From 2D to 3D Modeling – A case study of Walloon region-Belgium

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Abstract. The definition of a 3D Reference model is the prerequisite for supporting a large range of 3D applications such as urban planning and increasing 3D data interoperability. Such action requires investigation of 3D users requirements and a collaborative framework to reach a consensus on common 3D data specifications. The paper presents basic concepts related to 3D modeling and introduces collaboration as a promising solution to reach a 3D reference model. We demonstrate, through a case study, how 2D data collected from different providers in Walloon region in Belgium can be reengineered and then integrated in a 3D collaborative database compatible with CityGML.

Keywords: 3D reference model, Collaborative, CityGML, Integration

1. Introduction

In recent years, establishing 3D city models is getting more popular day by day. New applications based on 3D modeling such as virtual reality, 3D GIS and urban simulation are currently in development. To enable collaboration in heterogeneous environments, standardised data exchange methods for city models comprising both spatial and semantic information are required (Stadler & Kolbe 2007). CityGML, an open data model for the storage and exchange of virtual 3D city models addresses this issue (see Gröger & Kolbe (2008)).

Actually, free web-mapping services and virtual globes provide users with a large amount of 3D data. Moreover, new forms of data crowdsourcing are emerging at a rapid race. Anyone with internet access and mobiles devices (PDA, GPS, cameras ...) has the ability to produce data voluntarily and make it available to a large community of users. As it has been stated by Goodchild (2010), citizens become as “voluntary censors”. The emergence of social web platforms like OpenStreetMap (OSM) has demonstrated the potential to revolutionize the way geospatial data can be acquired and shared between users. Crowdsourced data called “Voluntary Geographic Information” (VGI) is a potentially attractive source of free information (Goodchild 2010; Genovese & Roche 2010). In the 3D context, Goetz & Zipf (2012) proposed a framework to extract geometric and semantic CityGML data from OSM data. National Mapping Agencies are beginning to show an interest in the VGI. As an example, the web platform “RIPART” (Remontée d’Information PARTagée) developed in the National Geographic Institute in France (Viglino, 2011).

However, the quality of VGI cannot be easily guaranteed (Mummidi & Krum 2008). Many authors have raised the issue about its credibility and longevity as well as the mechanisms to make it benefic (Goodchild 2010; Genovese & Roche 2010; Haklay 2010; Flanagin & Metzger 2008; Bishr & Janowicz 2010). Brando & Bucher (2010) proposed an approach based on the definition of specifications for VGI and automated mechanisms to reconcile eventual conflicts between contributions. So, until no framework is available to integrate the VGI, usage can be restricted to generating updating alerts. A benefic solution can be adopted by collecting VGI from a network of professionals.

Virtual globes are certainly optimized for exploration and browsing purposes, but cannot deal with a large spectrum of applications requiring geometric and semantic accurate 3D data. So, government agencies and potential producers are likely to establish a 3D reference model which can support “intelligent” 3D spatial analysis. To define specifications for a 3D reference model, users 3D requirements should be investigated. In reality, users requirements for 3D data are not well known. Indeed, users can ultimately state whether the data are fit for their purpose but cannot realistically make explicit statements anticipating what they would require in terms of 3D data measures and quality elements such as positional accuracy (Sargent et al 2007). We argue that a universal 3D model does not exist. Alternatively, work should focus on developing a basic 3D reference model which can be enriched by potential users. Defining specifications for 3D data co-production is also a promising solution to share resources in order to establish a 3D collaborative database.

In the following, we first expose and analyze the main concepts related to the 3D modeling and the definition of a 3D reference model, then we briefly present the future issues about 3D collaborative modeling. Finally, we explain, through a case study in Walloon region in Belgium, our proposed processing workflow for evolving from 2D multi source data to 3D information which can be integrated in a 3D collaborative database compatible with CityGML.

