Final Report on the EuroSDR CityGML Project

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1 Project Background and Objectives

Virtual 3D city models are employed by municipalities, companies, enterprises, and mapping/ cadastre agencies in an increasing number of application areas. It can be foreseen that 3D geoinformation will become a natural part of the geo base data on a regional, national, and European level in the future. In order to allow for a lossless information exchange, a proper standard for virtual 3D city models is needed. However, no European or international standard for virtual 3D city and regional models was available in the past.

The development on CityGML was started in 2002 by the initiative Geodata Infrastructure North-Rhine Westphalia (GDI NRW) in Germany. From 2002 until 2005 the Special Interest Group 3D (SIG 3D), one of the working groups within GDI NRW, worked on the development of a standard for the representation and exchange of virtual 3D city and region models called “CityGML”. The underlying data model was (and still is) based on ISO 191xx standards and was mapped to the Geography Markup Language version 3.1, the XML based exchange format of the Open Geospatial Consortium (OGC). By the time of the beginning of the EuroSDR CityGML project in 2005, CityGML had been already implemented within diverse (German) 3D GIS systems, and it was evaluated in five pilot projects in cooperation with different municipalities (among which were Berlin, Hamburg, Düsseldorf, and Cologne).

By 2005, CityGML represented the modelling consensus of over 70 institutions, companies, municipalities, and NMCAs. However, since it has been mainly developed within Germany, European and international aspects were not particularly addressed and the specification document was only available in German language. It soon became clear that in the context of ongoing European geospatial data harmonization efforts and the upcoming INSPIRE initiative it would not make sense to only concern about national modelling interests and requirements but instead address (at least) the European level. This was the moment when the CityGML project was brought to the attention of EuroSDR.

The EuroSDR CityGML project started in December 2005 and was carried out until August 2006 by Thomas H. Kolbe, Angela Czerwinski, Gerhard Gröger, and Lutz Plümer at the Institute for Cartography and Geoinformation at the University of Bonn. The aim of the project was to bring the specification and modelling strategies of CityGML to a broad and general discussion within EuroSDR. It was intended to identify the needs and potential applications of EuroSDR members regarding the modelling, representation, quality and exchange of virtual 3D city models within Europe. Amongst other indicators, the joint ISPRS / EuroSDR / DGPF workshop on Next Generation 3D City Models in Bonn in June 2005 showed that at that point in time, European research institutions, NMCAs, and municipalities had been working at the leading edge of building and maintaining 3D city models (Kolbe & Gröger, 2006). This in-

creasing momentum showed the potential to drive the development of a European standard, with potential international usefulness.

The long-term goal of the project was the development of a common European standard for the representation and the exchange of virtual 3D city and regional models. This includes the further development and discussion of the existing ontology and its mapping to an UML data model within the ISO 191xx and OGC frameworks. The mapping to GML3 should ensure the usability within international, national, and regional spatial data infrastructures.

2 Actions

The EuroSDR CityGML project was divided into two phases. The main goal of the first phase was to bring CityGML to discussion within EuroSDR. The members should become familiar with the background, the current specification draft and modelling issues and open problems. Small test data sets from German cities have been provided to illustrate the specification. Feedback was requested for analysis, evaluation and summary.

2.1 Working Plan for Phase I

The project application to EuroSDR (and funded period) did only address phase I. The working plan contained the following working items:

1. Translation of the mostly German specification documents and discussion papers.
2. Distribution of specification drafts to the EuroSDR members.
3. Preparation, distribution, and evaluation of a questionnaire about the technical and organisational issues.
4. Acquisition and distribution of demonstration data sets
5. Concrete specification of phase II; bring together the research / working group for phase II (including the identification of interested EuroSDR members)
6. Development of a financing concept for phase II

2.2 Phase II

It was intended to have a second phase during which the group of interested EuroSDR members would have worked on the definition and specification of a common CityGML standard. It was also intended to bring the work to the Open Geospatial Consortium to ensure international discussion and sustainability. The concrete working items and financial planning for phase II was to be developed in phase I.

However, phase II was not planned and carried out as it was outlined in the project proposal. The reason was, that the international discussion of CityGML was quickly picked up by the Open Geospatial Consortium on the one side, and that there was very limited feedback from the questionnaire on the other side. Funding for the continuation of the specification work was raised from research projects like the OGC Open Web Services Testbed #4 (see below) and the development of the 3D city model (and 3D geodatabase) for the cities of Berlin and Bonn. In effect Phase I acted as a successful seeding mechanism for these follow-on activities, particularly by making English language documentation available.

3 Results

Within the funded project period (December 2005 – August 2006) all items from phase I had been addressed and were carried out successfully. The German specification document was translated and the English version was distributed to the EuroSDR members together with the questionnaire enclosed as appendix A of this report. Test datasets and a free, Java 3D-based GML3 viewer have been provided on the CityGML homepage (see below).

