Implementation of a National 3D Standard: Case of the Netherlands

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Abstract This paper describes the motivation and problem statements as well as the ongoing investigations regarding the follow-up activities of the 3D Pilot NL.

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This pilot is a large collaboration in the Netherlands aiming at pushing 3D developments in the Netherlands. The first phase resulted in a national 3D standard, modeled as CityGML Application Domain Extension. Some insights obtained during this phase are sufficiently mature to be anchored in practice such as maintaining and further developing the 3D standard by Geon ovum and the provision of a countrywide 3D midscale base dataset which is currently under study at the Kadaster. Other results need further attention in a collaborative setting, specifically how the new 3D standard works in practice. This is currently being further explored in a second phase of the 3D Pilot in which over 100 organizations are participating. The goal of the follow-up pilot is more focused than the first pilot and aims at writing best practice documents by joint effort of the 3D Pilot community. The best practice documents are based on tools and techniques that are being developed for supporting the implementation of the 3D standard. Specific attention is being paid how to align City GML to the standard in the BIM (Building information Model) domain (IFC). Initial findings and work in progress are presented.

Keywords 3D city and landscape models · 3D standard · City GML

1 Introduction

Over the past 10 years technologies for generating, maintaining and using 3D geo-information have matured. In addition many local governments have 3D models of the city, a large number of companies are providing services for constructing 3D models, and universities and research organisations are investigating 3D technologies (3D re-construction, data management, validation and visualisation). Yet many (governmental) organisations face numerous challenges in introducing 3D applications and technologies in their day-to-day processes. Despite the practical difficulties, it is clear that 3D information is becoming increasingly important in many applications. These developments motivated a pilot in the Netherlands to advance the use of 3D in this country. The pilot was initiated by the Dutch Kadaster, Geonovum (the National Spatial Data Infrastructure executive committee in the Netherlands which develops and manages the geo-standards), the Netherlands Geodetic Commission (NCG) and the Dutch Ministry of Infrastructure and Environment.

From January 2010 until June 2011 a uniform approach for acquiring, maintaining and disseminating 3D geo-information has been explored in collaboration between over 65 stakeholders in The Netherlands (Stoter et al. 2011a). A major result of the pilot was the proof of concept for a 3D Spatial Data Infrastructure (SDI), covering issues on the acquisition, standardisation, storage and use of 3D data. The findings of the pilot were formally established in a national 3D standard realised as a CityGML Application Domain Extension. The ADE completely integrates the OGC CityGML Encoding Standard (OGC 2008, 2012) with a new version of the existing national Information Model for Geo-information

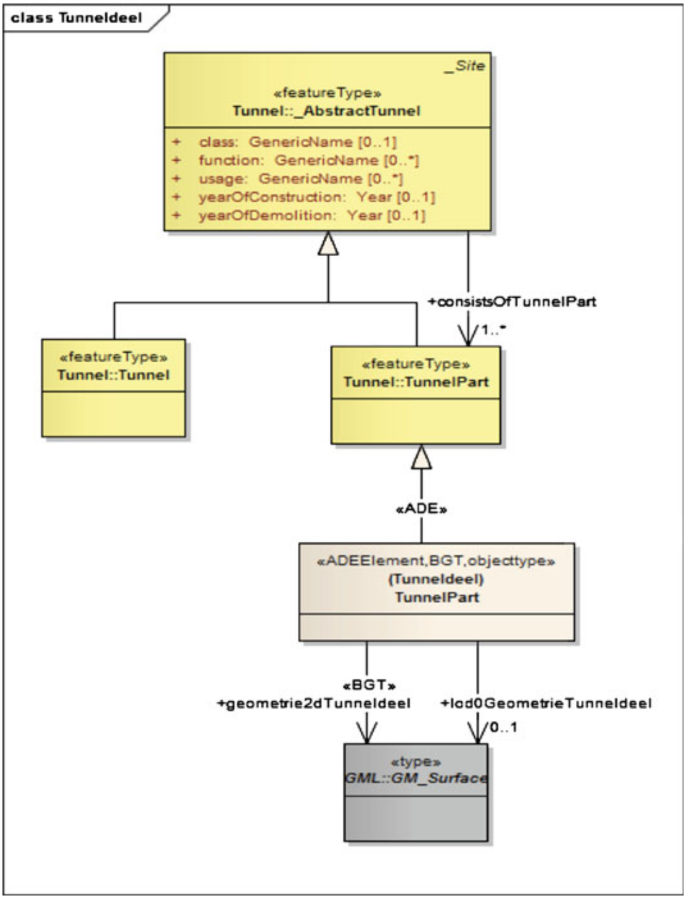

Fig. 1 TunnelPart AD element with 2D geometry

(called IMGeo; described in IMGeo 2007). IMGeo contains object definitions for large scale representations of roads, water, land use/land cover, bridges, tunnels etc. and prescribes 2D point, curve or surface geometry for all objects. As the new version of IMGeo is completely integrated with CityGML, (see Fig. 1), IMGeo version 2.0 also facilitates extensions to 2.5D representations (i.e. as height surfaces; equivalent to CityGML LOD0) and 3D (i.e. volumetric; i.e. CityGML LOD1, LOD2 and LOD3) representations of the objects according to geometric and semantic principles of CityGML.

The close integration between an existing information model for 2D geo-information and CityGML is an important step toward the practical use and re-use of 2D and 3D information. Further technical details about the ADE are reported in van den Brink (2012a, b).

Although the 3D standard is an important prerequisite for further 3D developments, wide use of 3D is still not common practice in the Netherlands. Further advances are required to assure that 3D Pilot results are implemented in actual applications. Therefore the follow-up activities have been started to make the results of the 3D Pilot further ready for practice.