2. Basic concepts about a 3D reference model

2.1. 3D models versus 2D/2.5D models

Several intermediate solutions between 2D and 3D representations, as Digital Terrain Models (DTM) and 2.5D representations may be defined. A 2.5D is considered as a representation mode of a flat (or nearly flat) entity such that z=f(x, y) and f is a true function (De Cambray 1993). This definition encompasses both usual 2.5D maps and DTM. A DTM alone is not sufficient to represent a 3D map. A veritable 3D representation related to a 3D space is necessary to fully represent spatial reality and to remove some ambiguities in case of multi-level structures. In such representation, more than one z-coordinate is needed for a given (x, y) position. In the GIS field, spatial information stored in a DTM and in GIS can only be related through coordinates. Information derived from DTM must be converted into a form GIS can recognize in order to answer some requests like: which land parcels are subject to one-meter flooding? With an integrated 3D model, data conversion were no longer necessary and spatial analysis could be answered from one 3D model (Rahman & Pilouk 2008).

2.2. Reference data concept

In 2D maps, the concept of reference data refers to data that can be used to relate or "refer‟ external information to the real world such as infrastructure theme, terrain elevation, hydrography or abstract features like administrative boundaries, cadastral parcels and postal addresses (Neber 2008). So, the reference data plays for a geographic information user the same role as a geodetic frame does for cartographers and surveyors. Extended to the 3D field, the concept encapsulates both geometric and semantic aspect. Even if the third dimension represents the reality, the need of 3D information has been born and grown because of the limits of 2D data to deal with some application requirements. So, it seems obvious that basic objects of a 3D model are constructed by extending those of traditional 2D models (from 2D to 3D thinking) such as buildings, vegetation, city furniture and so forth. The semantic aspect addresses the granularity of 3D data. For instance, how rich is a 3D building representation in terms of internal structures description can be considered as a requirement for some applications like emergency services.

Reference 3D data can be defined as fundamental 3D data that can be shared by most applications and that potential producers must make available to deal with a large range of 3D applications. To reach this objective, it seems logical to investigate and rely on users requirements (Zlatanova 2000), to define the types of real world objects the 3D reference model must represent and to choose an appropriate design of an integrated model capable of maintaining all the components of the geometric representation of real world objects in the same database (Rahman & Pilouk 2008). We argue that the concept of reference data is dynamic until users requirements become more sophisticated when achieving a high degree of maturity.

2.3. The concept of level of detail (Lod)

Depending on application requirements, a certain spatial and thematic granularity is needed. Considering that several 3D applications may share a unique 3D reference database, dealing with multi representations is a fundamental issue. The concept is both associated to geometric accuracy and the semantic description. The definition of the relevant level of detail is application depending. Indeed, for many applications like emergency services, a high semantic Lod is more privileged than a geometric Lod. As it is defined in the CityGML specifications document (Gröger & Kolbe 2008), the concept of level of detail allows representing objects with regard to different degrees of resolution. It is characterized by differing accuracies (described as standard deviation of the absolute 3D point coordinates) and minimal dimensions of features. Objects become more detailed with increasing Lod regarding both geometry and thematic differentiation (Emgård & Zlatanova 2008). According to the CityGML specifications associated to each level of detail, the accuracy and the description of how rich would be a representation of a building in each level of detail might be confusing. Such as an example, a building with high semantic description might be classified in a lower Lod because a lack of accuracy. So, the definition of the Lod should be more sophisticated to ensure spatio-thematic coherence of a representation. It is recognized that acquiring data for representing an urban area with a high Lod is expensive, complex and time consuming. As an example, handling the complex internal structures of buildings is stymied by a lack of a cost-effective technology for indoor positioning that is comparable to GPS (Goodchild 2010).

2.4. Future issues about 3D modeling

An increasing number of 3D city models are developed for different purposes. 3D models should not be seen as an extension of 2D maps. Consideration of the geometric aspect is restrictive. A 3D model should be considered as a basic ground for integrating urban knowledge (Falquet & Métral 2005). Many 3D city models can be established to respond to specific requirements but the important issue is how to integrate knowledge and to make semantic enrichment of 3D models for a sustainable development. The challenge is so defining rules and principals of 3D city modeling based on urban ontologies (Métral et al 2010).

