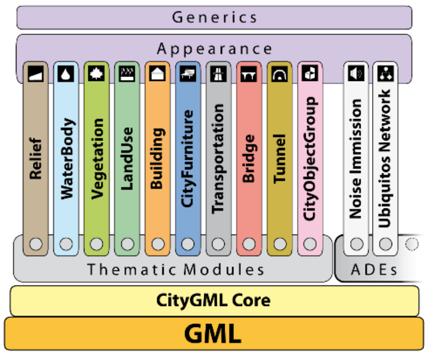

Figure 1: The CityGML Thematic Modules (from virtualcitysystems.de)

The Level of Detail (LoD), as the name suggests, is used to define different levels of information on the details of 3D city features. The LoD consist of five levels, with the higher level represents more detail on the 3D object being modeled (Figure 2). In short, LoD 0 represents the building footprint, LoD 1 shows the primitive block, LoD 2 represents roof and surfaces, LoD3 represents building surfaces in detail while LoD 4 represents a building with its interiors [8].

Figure 2: Different LoDs (from http://en.wiki.quality.sig3d.org/)

CityGML level of details are generated through different method of data acquisition as input. CityGML LoD 1 models are generated from extrusion of building footprints, whether by estimating the height through the building's stories or generating height from attributes obtained through volunteered geoinformation [6]. Futhermore, 2.5D models are also obtained to provides CityGML up to LoD 4. Such data are obtained, for example, from OpenStreetMap (OSM) data [22], [23]. Higher level of LoDs could also be obtained through direct 3D modeling or conversion from other 3D format (e.g. Trimble Sketchup) [24], [25]. Other sources such as point-cloud data are also employed to generate 3D models in CityGML format [26], [27]. Subsequently, various format could be combined to produce more accurate and higher level of LoDs [28]. Table 1 shows different method for generating CityGML data and their corresponding LoDs.

Table 1: Different Methods to generate LoDs

Method of Generation	Resulting CityGML LoDs	Example Researches
2D (footprint) extrusion	LoD1	[6]
2.5D attributes	LoD2-4	[22], [23]
3D modeling	LoD 4	[24], [25]
Point clouds (Terrestrial/Aerial)	LoD 3	[26], [27]
Combination of multiple methods	LoD 3	[28]

This research utilizes OSM data to provide 2.5D data of buildings in and around the study area. OpenStreetMap data is considered to be quite robust and is easy to define and edit [22] compared to other types of data acquisition. Also, converting OSM 3D data to CityGML is relatively easy as shown in previous research [29], 3D models generated from OSM data are also surprisingly detailed. Shown in [30], the crowdsourced data form OSM could also be used to develop LoD 4 of a building data. These factors, combined with the ease of obtaining OSM data, makes the OSM data as a strong candidate for generating CityGML data in SmartCity.

2.2. 3DCityDB

3DcityDB is a set of database schema and tools for storage, conversion and visualization of CityGML data [16]. 3DCityDB provides CityGML with the ability for database query and visualization, which is lacking in its native CityGML format. This free and open source software could be used for storing CityGML data into a spatial database. Currently, 3DCityDB supports storing and exporting 3D CityGML data in to Oracle and PostgreSQL (with PostGIS extension).

The 3DCityDB database schema extends Oracle and PostgreSQL with the ability to store semantic 3D models in accordance to CityGML Standards. Top-level features in CityGML are stored as tables in the database, which then could be exported into other 3D format for visualization [31].

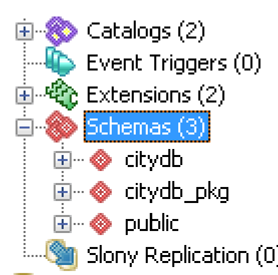

Figure 3: 3DCityDB Extends citydb and citydb_pkg Schema for storing CityGML

The imported/exporter tool is also a vital part in providing 3D visualization of CityGML model. The sematic database resulted from 3DCityDB importer tools is validated and then served as other 3D format into a tiled 3D models. The exporter tools could export CityGML format to Collada(DAE), KML/KMZ or glTF for further visualization. A 3DCtityDB web client is also provided as one of the tools for easy deployment of web. The webclient is built onon CessiumJS which could be able to display and perform queries of the 3D model.

2.3. 3D Building in OpenStreetMap (OSM)

OpenStreetMap (OSM) is a well-known crowdsourcing platform to enable collecton of georeferenced data in various form. Although mainly provides 2D editing and visualization, OSM also supports 3D building specification through specifically defined tags. The OSM Simple 3D Buildings Specification (wiki.openstreetmap.org/wiki/Simple_3D_buildings) defines some tags (which is actually a key-value pair) which can be used to depict buildings in their natural outlined shape.