These activities are described and justified in this paper. The main purpose of the paper is to describe the motivation and problem statements as well as ongoing investigations regarding the follow-up activities. On the one hand these activities elaborate on findings that are sufficiently mature to be picked in daily processes of governmental organisations (Sect. 2). On the other hand, these activities focus on further research within a similar collaborative and experimental environment as the first phase of the 3D Pilot. Section 3 describes the motivations and methodology of the second phase of the 3D Pilot and details the six activities. Initial conclusions and work in progress are finally described in Sect. 4.

It should be noted that main focus of this paper is on the construction and maintenance of 3D spatial data to support the national 3D SDI. The use of 3D data in applications was studied during the first phase of the 3D Pilot. Demonstrations of the use cases can be found at Geonovum (2012c).

2 Topics Ready for Practice

The pilot identified three main topics that are ready to put into practice in order to support further 3D developments.

Firstly, to assure that the established 3D standard NL serves as solid base for 3D innovations, the standard needs to be maintained as well as to be improved based on new insights. This is done by Geonovum and also includes studying extensions of other domain models with the notion of 3D if appropriate.

Secondly, besides the need for a national 3D standard, the pilot showed the need for a nationwide 3D base dataset. This dataset can serve as reference for (new) 3D information in the 3D virtual world and as a basis for 3D planning and management of public space, and can be further refined when a 3D project develops. Many large municipalities have 3D data sets, but these are specifically acquired for the territory of the city and in various formats and resolutions. The pilot has shown promising results for generating a 3D national topographic dataset as combination of 2D topography with high-resolution laser data, based on work of participants. Currently those results are extended to generate a national 3D topographic dataset covering the whole of the Netherlands in collaboration between University of Twente, Delft University of technology and the Kadaster (who also holds the national mapping agency).

The high-resolution data used to generate the 3D base dataset is AHN2: the National Height model of the Netherlands, obtained by airborne LiDAR systems with an average point density of 10 points per square meter. Two 2D topographic data sets are candidates for automated extension into 3D to obtain a complete 3D data coverage of the Netherlands: the large scale base data modelled according to IMGeo and TOP10NL data.

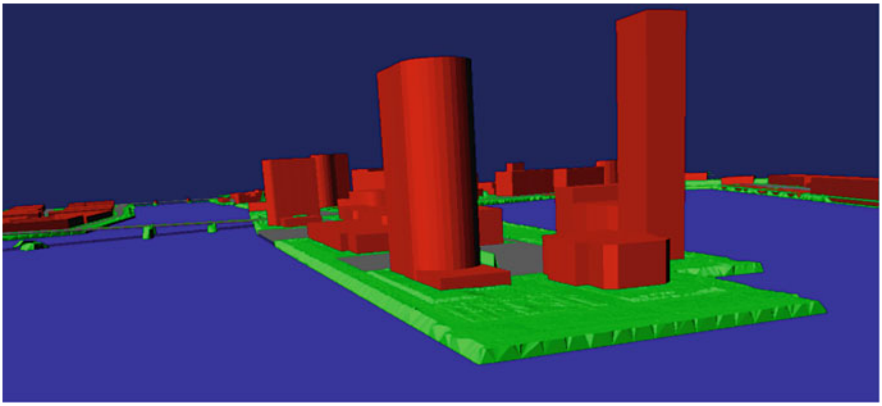

Fig. 2 First results of 3D TOP10NL (Oude Elberink 2010)

As mentioned before, the new version of the model IMGeo (focusing on scale 1:500–1:1000) has recently been established. It is expected that providers of this data—municipalities, water boards, provinces, ProRail (the manager of Dutch railway network infrastructure) and Rijkswaterstaat (Dutch Ministry for infrastructure)- will produce the data from 2015 onwards. The second candidate for the national 3D dataset (TOP10NL) is being maintained by the Netherlands' Kadaster and is available since 2005. This dataset is currently being used to generate a nationwide 3D base dataset.

The reason to focus first on the TOP10NL is not only because it is available nationwide. This less detailed scale is also better suitable for 100 % automated 3D object reconstruction since it is less demanding concerning 3D details. Consequently it was decided that 3D TOP10NL is the best option to generate and disseminate a nationwide 3D base dataset in a limited amount of time. This is currently realised by in collaboration between University of Twente and the Kadaster, see Fig. 2.

Finally, the accomplished network is considered crucial for further 3D developments in the Netherlands. Therefore the network is being maintained and supported by social media and further expanded by a continued facilitation of the 3D test bed (Stoter et al. 2011b) and through regular 3D symposia where organisations exchange ideas and experiences regarding 3D applications.

3 3D Pilot NL Phase II

In the development process of CityGML ADE IMGeo 2.0 a number of topics were identified that requires further attention before the standard can be widely implemented.

Firstly, more research is needed to understand how the national 3D standard works in practice including the consequences of this new modelling method for IMGeo when used for both 2D and 3D datasets, e.g. how to preserve the links between the different Levels of Detail (LODs) and how to upgrade 2D LOD to higher LODs. Also, knowledge is required on the ability to use 3D IMGeo data in CityGML-aware software, i.e. whether software systems are compatible with our extensions and which changes are necessary? Finally more research is needed concerning the creation and management of CityGML-IMGeo data. Which methods can be used to generate CityGML-IMGeo data? How should this data be validated and maintained?

These open issues are currently being studied in a follow-up project of the 3D Pilot. A pilot setting is again used because the first pilot has shown that fundamental 3D innovations can best be realised by an intensive collaboration of research institutes, private and public organisations. These organisations all possess unique knowledge and experiences that need to be brought together to accomplish 3D innovations. Also further agreements between many stakeholders are necessary for advances in 3D.

The goal of the follow-up pilot is more focused than the first pilot and aims at writing best practice documents by joint effort of the 3D Pilot community. The best practice documents are based on tools and techniques that are being developed for supporting the implementation of the 3D standard. Specific attention is being paid how to align CityGML to the standard in the BIM (Building information Model) domain (IFC).