One of the challenging issues about 3D modeling is the collaborative work. Collaboration is defined as: “The process through which parties who see different aspects of a problem can constructively explore their differences and search for solutions beyond their own limited vision of what is possible” (Gray 1989). Technical, standard, and policy deficiencies result in time and effort losses on data production, management, and sharing (Aydinoglu et al 2009). So, many actors must collaborate effectively to build a collaborative 3D model to respond to emergent challenges related to geospatial data.

In order to avoid duplicated efforts and expense, data provided by many contributors must be integrated to develop reference data sets (Neber 2008). Doing so, data interoperability can be greatly improved (Neber 2008). To reach the objective of establishing a collaborative 3D reference model, a geographic data framework must be established through agreement on content and specifications. The framework will constitute a collaborative “datum” on which organizations can build by adding their own details and compiling other data sets (Neber 2008). Upgrading to a 3D collaborative model would be a promising solution firstly, to anticipate interoperability and data consistency problems at a technical perspective and secondly to establish common specifications for 3D data co-production.

3. From 2D to 3D modeling

3.1. Problematic

In Belgium, many divergent initiatives have been conducted for each political region to establish Topographic Inventories (TI) with divergent models and different technical characteristics (resulting to PICC in Walloon region, URBIS in Brussels capital region and GRB in Flanders). Also, the National Geographic Institute (NGI) maintains and distributes a large set of geographic data and cartographic products. Actually, many individual initiatives are launched to upgrade the existing 2D Topographic Inventories into 3D geospatial databases. Some cooperation’s aspects exist but are not formalized enough to be really efficient. There is a strong need to share resources in order to define a 3D collaborative model. The main raised question is: How the existing 2D data collected from many actors may be reengineered to match 3D collaborative database specifications?

The objective of the experiment presented in this paper, aims at investigating how existing multi source 2D data can be integrated in a 3D collaborative database compatible with CityGML. Through a case study of the city of Liege, we aim at proposing a geometric process to construct 3D data and testing an umbrella of 3D technologies supporting the CityGML standard.

3.2. Used data

Two different data sets are used in this experiment. The first one has been provided by the SPW (Service Public de Wallonie) as map sheets of the PICC (Projet Informatique de Cartographie Continue) in a 3D shape file format where each X, Y point has a value of Z. The second data set has been provided by the NGI in an Esri geodatabase file format. In the two data sets, buildings have been restituted by photogrammetry at the cornice level.

3.3. Processing workflow

The workflow is illustrated in *Figure.1* which main steps are described in the following paragraphs.