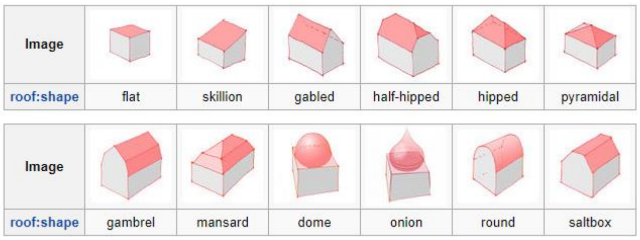

Figure 4: key-value tags defining roof shape in OSM Simple 3D Building

Form the specification, it can be inferred that the OSM are3D specification are compatible to LoD 1 in CityGML. However, as shown in [30], OSM data could also provide useful information for generating higher LoD of 3D CityGML from OSM [32].

2.4. Data Integration

SmartCity data integration [33]–[35]

3. METHODS

3.1. Data and Study Area

This paper focuses on the study area in Malioboro Street, Yogyakarta City, Indonesia. The area is infamous as tourist destination, with shops lined up in each side of the road. The street also infamous for historical, colonial-style buildings situated in some part of the street.

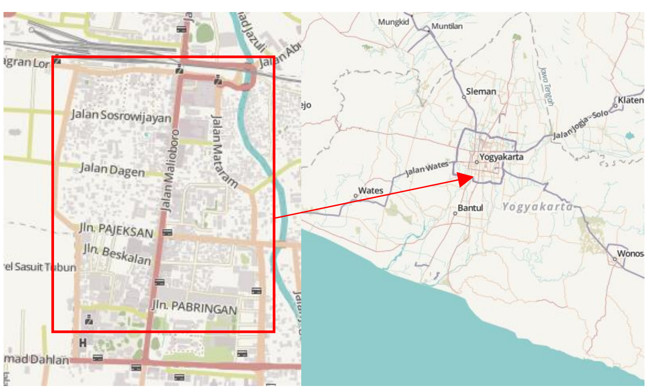

Figure 5: Location of study area

The data are obtained from crowdsourced data using OpenStreetMap (OSM) platform. Further editing on the OSM data, espescially 3D building tags were performed to obtain the required 3D model from CityGML. The OSM data are obtained through Overpass API and converted into CityGML for further visualization.

3.2. CityGML Conversion Methods

Previously, several methods on generating CityGML format has been discussed. This paper mainly discusses our findings in employing OpenStreetMap (OSM) data to generate LoD1 CityGML model for use in SmartCity applications. This research follows the steps shown in Figure 6 to provide a smartcity platform which able to perform queries on 3D model using CityGML standard.

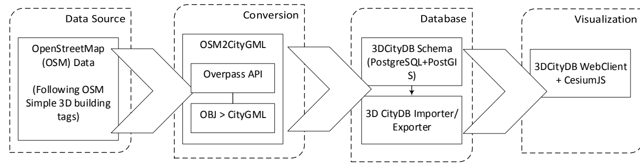

Figure 6: Research Procedures

This research can be divided into four main parts, namely 1) Editing OSM 3D data, 2) Conversion of OSM data to CityGML format, 3) Importing CityGML data into spatial database, and 4) Visualization of queryable CityGML building models in a 3D viewer/web client. Different software and libraries are employed through each stage, each of which serves different purposes for obtaining semantically rich 3D models from OSM data.

3.2.1. Editing OSM 3D Data

Editing of OSM data are performed in JOSM. The OSM Simple 3D buildings is implemented by defining tags (key-value pair) according to ground-truth situation into existing or new OSM building relation. Kendzi 3D, a JOSM plugin, is utilized for editing and directly viewing 3D data of OSM.

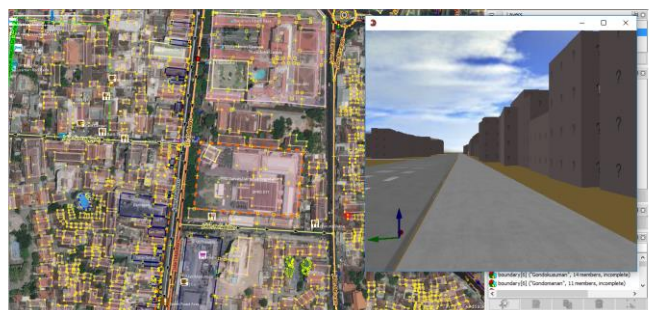

Figure 7: Editing OSM 3D tags using JOSM and Kendzi 3D

3.2.2. OSM2CityGML Conversion

Conversion from OSM format was conducted using OSM2CityGML tools (available at https://github.com/stirringhalo/osm2citygml). The tool performs several steps to convert OSM data into CityGML. Firstly, the tool obtainOSM data from Overpass API and save the OSM XML format. Next, the tool convert the XML into 3D OBJ files using OSM2World. Last but not least, the OBJ format are then converted into CityGML format using FME.