In summer 2011 a new call was launched responded by over 100 organisations. These organisations, listed at Geonovum (2012b), are currently executing the six activities of the second 3D Pilot NL. The activities, including background, motivations and work in progress, will be further explained in the remainder of this section and are:

1. Generating example 3D IMGeo data for several levels of detail and classes
2. Writing example tendering documents for creating 3D information
3. Designing and implementing a 3D validator
4. Describing a generic approach for maintenance, update and dissemination of 3D IMGeo data
5. Collecting examples of 3D killer applications
6. Align CityGML and IFC/BIM

3.1 Generating Example 3D IMGeo Data

To understand how IMGeo works for the integrated 2D and 3D approach example 3D IMGeo data is being built and made available to wider audiences. The example data is also used to check whether CityGML compliant software is capable to understand the 3D IMGeo data. The example data will be specifically useful to:

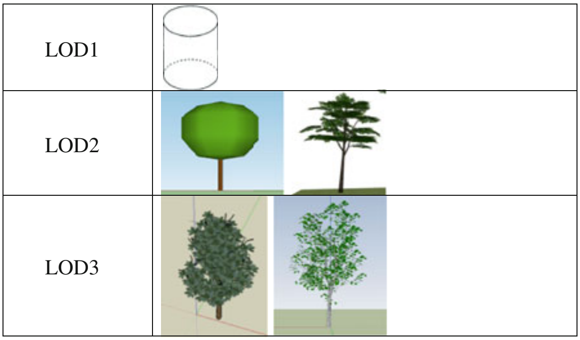

Fig. 3 LOD concept applied to trees (Clement 2011)

- Obtain insights into the 3D aspect of our approach including different LOD's, i.e. for buildings the LOD concept is well-defined, but how does the LOD concept applies to other object such as trees, see Fig. 3;
- Provide the possibility for third (new) parties to experiment with 3D IMGeo data;
- Provide test data for 3D validation tests (see Sect. 3.3);
- Show how the standard is interpreted when applied to real data (helpful for future data providers).

3.1.1 Test Area

In the previous 3D Pilot the test area was located in the City of Rotterdam. For this phase we selected a test area which is more familiar to an average municipality: situated in the municipality of Den Bosch (southern part of The Netherlands) containing a usual living area with common houses, a river and a bridge:

The source data that has been made available on the 3D Pilot data server (hosted by the Delft University of Technology) are:

- IMGeo compliant 2D data (see Fig. 4a, provided by the municipality of Den Bosch;
- Stereo photos (30 march, 2011), 10 cm resolution, provided by the municipality of Den Bosch;
- Point cloud (3 points per m2), DTM&DHM, date: April 2009, provided by the municipality of Den Bosch;
- High resolution laserdata (selected from a data set available for the whole country: *Actueel Hoogtebestand Nederland*, AHN), provided by Het Waterschapshuis;
- Ortho photos (provided by Cyclomedia);
- High resolution point cloud obtained from terrestrial laser scanning (by Cobra, see Fig. 4b
- Point clouds generated from aerial photographs (Imagem)
- Oblique photos (Slagboom en Peeters)

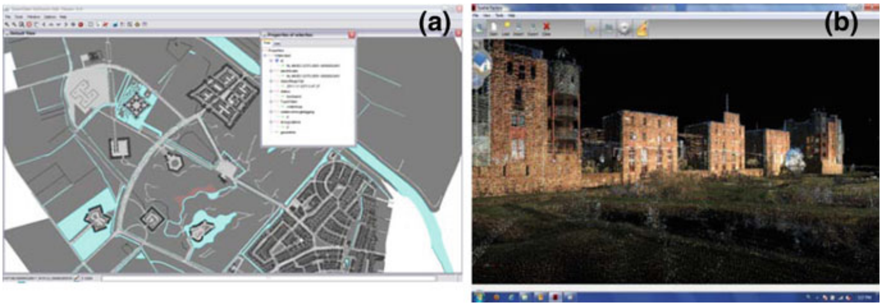

Fig. 4 Example source data available for the 3D Pilot test area. **a** 2D IMGeo data. **b** High resolution laser data, obtained by terrestrial laser scanning

To get thorough insight into the key aspects of 3D IMGeo data including how the LOD concept applies to several themes and how these data can be created accordingly, the following 3D information will be created:

- LOD3 of a selected number of buildings as combination of AHN2, stereo photo's, texture information and 2D IMGeo data;
- LOD3 of both the bridge and the lock situated in the test area (see Fig. 5a, b); This is being done by the company "Coenradie". The modelling of the bridge are visualised in Fig. 5c and d.
- LOD0 of the complete test area (as combination of AHN2 and 2D IMGeo);
- LOD1 of all buildings in test area (as combination of AHN2 and 2D IMGeo);
- LOD2 of city furniture (traffic signs);
- LOD2 of trees;
- LOD3 of a selected number of points of interest.

During the work of activity 1, decisions have to be made and tips and tricks will be formulated. These experiences gained from the technical operation of IMGeo 2.0 will be supportive for future use and creation of 3D IMGeo data. And this will be important input for the example tendering documents (Activity 2).

3.2 Tendering Documents for Creating 3D Information

Usually a municipality will outsource the 3D data acquisition for 3D IMGeo data. For most municipalities 3D is a new domain and example-tendering documents may help them to precisely specify what to ask the market. In a next step, when the data is delivered, the specifications can be used as acceptance criteria, i.e. to check the quality of the data. For private companies these documents are helpful since they both clarify and unify the demand for their services.