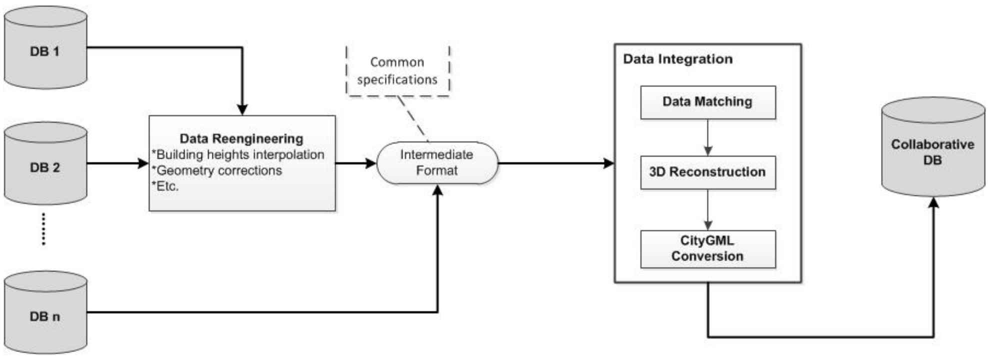

Figure 1. Processing Workflow

Building heights interpolation

Before any process on multi source data takes place, we had to interpolate the building's heights for each data set. To accomplish this task, a Digital Surface Model (DSM) and a Digital Terrain Model (DTM) were established. The DTM was created from cloud points, axis layers and a selection of terrain characteristic lines by defining how features should participate at the triangulation process (mass points or hard lines). The DSM or exactly a "Digital Cornice Model" (DCM) was generated from the contours of building's roofs. After rasterization of the two TINs surfaces and the building contours roofs, statistical computing was used to extract the height of each building. As shown in *Figure2*, “Zonal Statistics” function (of ArcGIS) was applied to the DTM, the DSM and buildings to extract the minimum and the maximum height. The difference represents the interpolated height of each building.

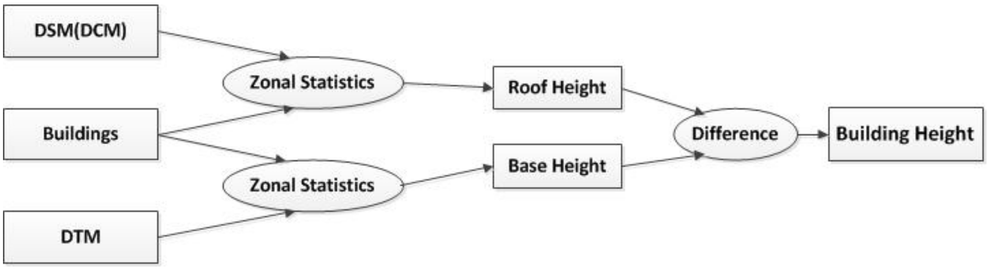

Figure 2. Building heights interpolation

3D Building Model

It is obvious that defining a 3D reference model is beyond the scope of this paper. Our contribution is rather technical. For experimentation, we have adopted the CityGML standard, a common information model for the representation of 3D urban objects. It plays a leading role in the modularization of urban geospatial information (Gröger & Kolbe 2008, Mao 2010). But, its complexity makes it is hard to implement all its specifications (Mao 2010). For our experiment, we have adopted a simplified version of CityGML based on the building thematic module (*Figure 3*) where buildings are represented in Lod2 with flat roofs.