Comments, remarks, and discussion results with EuroSDR and SIG 3D members were then taken into account and led to a new version of the specification document (V0.3.0). This document was brought to the attention of the Open Geospatial Consortium and became an adopted OGC Discussion Paper (Gröger et al., 2006) by June 2006.

The first English specification document and the subsequent version V0.3.0 are part of this final report. The following section provides a short summary of the most important features and design decisions from the CityGML specification.

3.1 CityGML Overview

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, semantic and appearance properties. Included are generalization hierarchies between thematic classes; aggregations; relations between objects; and spatial properties. This thematic information goes beyond graphic exchange formats and supports the use of virtual 3D city models for sophisticated analysis tasks in different application domains like simulations, urban data mining, facility management, planning and thematic inquiries.

The semantic data model comprises representations for digital terrain models, buildings, vegetation, water bodies, transportation facilities, and city furniture. It can be extended by generic objects and specific models for different application domains. CityGML differentiates between five consecutive levels of detail (LOD), where objects become more detailed with increasing LOD regarding both geometry and thematic differentiation. Different LODs often arise from independent data collection processes and facilitate efficient visualization and data analysis. In a CityGML dataset, the same object may be represented in different LODs simultaneously, enabling the analysis and visualization of the same object with regard to different degrees of resolution. Furthermore, two CityGML data sets containing the same object in different LOD may be combined and integrated.

The coarsest level LOD0 is essentially a two and a half dimensional digital terrain model (DTM). LOD1 is the well-known blocks model, without any roof structures. A building in LOD2 has distinctive roof structures. LOD3 denotes architectural models with detailed wall and roof structures, balconies and bays. LOD4 completes a LOD3 model by adding interior structures like rooms, interior doors, stairs, and furniture. Beyond buildings, the LOD concept applies to other object classes as well. The focus is on model resolution and perceptibility of object parts, but it addresses also geometrical accuracies and minimal dimensions of objects. The classification may also be used to assess the quality of a 3D city model data set. Furthermore, the LOD category makes data sets comparable and thus supports the integration process of those sets.

CityGML is realised as an object oriented data model and XML based format for the storage and exchange of virtual 3D city models. It is implemented as an application schema for the

Geography Markup Language 3 (GML3), the extendible international standard for spatial data exchange issued by the Open Geospatial Consortium (OGC) and the ISO TC211 (Cox et al., 2004). CityGML is an open, royalty-free standard and can be used free of charge.

Details on CityGML are provided in the enclosed implementation specification documents or in later versions like the OGC Doc. No. 07-062 (Gröger et al. 2007), which can be freely downloaded from the "Best Practice" section of the "Standards" section of the OGC website.

3.2 Feedback from the Questionnaire

The questionnaire as given in Appendix A was sent to all EuroSDR members in April 2006 with a four weeks answer period. Only four replies have been sent back to us. We assume that the most important reasons for the small number of replies is that most EuroSDR members did not hear about CityGML before and were unsure about its future acceptance and relevance. In several discussions it also became apparent that it is (still today) not yet clear for most NMCAs if – and if yes: to what degree and level of detail – they should provide 3D geoinformation as a product. This should be discussed within EuroSDR in the future.

All four replies came from members in the UK; one from a NMA, two from universities, and another one from a company. Due to the few responses we only provide a short summary in text form.

The participants have been using / investigating 3D city models in the context of 3D topological modelling, feature and object recognition, real-time simulation and visualization, and as providers of data and technology. All of them were employing 3D models where the geometry was given in the Boundary Representation (B-Rep). Two participants have been representing their digital terrain models by regular rasters or TINs, the others did not provide an answer to this question. Except for one answer, the 5 LODs were mostly seen as well defined and appropriate. Concerning the usage of the OASIS xAL standard the participants agreed that an international standard is needed, but were not sure about that specific one.

The thematic differentiation within CityGML was generally confirmed, but further extensions like utility networks and other underground facilities and a more sophisticated support for visualization (especially multi-texturing) was requested. One participant proposed that CityGML could be used as a starting point for the definition of a European 2D data model.

Only half of the participants stated their interest in joining the future CityGML development, but all expressed their explicit interest in future European research projects on 3D city modelling. The harmonisation of CityGML with the developments of the Open Geospatial Consortiums was generally recommended.

3.3 Further Results after Project Phase I

After the conclusion of phase I the CityGML specification has been further developed by the SIG 3D of GDI NRW in cooperation with the members of the 3D Information Management Working Group (3DIM WG) and the CityGML Standard Working Group (CityGML SWG) of the OGC. The specification document (Version 0.4.0) was brought to the next stage of the standardization process and became an OGC Best Practices Paper by July 2007.

In addition to the development of the specification document a CityGML website was created. At the address www.citygml.org it provides current news, background and contact information, test datasets, and publications and presentations related to CityGML. Interested parties can find and provide further information about implementations, test datasets, accessible Web Feature Services, projects, and initiatives on the CityGML Wiki site at www.citygmlwiki.org. The wiki was started and is operated by the Research Centre Karlsruhe.

