CityGML 3.0: Sneak Preview

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Abstract: The next major version 3.0 of the international OGC standard CityGML is going to be released by the end of 2018. This paper provides an insight into the current developments and presents the most relevant new concepts and modifications which includes new modules as well as revisions of existing modules and concepts.

1 Introduction

Semantic 3D city models represent city objects such as buildings, bridges, tunnels, roads, and vegetation, allowing in this way for an accurate representation of landscapes as well as urban areas. CityGML is the well-established international standard of the Open Geospatial Consortium (OGC) for modelling and exchanging semantic 3D city models (GROEGER et al. 2012). The specification defines both, a data model which can be implemented on different platforms (e.g. Oracle, PostGIS) and an exchange format for transferring data between these platforms.

In order to increase the usability of CityGML for more user groups and areas of application, the OGC CityGML Standards Working Group (SWG) and the Special Interest Group 3D (SIG 3D) of the initiative Geodata Infrastructure Germany (GDI-DE) work since 2014 on the further development of CityGML. This development will result in the next major version *CityGML 3.0* which is to be released by the end of 2018. The new version will bring a number of improvements, extensions, and new functionalities. This paper provides an insight into these developments by presenting the most relevant new concepts and modifications to be included into CityGML 3.0. UML diagrams of the new CityGML 3.0 data model are not provided here, as they are in the current stage of development still subject to changes.

2 New and revised features and modules in CityGML 3.0

The CityGML model is being fully revised to reflect the increasing need for better interoperability with other relevant standards in the field like IndoorGML (LEE et al. 2016), Industry Foundation Classes (IFC) (ISO 2013), Land Administration Domain Model (LADM) (ISO 2012), as well as with Semantic Web Technologies like Resource Description Framework (RDF) (W3C 2014).

All modifications to the new CityGML 3.0 model are carried out in a way to ensure backwards compatibility with CityGML 1.0 and 2.0, with the aim in mind that it should be possible to transform all CityGML 1.0 and 2.0 datasets into the new model by applying syntactical

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transformations only. Backwards compatibility is a major requirement for CityGML 3.0 in order to preserve investments by anybody providing CityGML tools, datasets, and extensions.
CityGML 3.0 will apply a model-driven approach in the generation of the data model and exchange formats. The data model is now based directly on the ISO 191xx standards. The data model has been created using Enterprise Architect (EA) and makes use of the EA files provided by ISO and OGC on the underlying standards. The GML encoding (CityGML XML schema) will be fully automatically derived from the data model using the software tool ShapeChange. Also, the feature catalogue with a detailed overview and explanation of all classes, attributes, and relationships will be derived automatically.

2.1 Revised CityGML Level of Detail Concept

CityGML 3.0 will include a revised Level of Detail (LOD) concept. LOD4, which is used for representing the interior of objects (like indoor modelling for buildings and tunnels) has been removed, only the LODs 0-3 will remain. Instead, the interior of objects can be expressed now integrated with the LODs 0-3. It will even be possible to model the outside shell of a building in LOD1 while representing the interior structure in LOD2 or 3. Details on the changes to the CityGML LOD concept are provided in (LÖWNER et al. 2016).

2.2 Revised CityGML Core Model

The CityGML *Core* model has been substantially redesigned as well. A key feature of the new *Core* Model is that all spatial representations are rephrased based on the two pivotal abstract classes *Space* and *SpaceBoundary* from which a number of subclasses are derived. All geometric representations are associated with the semantic concepts of spaces and space boundaries. Furthermore, all feature classes in the thematic modules represent their spatial characteristics almost exclusively using *Space* and *SpaceBoundary* classes and no longer have direct associations with geometry classes. This simplifies geometry handling of CityGML for software developers in general.
The *Core* model implements the new CityGML LOD concept, mentioned above. In addition, a point cloud representation for spaces and space boundaries is being introduced which allows for spatially representing all thematic feature types just by a point cloud. Furthermore, new relationship associations are being introduced to express topologic, geometric, and semantic relations between spaces as well as between space boundaries.
A new class *AbstractToplevelCityObject* will allow to restrict the feature types that are allowed as members of a *CityModel* feature collection. In this way, one can express in the data model that, for instance, from the *Building* Module only the class *Building* can occur as a member of a *CityModel* and that *Door* or *RoofSurface* are not allowed as direct members of *CityModel*. This information is required for software packages that want to filter imports, exports, and visualization according to the general type of a city object (e.g. only show buildings, solitary vegetation objects, and roads).
Another advantage of the space concept is that CityGML objects representing buildings can now directly be mapped onto IndoorGML and vice-versa. Furthermore, spaces which are not bounded by physical objects but are defined according to logical / thematic considerations can now be modelled. This includes building storeys as well as building units like apartments or public

spaces in buildings which are going be represented in CityGML 3.0 based on the new feature type *AbstractBuildingSubdivision* in the *Building* module. The notion of a logical space is also important to express ownership and usage rights as required by the LADM standard.

External references are rephrased and are now better aligned to an RDF representation. Like before, each city object can have an arbitrary number of references to other objects in other datasets / databases, but these can now be additionally qualified by a relation type given by an additional URI.