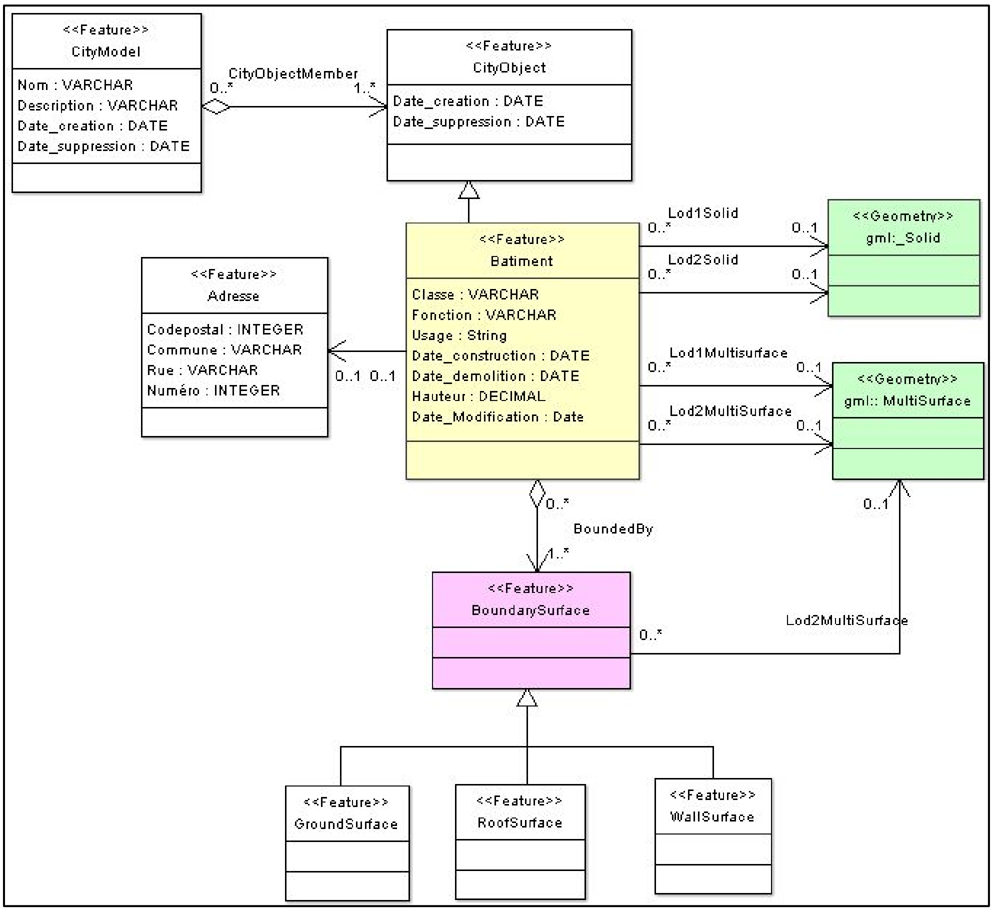

Figure 3. 3D Building Model.

Data integration

Data integration is recognized as a very complex process that researchers still accord much attention. It is conducted through tree main steps:1) The preintegration which consists of a good understanding of the content of each database and the rearrangement and mapping between models to show similarities and possible connections; 2) The correspondences investigation: through an identification and declaration of correspondences between the elements of the schemas and the geometrical instances of the databases and finally 3) The integration by defining explicit rules to translate and restructure the initial schemas and data transfer to the new system (See Sheeren et al (2004) for a detailed description). In our experiment, we have to deal with multi source data, so a data matching process is used to select the appropriate one is required.

Data matching

Since the process presented here is geometry-based, a semantic schema matching between the source model and that of CityGML is not addressed here. The objective is focused on a reconstruction of 3D geometric building features according to the CityGML geometric schema. The correspondences are investigated between the schema sources to extract features to be integrated in the CityGML database.

An obvious problem when integrating multi source data representing the same area is about geometric and semantic conflicts between competitive data. Indeed, we have encountered some data discordance due to the mode of representation of the geometry. For instance, an object can be represented in one database and correspond to a group of primitives in the second one (ex: the PICC and IGN buildings are regrouped geometrically according to differing grouping criteria which is respectively the address number and the building function). In general, matching algorithms are based on the distances between geometric locations, the shape of the objects and the topological relations. In our experiment (where data is isolated), the rules guiding the process of data matching were based on the comparison of some elements (mostly taken together) such as attributes, positions, shapes and geographical names, etc. The strategy of geometric integration was conducted with regards to quality components of source data such as accuracy, resolution, completeness and consistency. Precision and completeness of the 2D geometry were the main criteria. In some cases, two competitive data can be maintained to populate different CityGML modules. As it was indicated in the CityGML, the grouping concept allows for the aggregation of buildings according to user-defined criteria (Gröger & Kolbe 2008). Indeed, building groups according to their functions (ex: school building) can be maintained in the thematic module “City Object Group” of CityGML. This module can be used to have a generalized city model for some applications that doesn’t require detailed information on buildings. *Figure.4* illustrates a 3D Model in Arcscene obtained by extrusion of building layer resulting from data integration process.