CityGML has been employed in a number of different application projects so far:

- From May until December 2006 the Open Geospatial Consortium conducted the Open Web Services Testbed #4 (OWS-4). The testbed evaluated the implementations and usability of OGC standards within a homeland security application scenario. CityGML was employed to identify a potential location and building for a field hospital in an emergency situation. Datasets were registered in Catalog Services and accessed using WFS (Lapierre & Cote, 2007). Also the mapping of building information models given in the IFC format (Industry Foundation Classes) to CityGML has been investigated and was applied (Benner et al., 2005).
- In order to implement the EU directive 2002/49/EC for the mapping of environmental noise, a regional model for the whole state of North-Rhine Westphalia in Germany has been built and will be maintained in the future by the state mapping agency. It comprises 8.6 million 3D building models in LOD1, 3D road and railway networks, 3D noise barriers and shields, and a statewide digital terrain model. All data are exchanged via (transactional) Web Feature Services and a Web Coverage Service. An application domain extension for the noise dispersion simulation was developed (CityGML Noise ADE) to augment CityGML objects with application specific information (Czerwinski et al., 2006a; Czerwinski et al., 2006b). By the beginning of 2008, the noise pollution mapping was completed and the results are now published on the Internet for the citizens (http://www.umgebungslaerm.nrw.de).
- CityGML is now employed by a number of municipalities: it is the base model for the official 3D city models of Berlin (Döllner et al., 2006), Bonn, and Stuttgart; it is used in Düsseldorf, district of Recklinghausen, Munich, Bochum, Dresden, Frankfurt, and other German cities. Further European cities like Zurich, Rotterdam, and Goteborg are currently investigating the support of CityGML for their models.

CityGML is also being used as a base ontology for the development of new methods for 3D object recognition (Schmittwilken et al., 2007), to support indoor navigation (Mäs et al., 2006), and in training simulators like driving simulation (Randt et al., 2007). Above, it was used to examine the coherence of spatial and semantic decompositions within complex spatial data models (Stadler & Kolbe, 2007).

4 Current Status of CityGML and Outlook

It is expected that the current candidate specification version 1.0 (Gröger et al., 2008) will be adopted as an international OGC standard by July or August 2008. The public request-for-comments (RFC) period ended successfully in March and currently final revisions are carried out by the specification editors.

As soon as CityGML is adopted as a standard, the CityGML Standard Working Group of the OGC will be dissolved, because it will have fulfilled its task. Discussions and the future development will be continued within the SIG 3D and the 3DIM WG of the OGC. Since the SIG 3D is an open group and participation is free, it will allow interested EuroSDR members to join easily. For example, the British Ordnance Survey has taken part in the SIG 3D for more than two years now. EuroSDR members that are also OGC members can join the 3DIM Working Group, too. When CityGML is a standard the current specification document will be found in the “Standards” section of the OGC website.

Discussions about future developments and extensions of CityGML have started already. This includes possible extensions by new themes like tunnels, walls, bridges, and utility networks. Another discussion relates to the definition of core metadata properties for 3D city models.

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Appendix A

Questionnaire for the EuroSDR project "CityGML – modelling and exchange of virtual 3D city models"

Please answer the following questions. Skip any questions you are not concerned with. We kindly ask you to type the answers directly at the appropriate position within this Word document. Please send this file back until **26th of May 2006** to **citygml@ikg.uni-bonn.de**. Your answers will be treated confidentially and the results will be published in aggregated / anonymised form.

1. **In which fields do you use 3D building/city models? What is your role concerning virtual city models (user, provider, refiner, researcher)?**

2. **Does CityGML cover your application fields/needs? Would you use CityGML in the context of your virtual 3D city resp. regional models?**

3. **Do you see application fields for 3D city models, which are not well addressed by CityGML yet? Which additional objects and functions would be required in your application context? Is the thematic differentiation appropriate?**

4. **Would you be interested to take part in the further development of the CityGML specification? How should the 3D harmonisation process be continued in Europe? Is the OGC specification process sufficient?**

5. **Could you imagine to take part in a larger European project to strengthen the development and use of 3D city models and what would be your possible contribution?**

6. **Do you agree with the definition of the 5 LODs and the accuracy requirements of 3D city models given in chapter 7.1/Tab.1 ? If not, do you have any recommendations?**

7. **How do you represent your Digital Terrain Model: as a raster or grid, TIN, break lines or mass points? Do you use/need combinations of these types?**

8. **Do you agree with the use of the OASIS xAL address standard?**

9. **Which geometry types do you use for the representation of your 3D city models – Boundary Representation (B-Rep.) or Constructive Solid Geometry (CSG)? If B-Rep., do you have solids or composite surfaces? Which formats do you employ to represent your 3D city models so far (shape files, 3D studio max, CAD formats…)?**

10. **Do you have other revision proposals or further comments?**