Apart from the experiences gained from building example data (activity 1), the tendering documents will be based on experiences of cities that have already invested in 3D city models, i.e. The Hague and Rotterdam. Both cities faced difficulties in

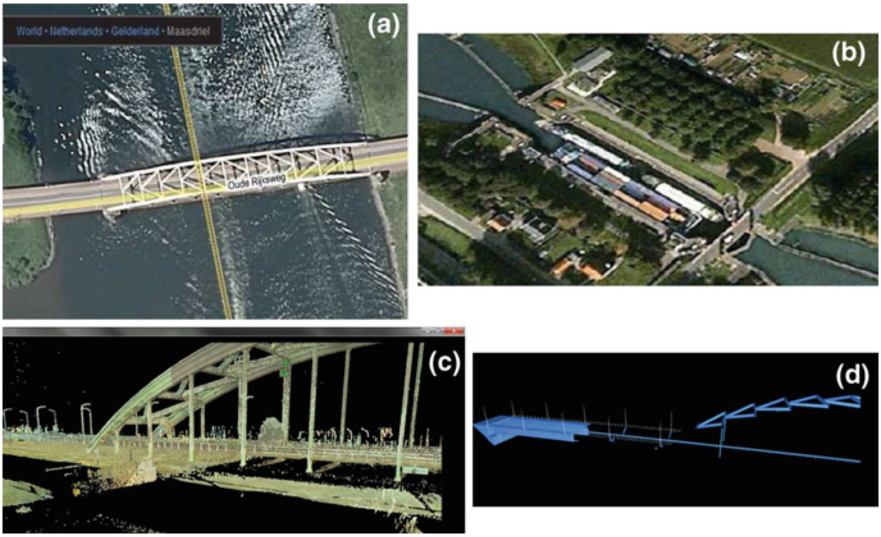

Fig. 5 Objects in test area to be modelled at CityGML LOD3. **a** Bridge. **b** Lock. **c** Point cloud of the bridge. **d** Model of the bridge (in progress)

comparing offers from different companies because the specifications appeared to be interpretable in several ways and this also caused problems in setting up acceptance criteria for the delivered product. The result is that the CityGML datasets differ between the two cities but it is not always clear whether this was intended.

Since the example tendering documents will be a joint effort of the 3D pilot community, they will be based on knowledge, interests and experiences of research institutes, private and governmental organisations and not only based on the information available at the bidder as currently practiced.

Several variants of the tendering documents are possible based on the available source data (i.e. point clouds or high resolution photographs) and the ambition level (i.e. which information at which LOD).

3.3 Design and Implementation of a 3D Validator

A validator is necessary as an independent tool to verify whether a dataset is compliant with IMGeo 2.0, or not. This also applies for the 3D extensions. When validating objects, it is necessary to validate both the semantics and the geometry. The former is according to the classes of CityGML and/or of the IMGeo extensions, and the latter is according to the international specifications (e.g. ISO19107 and GML). Geonovum has already built a validator for IMGeo datasets [the software is available as open source software, see Geonovum (Geonovum 2012a)], but it is only for two-dimensional primitives.

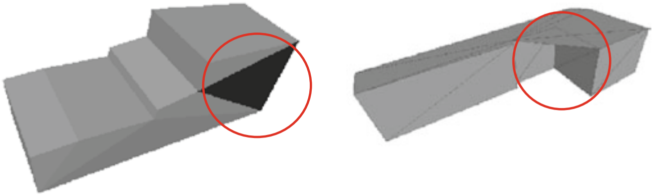

Fig. 6 Two real-world invalid buildings

This activity primarily studies which functionalities are necessary to validate the geometry of 3D solids. During the first 3D Pilot we have noticed that several real-world datasets have objects that appear to be valid when looking quickly at them, but in reality they are not. Figure 6 shows two examples. These (often small) problems prevent users from, for instance, convert their objects to other formats (including BIM and CAD formats, see Sect. 3.6) and also to analyse them (the volume of an invalid solid could be impossible to calculate).

While different definitions of a valid 3D object are used in different disciplines, we focus on the definition given in the ISO standards (ISO 2003) and implemented with GML (OGC 2007). A GML Solid: "The extent of a solid is defined by the boundary surfaces as specified in ISO 19107:IS0 2003. gml: exterior specifies the outer boundary, gml: interior the inner boundary of the solid" (OGC 2007). Without going into all the details, we can state that a solid is represented by its boundaries (surfaces), and that like its counterpart in 2D (the polygon), a solid can have 'holes' (inner shells, or cavities) that are allowed to touch each others, or the outer boundary, under certain circumstances. To be considered a valid solid, a solid must fulfil several properties. The most important are: (1) it must be simple (no self-intersection of its boundary); (2) it must be closed, or 'watertight'; (3) its interior must be connected; (4) its boundary surfaces must be properly oriented; (5) its surfaces are not allowed to overlap each other.

We are currently building an open-source 3D validator. This is because none of the surveyed GIS packages that provide functionalities for validating 3D objects was fully compliant with the definition of the ISO. Our validator is based on the work of Ledoux et al. (2009) and is ISO-compliant. It uses advanced data structures and operations to analyse the topological relationships between 3D objects. Furthermore, it will be built as an extension to the current validator for 2D (developed by Geonovum) so that the geometry of 3D objects can be taken into account while using the same website with the same workflow.

Finally, other validation issues will be investigated. We plan to investigate the validation of not only solids, but also 3D MultiSurfaces as these are often used (buildings are often modelled without the ground floor for instance).

3.4 Maintenance, Update, Visualisation and Dissemination of 3D IMGeo

After having invested in a good 3D model, the next question is how to maintain and update the model. Can mainstream DBMSs be used? How to update: integrated with the existing data processes, renewed creation when the 2D data changes or a mix of both? For the maintenance of the data it is a relevant question how to guarantee that 3D IMGeo data remains synchronized with the 2D data. The challenge differs if the 3D data is managed separately from 2D (how to maintain 3D data? In a 3D spatial DBMS?) or generated on the fly.

An important first step is to obtain more insight into how CityGML data encoded in CityGML files can be maintained and updated.

Therefore a challenge was organized in order to study the state-of-the-art of 3D editing in commercial software. Four neighboring CityGML data sets (courtesy of the Municipality of The Hague) were provided and the following challenges were defined:

1. Integration of CityGML files

   Create one 3D model of the four adjacent neighbourhoods by integrating the eight CityGML files. The resulting 3D model can either be stored in a database, a CityGML file or another file format (without loss of information).