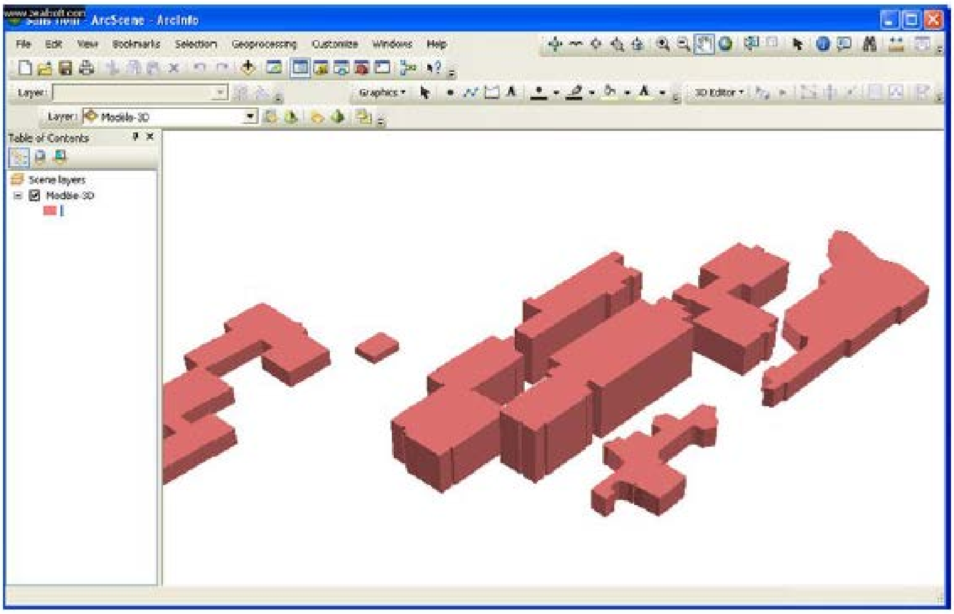

Figure 4. 3D Buildings after data matching.

3D Reconstruction

Several researchers have studied the issue about 3D reconstruction of buildings and have proposed different methods depending on the initial data source (Pénard et al 2006, Horna et al 2006, Frédérique 2008). Extruding buildings from footprints is the simplest and the well-known method to construct 3D buildings if the topological relationships between the footprints are not taken into account (Ledoux & Meijers 2009). Constrained by the nature of data source, we have adopted extrusion as a simplest way to construct 3D buildings. The file resulting from data matching is converted in 3ds format and extruded by the height attribute with FME Workbench program. The 3ds mesh file is then imported in 3dsMax to be structured in different layers, defined in the building module of CityGML (Roof Surface; Ground Surface and Wall Surface).

CityGML Conversion

After the 3D reconstruction and building structuring in different boundary surfaces, the buildings are geometrically ready to be converted to CityGML. To perform this task, FME program was used. FME is a Spatial ETL (Extract, Transform and Load) application concept which provides unlimited flexibility in data model transformation, translation and integration (Şengül 2010). The conversion process was done with several transformers. The challenge was to select the adequate ones for the conversion. Many works have addressed the CityGML conversion from shape file data using FME (as Şengül (2010)), but there is no unique way to do the conversion because FME provides a large library of transformers and also offers the possibility to develop plug-ins to reconstruct the 3D structure. In this way, the CityGML conversion can be done in one integrated process. Alternatively, we chose to use an external tool (3dsMax) for 3D modeling which offers an efficient solution to construct complex 3D structures and to prepare data to be converted to CityGML.

After conversion with FME, the resulting writer is a CityGML file which can be viewed via the LandXplorer CityGML viewer program (*Figure 5*).