2.3 New CityGML Construction module

CityGML 3.0 will be complemented by a new *Construction* module which defines concepts that are common to all kinds of man-made constructions like buildings, bridges, tunnels, and other constructions. The module will also comprise the definition of the different kinds of thematic surfaces like *RoofSurface*, *GroundSurface*, *WallSurface* etc., which are passed on to the thematic modules *Building*, *Bridge*, and *Tunnel* by making use of inheritance. This leads to a substantial simplification of the data models of these modules. Man-made structures that are neither buildings, tunnels, nor bridges (e.g. large chimneys, city walls, etc.) can now be modelled by using the new feature type *OtherConstruction*. The interoperability of CityGML with INSPIRE is improved by adopting attributes from the INSPIRE Building data theme (JRC 2013) which allow for specifying multiple elevation levels and measured heights as well as for storing a date of construction, demolition, and multiple dates of renovations. A new feature type *AbstractConstructiveElement* and its concrete building-, bridge-, and tunnel-specific subtypes will allow for mapping constructive elements from BIM datasets given in the IFC standard (e.g. the IFC classes *IfcWall*, *IfcRoof*, *IfcBeam*, *IfcSlab*, etc.) onto CityGML.

2.4 New CityGML Versioning module

Within the new *Versioning* module, CityGML 3.0 will introduce bitemporal timestamps for all objects in alignment with the INSPIRE data specifications. Besides the attributes *creationDate* and *terminationDate* from CityGML 2.0, which refer to the time period a specific version of an object is an integral part of the 3D city model, all objects now can additionally have the attributes *validFrom* and *validTo*, which represent the lifespan a specific version of an object exists in the real world. Furthermore, each geographic feature is being provided with two identifiers: the *identifier* property which is stable along the lifetime of the real-world object, and the *gml:id* attribute which is to mark the respective version of the object. In this way not only the current version of a 3D city model, but its entire history can be represented in CityGML and exchanged. The module will define two new feature types: *Version*, which can be used to explicitly define named states of the 3D city model and denote all the specific versions of objects belonging to such states, and *VersionTransition*, which allows to explicitly link different versions of the 3D city model by describing the reason of change and the modifications applied. Details on the versioning concept are given in (CHATURVEDI et al. 2017).

2.5 New CityGML Dynamizer module

A new *Dynamizer* module has been developed to improve the usability of CityGML for different kinds of simulations as well as to facilitate the integration of sensors with 3D city models. The integration of sensors with 3D city models is important e.g. in the context of smart cities and digital twins. Both, simulations and sensors provide dynamic variations of some measured or simulated properties like, for example, the electricity consumption of a building. The variations of the value are typically represented using time series data. The data source of the time series data are either sensor observations (e.g. from a smart meter), pre-recorded load profiles (e.g. from an energy company), or the results of some simulation run. A new feature type *Dynamizer* will represent special objects linking the time series data to a specific attribute (e.g. geometry, thematic data, or appearance) of a specific object within the 3D city model. In this way, dynamic variations of city object properties can be injected into an otherwise static representation. For details on the Dynamizer concept and some demonstration applications please refer to (CHATURVEDI & KOLBE 2017).

3 Conclusions

This short paper provided an insight into new features which are to become part of the next major CityGML version 3.0. This new version will provide the new modules *Construction*, *Versioning*, and *Dynamizer*, but will also contain revisions of existing modules and concepts including the LOD concept, the *Core* model, and the *Building* module, and of other modules not mentioned in this paper, such as the *Transportation* module (BEIL & KOLBE 2017). Please note that all changes are subject to the final voting of the OGC CityGML SWG and the Technical Committee.

The CityGML 3.0 standard will consist of at least two parts: 1) the CityGML 3.0 Conceptual Model specification, which is to be released at the end of 2018, and 2) the CityGML 3.0 GML Encoding specification, which is to be published early 2019. Further encoding specifications (e.g. relational database schema, JSON-based representation) may follow in the future.

4 Literature

BEIL, C. & KOLBE, T. H. 2017: CityGML and the streets of New York - A proposal for detailed street space modelling. ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., **IV**(4/W5), 9-16.

CHATURVEDI, K., & KOLBE, T. H. (EDS.), 2017: Future City Pilot 1 Engineering Report. OGC Document 16-098. Open Geospatial Consortium.

CHATURVEDI, K., SMYTH, C. S., GESQUIÈRE, G., KUTZNER, T. & KOLBE T. H., 2017: Managing Versions and History Within Semantic 3D City Models for the Next Generation of CityGML. Lecture Notes in Geoinformation and Cartography, Abdul-Rahman, A. (ed.), Advances in 3D Geoinformation, Springer, Cham, 191-206

GRÖGER, G., KOLBE, T. H., NAGEL, C. & HÄFELE, K.-H. (EDS.), 2012: OGC City Geography Markup Language (CityGML) Encoding Standard, Version 2.0.0. OGC Document 12-019. Open Geospatial Consortium.

ISO 2012: ISO/TS 19152:2012 Geographic information – Land Administration Domain Model.

ISO 2013: ISO 16739:2013 Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries.

JRC 2013: D2.8.III.2 Data Specification on Buildings – Technical Guidelines. European Commission Joint Research Centre.

LEE, J., LI, K.-J., ZLATANOVA, S., KOLBE, T. H., NAGEL, C. & BECKER, T. (EDS.), 2016: OGC IndoorGML, Version 1.0.2. OGC Document 14-005r4. Open Geospatial Consortium.

LÖWNER, M.-O., GRÖGER, G., BENNER, J., BILJECKI, F. & NAGEL, C., 2016: Proposal for a new LOD and Multi-Representation Concept for CityGML. ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., **IV**(2/W1), 3-12.

W3C 2014: RDF 1.1 specifications. URL: https://www.w3.org/standards/techs/rdf#w3c_all