2. Editing in CityGML files

   File 13_buildings.xml contains a building with id {B65F9980-76C8-4F8C-8449-243FE4FD168E}. Select this building, add another storey on top of it and save the results in another CityGML file

3. 3. Enrichment of CityGML files from other sources

   File 12_buildings.xml contains o.a. the “Binnenhof” in The Hague (houses of parlement) in CityGML format. Show how the two more detailed KMZ models of the Binnenhof can be used to enrich the CityGML files and save this enriched model as a CityGML files.

4. 4. Bonus question

   For those vendors that encounter no problems with the challenges above: pick a more complex operation and demonstrate this

In addition to these challenges it was mentioned that it was up to the vendors to decide in which environment or format the actual edits were made, as long as both input and output were in CityGML format without any loss of data.

Up till now the following companies demonstrated their capabilities: StrateGis, Toposcopie, CPA Systems, Safe and Bentley. Results and findings are presented in the remainder of this subsection.

3.4.1 StrateGis—Gebiedsontwikkelaar

StrateGis is a Dutch company, founded in 2006, focusing mainly on decision support systems for urban planning. Their system "Gebiedsontwikkelaar" (which roughly translates as "Space developer") supports interactive planning and provides insight in the costs and benefits of different versions of plans. Although originally based on Microsoft Excel, with the emphasis on financial consequences, StrateGis now also supports 3D planning. The 3D modeling module is based on Sketch Up.

Challenge Results

Importing the separate citygml files turned out to be a straightforward operation, although it took a significant amount of time (30–60 min). Since the Gebiedsontwikkelaar incorporates the SketchUp API for editing, the challenges on building edits and KMZ texturing were easy. Exporting the results back to CityGML is also possible with the export to citygml functionality of Sketch Up. So from a modelling point of view the Gebiedsontwikkelaar does not offer any additional functionality over Sketch Up, But the product enables financial analysis based on the 3D model of The Hague, although it turned out to be rather time consuming. Outputs are visualized in Fig. 7.

3.4.2 Toposcopie—Toposcopie

Toposcopie is a small Dutch company that has developed 3D modelling software based on terrestrial photogrammetry, using inexpensive regular cameras. Already in 2007 the support of CityGML was added to te existing VRML support.

Challenge results

The Toposcopie module Append is designed for this purpose. As a result, integrating the CityGML files was easy.

Toposcopie also uses SketchUp for 3D edits. Two different approaches were selected for this challenge. This first option is to separate the specific building from the CityGML file and import only this building into Sketch Up. After editing, the results are exported to CityGML format and integrated in the CityGML file. Although this approach is the fastest, it does require specific knowledge of CityGML in order to be able to separate and later integrate the specific building. The second option does not require specific CityGML knowledge, as it converts the entire file into Sketch Up. After editing it converts the entire file back into CityGML format. Although easier, it is obviously more time consuming.

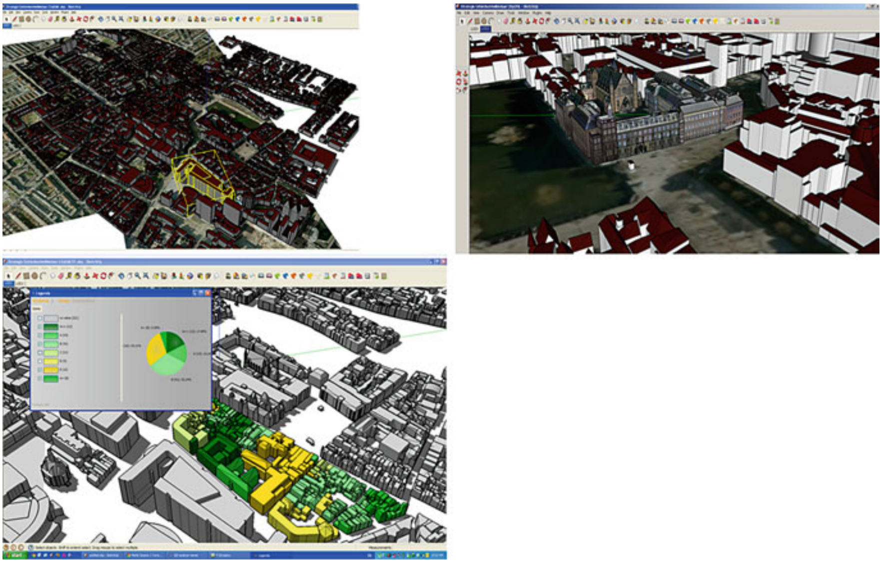

Fig. 7 Screenshots of the strateGIS solutions

This time the KMZ is directly imported into SketchUp and than exported together with the 3D model exported to CityGML. In order to position the KMZ-model Toposcopie uses its module Convert And Translate KML.

Although the conversions between CityGML and Sketch Up include the ID's it has to be checked whether the other attributes are also preserved during these conversions. Outputs are visualized in Fig. 8.

3.4.3 CPA Systems—SupportGIS

CPA systems is a German company that focuses on OGC compliant geo DBMS's, 3D city models and municipal applications. With Support GIS CPA offers a database solution, independent of any specific GIS software, DBMS manufacturer and operating system (see Fig. 9). Their solution is based on ISO and OGC standards in order to achieve interoperability. Data models can be incorporated through XSD schema's, geo-information is im- and exported in GML, the JDBC kernel is used to create OGC compliant web services. Support GIS consists of a database, an editor and a viewer. Support of 3D data is accomplished through the Google Sketch Up API. In cooperation with GeoRes, one of CPA's partners, exports to Google Earth and Bing are created.