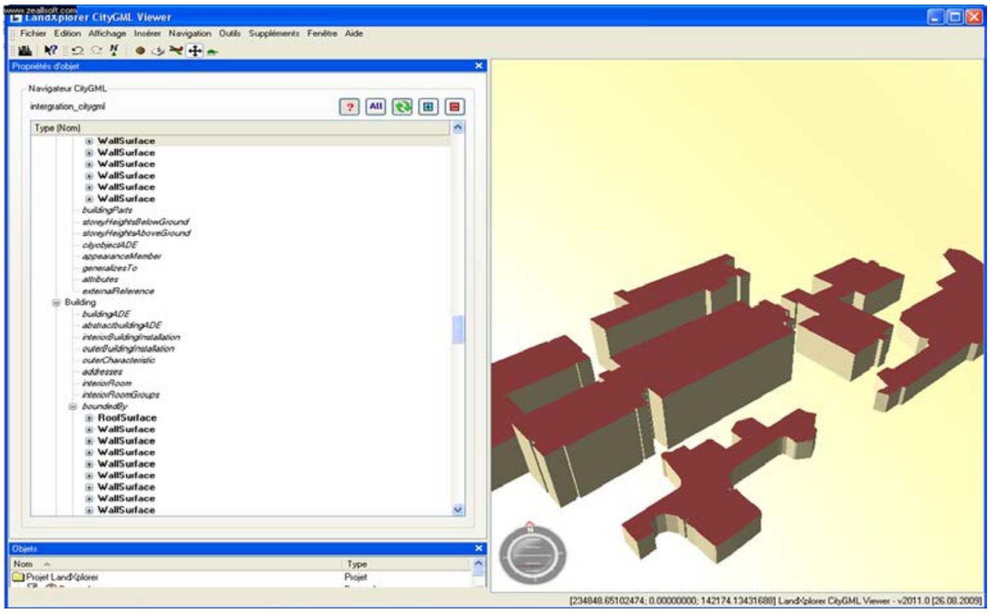

Figure 5. Building model view in LandXplorer CityGML Viewer.

Data import

For a basic experimentation, we adopted the "3DCityDatabase": a free and open source 3D geo database to store, represent and manage virtual 3D city models. The database model, based on CityGML, contains semantically rich, hierarchically structured and multi-scale urban objects facilitating complex GIS modeling and analysis tasks (Flanagin & Metzger 2008). After creating and configuring an oracle 11g/R2 database instance, the database schema was installed using the creation script (Create_DB.sql) for 3D City

Database (http//opportunity.bv.tu-berlin.de/software/projects/3dcitydb). The CityGML file resulting from the conversion is imported in the oracle database using the “3DCityDatabase Import/Export tool”: a Java based front-end for the 3DCityDatabase that allows importing and exporting spatial data for a virtual 3D city model. The Oracle SQL Developer is then used to make a connection in the Oracle database and to query the CityGML tables.

4. Conclusion

In this paper, concepts and main issues about adopting a 3D reference model are discussed. Collaboration is introduced as a promising approach to face new challenges and adopt a collaborative 3D model. A geometric process is presented to integrate existing 2D data in a 3D database compatible with CityGML. However, the data reengineering is not trivial. 3D data is more than the extension of 2D maps. Besides of establishing a common 3D model and making agreement on specifications for 3D coproduction, the future challenges are to deal with multi source 3D data integration regarding both geometric and semantic aspect.

References

Aydinoglu A.C, Quak W, Yomralioglu T (2009) Some Spatial Data Management Issues towards building SDI. In International Workshop on Spatial Information for Sustainable Management of Urban Areas, FIG Commission 3 Workshop, Mainz, Germany.

Bishr M., Janowicz K. (2010) Can we trust information?-the case of volunteered geographic information. In Towards Digital Earth Search Discover and Share Geospatial Data Workshop at Future Internet Symposium, volume (Vol. 640).

Brando C, Bucher B. (2010) Quality in User Generated Spatial Content: A Matter of Specifications. 13th AGILE International Conference on Geographic Information Science 2010 Page 1 of 8 Guimarães, Portugal

De Cambray B (1993). Three-Dimensional (3D) Modeling in a Geographical Database. Published in the proceedings of the: Auto-Carto'11, Eleventh International Conference on Computer Assisted Cartography, Minneapolis, USA, 30/10/1993 - 1/11/1993, p. 338-347.