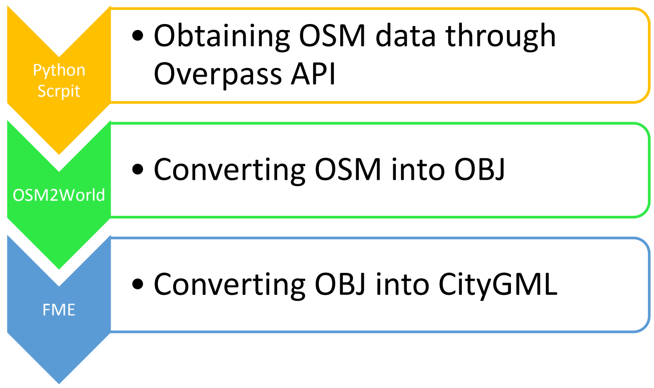

Figure 8: Steps for obtaining CityGML from OSM data

3.3. 3DCityDB Importer/Exporter

As a standard format for 3D semantic data exchange, CityGML can be implemented in various forms. Among the tools that can be used to create a CityGML schema in database form is 3DCityDB (www.3dcitydb.org). This open source utilities can be used to form database schema in a format that complies with CityGML version 2.0 standard. Supported databases are Oracle and PostgreSQL which are equipped with PostGIS. In contrast to the three-dimensional format in general, the establishment of 3DCityDB database schema will provide the semantic structure and geometry of the 3D model used. Furthermore, a query linking geometric and attribute data can be performed in accordance with CityGML elements.

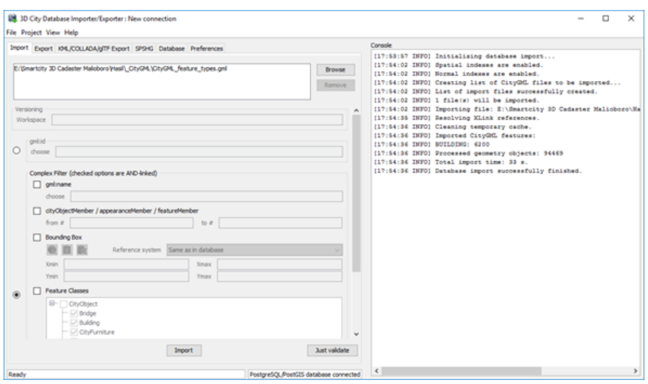

Figure 9: Importing CityGML data into database

4. DISCUSSIONS AND CONCLUSIONS

The result of this research is a CityGML format obtained from OSM data conversion. Also, a webclient was built on top of Cessium JS for visualization purpose. The webclient is capable of performing visualization and queries of CityGML data in Malioboro.

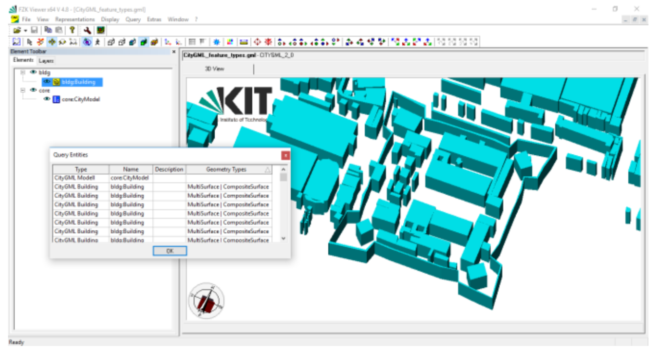

Figure 10: The CityGML data Obtained from conversion

The pipeline for producing visualization of semantic 3D model has been successfully obtained by using OSM as data input for CityGML and 3DCityDB for storing, tiling and querying of CityGML as semantic spatial database. However, there also exist some bottleneck of the pipeline, namely the visualization of 3D geometry stored in the database. Since CityGML is focused on delivering interoperable 3D format instead of visualization, the visualization of CityGML still needs another conversion to 3D format such as OBJ or glTF to be able to function as visualization format. Future researches need to focus on visualization of CityGML and its adaptation in industry standard for 3D exchange format.

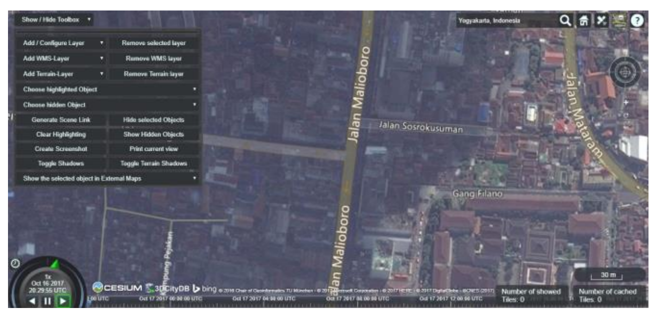

Figure 11: Webclient for Visualization of CityGML data

Aside from the 3D geometry visualization, there exist another problem regarding to visualization of CityGML in a web app. The attribute of 3D geometry could not be saved in a single CityGML file, since the format have no fields related to custom attributes. Therefore, the attribute of a CityGML Building feature should be stored somewhere else and connected to the geometry in some way. For application in smartcity this could potentially be advantageous as well as disastrous at the same time. First, the data could be separated for query and visualization, thus preserving size and reducing load time of the application. Second, the application would need specifically designed modules to handle the join operation, which in turn would add the load to the program. However, it has been shown that CityGML is the suitable format for 3D SmartCity in the future.

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