Challenge results

Merging the files was done by loading all CityGML files into the database. This turned out to be easy, since there were no gaps or overlaps between the separate

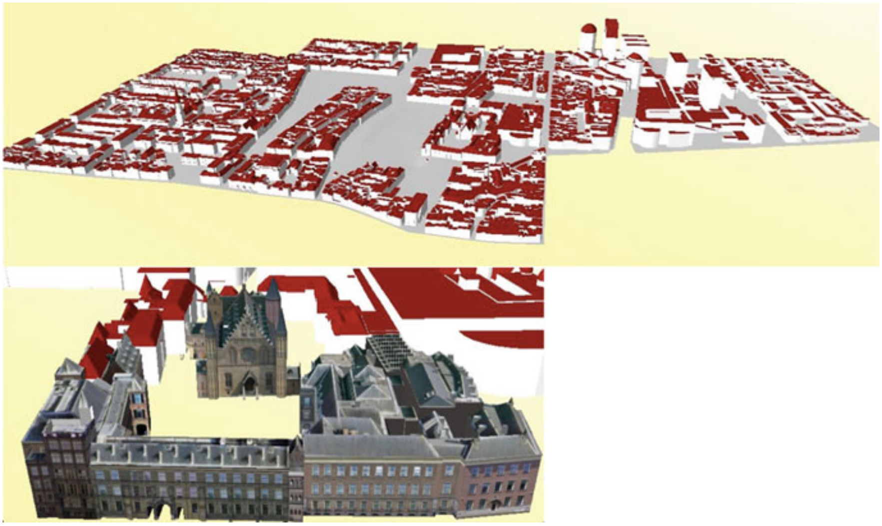

Fig. 8 Screenshots of the toposcopie solutions

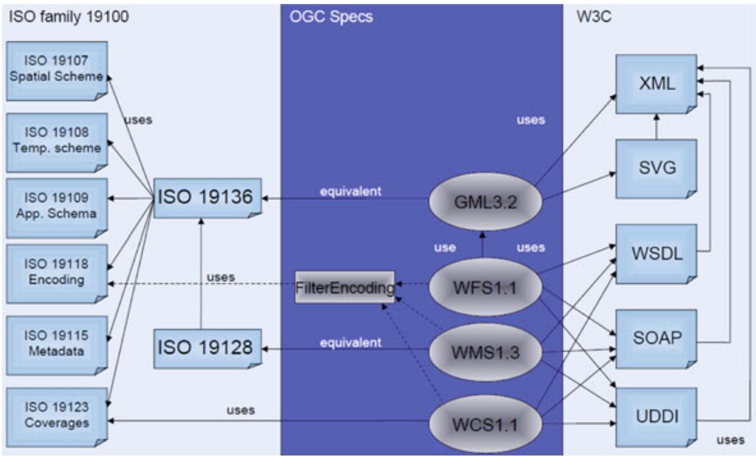

Fig. 9 Schema of the CPA approach

cityGML files and all ID's were unique. Editing is also enabled in a separate Editor. Since the building consists of multiple building parts, it was decided to select all building parts of this building and raise their height with a standard function of the editor. Integrating the KMZ model was performed again trough the Sketch Up API, followed by an export to CityGML format.

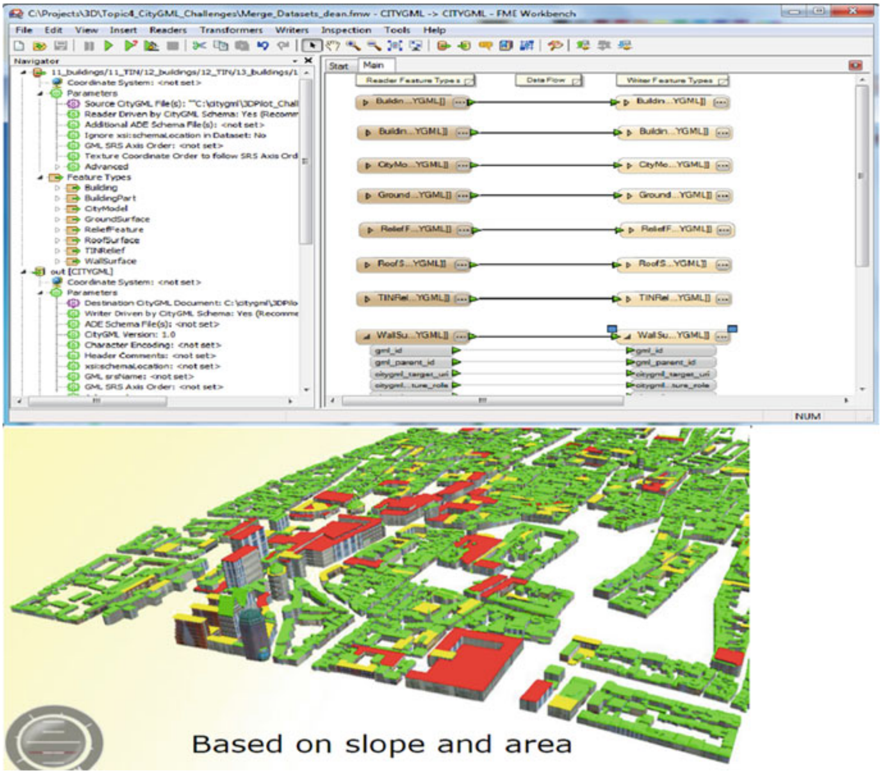

Fig. 10 Screenshots of the safe software approach

3.4.4 Safe—FME

Safe offers with FME a solution for data transformation issues, supporting over 275 different data formats. Transformation issues include both transforming between formats and coordinate systems and transforming data models and schemas.

Challenge results

Merging the separate files is done by a simple workbench, with multiple readers and writers. As FME is not a intended as an editing environment, the editing challenge was not presented.

The integration of a KMZ model was also performed with a simple workbench, although it turned out that the FME Data inspector did not show texture. In the CityGML file itself however, the textures were present. As an additional challenge a filter was presented to identify high risks in case of huge snow loads, based on roof area and slope. Screenshots by Safe Software are visualized in Fig. 10.