Emgård L, Zlatanova S (2008) Design of an integrated 3D information model In Coors, Rumor, Fendel & Zlatanova (Eds,), Urban and regional data management: UDMS annual 2007 (pp. 143-156), Taylor & Francis Group, London, UK

Falquet G, Métral C (2005) Integrating urban knowledge into 3D city models, proceedings of workshop on Next generation 3D city Models, Bonn 2005.

Flanagin A, Metzger (2008) The credibility of volunteered geographic information. GeoJournal 72(3): 137-148.

Frédérique B (2008) Saisie photogrammétrique multireprésentation de bâtiments: Une approche Semi-Automatique Initialisée et Supportée par l'Intervention humainE. PHD Thesis, Faculty of Graduate Studies, Laval University

Genovese E, Roche S (2010) Potential of VGI as a Resource for SDIs in the North/South Context. GSDI Conference.

Goetz M., Zipf A. (2012) Towards defining a framework for the automatic derivation of 3D CityGML models from volunteered geographic information. International Journal of 3-D Information Modeling (IJ3DIM), 1(2), 1-16.

Goodchild M.F (2010) Twenty years of progress: GIScience in 2010. SIS, 1: pp.3–20

Gray B (1989) Collaborating: Finding Common Ground for Multiparty Problems. San Francisco: Jossey-Bass.

Gröger G, Kolbe T (2008) OpenGIS City Geography Markup Language (CityGML) Encoding Standard (OGC 08-007r1).

Haklay M (2010) How good is volunteered geographical information? A comparative study of OpenStreetMap and Ordnance Survey datasets, Planning and Design 37: 682 – 703.

Horna S, Damiand G, Meneveaux D, Bertrand Y (2006) Reconstruction topologique 3D de bâtiments

Ledoux H, Meijers M (2009) Extruding building footprints to create topologically consistent 3D city models.

Mao B (2010) Visualisation and Generalisation of 3D City Models [Elektronisk resurs]. Stockholm, KTH

Métral C, Billen R, Cutting-Decelle A-F, Van Ruymbeke M (2010). Ontology-based approaches for improving the interoperability between 3D urban models. Journal of Information Technology in Construction 15: 169-184.

Mummidi L. N, Krumm J (2008) Discovering points of interest from users' map annotations GeoJournal, Volume 72, Numbers 3-4.

Neber D (2008) Developing Spatial Data Infrastructures: the SDI cookbook.

Pénard L, Paparoditis N, Pierrot-Deseilligny M (2006) Automatic 3D Building Facade Reconstruction from Multiple Views.

Rahman A.A, Pilouk M (2008) Spatial Data Modeling for 3D GIS ISBN 978-3-540-74166-4 Springer Berlin Heidelberg New York

Sargent I, Harding J, Freeman M (2007) Data quality in 3D: gauging quality measures from users requirements

Şengül A (2010) Extracting semantic building models from aerial stereo images and conversion to CityGML. Master Thesis, Geomatic Engineering, Ýstanbul Technical University Institute of Science and Technology

Sheeren D, Mustière S, Zucker J.D (2004) How to Integrate Heterogeneous Spatial Databases in a Consistent Way? Advances in Databases and Information Systems. A. Benczúr, J. Demetrovics and G. Gottlob, Springer Berlin/ Heidelberg. 3255: 364-378 J. in 1983)

Stadler A, Kolbe T (2007) Spatio-semantic coherence in the integration of 3D city models. The 5th international ISPRS symposium on Spatial Data Quality ISSDQ.

Viglino J.M. (2011) Vers un système collaboratif pour la mise à jour de référentiels géographiques. Proceedings of the 25th international Cartographic Conference (ICC, 2011). Paris, France

Warnest M, Rajabifard A, Williamson I (2005) A Collaborative Approach to Building National SDI in Federated State Systems: Case Study of Australia.

Zlatanova S (2000) International Institute for Aerospace Survey and Earth Sciences. 3D GIS for urban development, International Institute for Aerospace Survey and Earth Sciences.