3.4.5 Bentley—Bentley Map

Bentley (a GIS/CAD vendor) used their module Bentley Map to face this challenge.

Challenge results

Merging the files was accomplished by importing all files into Bentley Map. Since Bentley Map uses FME to do so, the results were the same as the results of Safe. Modifying structures is well supported with the drawing functionality from Micro station. An edit was demonstrated in which a surface was extruded first, then a center line was added and as a last step this center line was extruded in order to create a saddle roof. Converting the results back to CityGML format was performed using FME again. Bentley showed two additional edits: first the creation of cross sections of 3D models to simplify interpretation of 3D situation and second a solar exposure analysis.

The preliminary conclusion of the challenge to maintain City GML data is first that the five vendors showed solutions that (partially) rely on either Google Sketch Up (or the Google Sketch Up API) or FME. In addition database solutions for 3D data are rare. Therefore the availability of good import and export functionalities for CityGML (and the ADEs) is essential, which gave motivation to plan a "City GML relay" as follow up step of these challenge-outcomes (work in progress).

3.5 Collecting Examples of 3D Killer Applications

Although a 3D application are common practice for many professionals, 3D is new and considered as "complex" and "expensive" to others. To show the need for 3D to policy makers and new comers in the field, this activity is collecting examples of 3D applications that are already practised by the 3D pilot participants and make them available in an easy accessible format (flyer, PPT, Website). Specific attention is paid to the integration-role of 3D information, i.e. as base information for many applications, see Fig. 11.

3.6 Align CityGML and IFC/BIM

In both GIS and BIM domains it is acknowledged that the integration of both types of data is beneficial. BIM data is commonly modelled in the IFC standard and 3D GIS data can be encoded in CityGML. The two standards model similar object types. Therefore it is relevant to see how these two standards map, integrate and interact with each other.

BIM (i.e. design) data can feed GIS data and GIS can serve as reference for BIM data. However, integration should acknowledge the differences between both

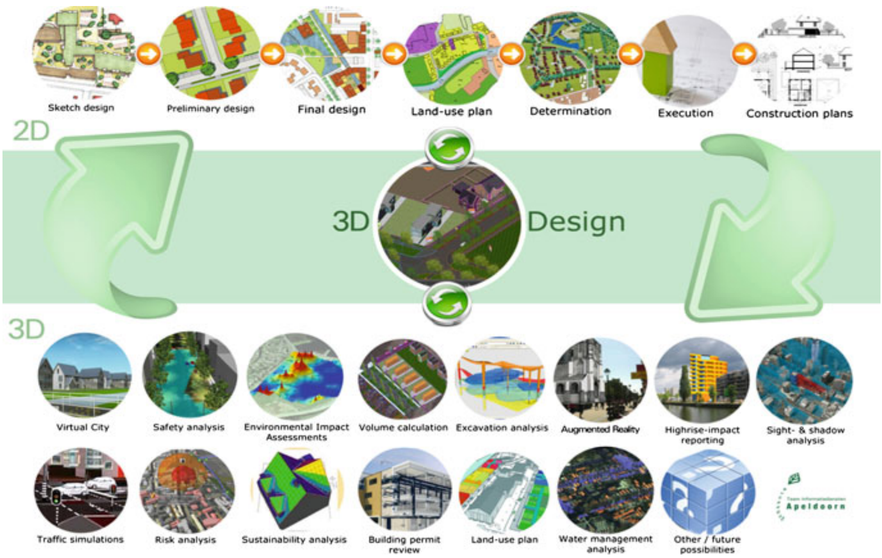

Fig. 11 Screenshot of the 3D pilot website with uses cases (the *circles* represent the different uses cases)

types of data. To start with, the object description of BIM and GIS (e.g. CityGML LOD4) differs significantly. In addition GIS is characterised by coverage of large areas (e.g. a complete city) and lower precision, while BIM is characterised by its local and very detailed approach, the limited number of construction models usually available in a city and high precision necessary for reliable construction calculations. Also the modelling approaches of CityGML and IFC differ significantly, i.e. IFC models much more classes and allow also non-hierarchal relationships, where CityGML contains a limited number of classes structured via hierarchical relationships. Another core issue for bidirectional transformations are additional geometry types that are handled in the building industry and can be captured in IFC instances (Nagel 2007). Among them are Boundary Edge Representations (BRep) and Constructive Solid Geometry (CSG), which are frequently used as implicit capturing formats while CityGML is limited to explicit polygonal representations. While polygonal representations can be derived from these geometry types in a straightforward manner (thus transforming IFC to CityGML), it is impossible to generate e.g. efficient CSGs from triangulated surface representations.

Several studies have shown that a conversion between IFC and CityGML is possible, see (Isikdag and Zlatanova 2009; Berlo and De Laat 2010; Bormann 2010; El-Mekawy et al. 2010). However, because of the different modelling approach of both information models, there is not one optimal or uniform conversion.

Therefore, based on experiments and a study on best practices, this activity is working on making agreements how to best realise the alignment between the two standards; e.g. agreements on a unique mapping between IFC and CityGML to make sure that a conversion always happens in the same meaningful way. This will also avoid the currently common situation that the rich semantics of IFC is lost because all objects are converted in the GenericObjectClass. Also it may help to model according to specific rules in IFC to make sure that specific CityGML concepts can be derived (e.g. LOD2 Buildings) from the IFC data. Those agreements will be formulated as recommendations to the relevant standardisation organisations, i.e. as change requests to Building Smart (2012) and OGC for generic issues and to national standardisation organisations for the national specific issues.

Because IFC and CityGML both serve different applications, it is important that both the original IFC source data and a CityGML representation are available and that CityGML objects explicitly refer to their interrelated IFC objects and vice versa. In this specific activity we studied how this can be done by joint effort from IFC and CityGML experts.

Referring from CityGML objects to IFC objects

The integration between the source IFC data and the 3D CityGML data can be maintained through a link between the two representations.

In CityGML one can refer to an external object via “external references”. This reference maintains the link to the external objects from which the CityGML data was derived. One CityGML object can contain more of such external references.

The external reference is a URI (either URL or URN). Every object that is a subclass of IfcRoot (all semantic classes) has an UUID identity that is compressed into a unique ID within the specific dataset, for example 3QbcAsYsg7Hvx$4VHzijdF. This ID can be converted into a 128-bit UUID via a publicly available method and can be used in the CityGML external reference.

For example linking a CityGML Building to a IfcBuilding can be done via an URN based on the decompressed GUID of the IfcBuilding:

urn:uuid:[UUID]
or based on the compressed ID:
urn:ifc-guid:3QbcAsYsg7Hvx$4VHzij

It is still not clear if the IFC GUIDs should be used in the reference or the uncompressed UUID. Both seems possible because a compressed ID can be converted into an uncompressed ID and vice versa.

Another option is to use an external Reference that contains a http URL. The advantage is that it is both identification and a reference to the location where more information can be found about the object. In contrast, a URN is only an identification; to find more information about the object an extra step is required to resolve the URN to a location on the internet. An example is the BIM Server (www.bimserver.org) where every IFC object has a URL. This could simply be used as CityGML external Reference for every object that was derived from an Ifc object.

This next example shows a CityGML XML fragment with in **bold** an external reference:

<core:cityObjectMember>

<bldg:Building gml:id = ”Build0815”>

<core:externalReference>

<core:externalObject > .

<core:uri > urn:uuid:550e8400-e29b-41d4-a716-446655440000 </core:uri>

</core:externalObject>

</core:externalReference>
<bldg:function
codeSpace = ”http://www.sig3d.org/codelists/standard/building/2.0/_Abstract Building_function.xml”>1000</bldg:function>
<bldg:measuredHeight uom = ”#m” > 8.0 </bldg:measuredHeight>
<bldg:storeysAboveGround > 2</bldg:storeysAboveGround>
<bldg:storeyHeightsAboveGround uom = ”#m” > 2.5 2.5 </bldg:storey HeightsAboveGround>
<bldg:lod2Solid > … </bldg:lod2Solid>

</bldg:Building>

</core:cityObjectMember>

A similar approach of referring to external objects is available in IFC and therefore this solution can establish an integration on the semantic level. It should be noted that this reference mechanism does not solve the problem of mapping the boundary-presentations of CityGML to the component-assemblage representations of IFC. Instead, the external references make it possible to use IFC as a kind of additional LOD5 representation of CityGML objects. This is a simpler approach, than modeling IFC as Application Domain Extension (Berlo and De Laat 2010).

4 Initial Conclusions and Work in Progress

This paper presents the follow-up of the 3D Pilot NL, which is a large collaboration in the Netherlands aiming at pushing 3D developments in the Netherlands. The first phase resulted in a national 3D standard. Some results and insights obtained during the first phase are sufficiently mature to be anchored in practice such as maintaining and further developing the 3D standard by Geonovum and the provision of a countrywide 3D midscale base dataset which is currently under study at the Kadaster (collaboration with University of Twente). Other results of the first 3D Pilot NL phase need further attention, specifically how the new 3D standard works in practice. This is currently being further explored in a second phase of the 3D Pilot in which 100 organizations are participating.

The main conclusion of running the 3D Pilot is the change of vision concerning 3D in the Netherlands. At the start of the 3D Pilot (March 2010) many saw that 3D had potentials, but did not know how to deal with 3D. In the course of the pilot the ambitions for 3D have become much more focused, also supported by the national 3D standard. These ambitions are further developed now the second phase of the pilot is running. Several aspects appear to be crucial for the adoption of the 3D standard. Firstly, the engagement of many stakeholders is important to gain the necessary support. Secondly, aligning to the ongoing 2D efforts makes that 3D applications become in reach for governmental organizations. In addition, collaborating is important because the issues of 3D are complex and sharing knowledge between different 3D experts is therefore important to realize innovations. Finally, it has been important that some national organizations took the responsibility to facilitate the process. Although the pilot is a joint effort and 'owned' by the community, national organizations have to initiate and facilitate such a network organization and they are important for anchoring the results.

Currently the work on the six activities of the 3D Pilot NL II is running in parallel, supported by discussions within the 3D Pilot NL LinkedIn group (over 500 members) and frequent meetings. 3D test data have been prepared for the test area and several participants are currently working on generating different LODs and different themes for 3D IMGeo data. The 3D validator is being developed, a contest for maintaining and updating 3D CityGML data has been launched and killer applications for 3D are being collected. In addition the information models IFC and CityGML are studied for possible integration, and the possible mappings, alignments and conversions are discussed in dedicated working sessions. Also the integration of 3D IMGeo with the subsoil (i.e. geology and cables & pipelines) is being studied (see also the work of Becker et al. 2010; Hijazi et al. 2010; Zobl and Marschallinger 2008).

The 3D Pilot will finish in summer 2012. Among the end results are: examples of 3D IMGeo data, a 3D validator, best practice documents of how to acquire, maintain, update and disseminate 3D IMGeo data, demonstrators that show the potentials of 3D, and recommendations for further developing CityGML compatible with 3D standards in other domains and with the established 2D information models. The results will be presented to the wider (professional) public in a special issue of a Dutch professional magazine on geo-information and a national 3D symposium.

From our national pilot we have observed that 3D is increasingly vital for managing and planning our densely built environment. Therefore 3D information will be more and more important for governmental organisations. To move forward in the highly complex domain of 3D information, we consider agreements and collaborations essential. In addition a national consensus on a generic 3D approach supported by a 3D standard diminishes the risks of investment for individual organisations. This is accomplished in the 3D Pilot NL.

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