TOPOSCOPY: A MODELING TOOL FOR CITYGML

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Abstract:

The new 3D standard CityGML has been attracting a lot of attention in the last few years. Many characteristics of the XML-based format make it suitable for storage and exchange of virtual 3D city models. It provides possibilities to store semantic and geometric information and has the potential to incorporate topological models. A large number of CityGML models are already available in different parts of the world. However, still the creation of a 3D model according to conceptual schema of CityGML remains a challenge. In this paper we present a modeling software Toposcopy, which allows for creating 3D models and exporting them in CityGML format. Toposcopy follows basically a close-range photogrammetric approach to re-constructs 3D models with the help of 2D map and terrestrial geo-referenced images. The approach uses perspective projection to link points on the photos with the corresponding points on the 2D map. A soon as the 3D model is re-constructed, it can be organised according to CityGML spatial schema. Toposcopy appeared to be a handy tool to produce CityGML in LOD 1, 2 and 3. The process of modeling is relatively fast, since various parametric shapes can be applied for a large number of houses. Import and export routines are written, that allows visualizing spatial designs in a 3D topographic data-set. The developed software was tested in several projects. The paper will present the software, the performed tests and will discuss challenges in creating of CityGML features. The paper concludes with suggestions for improving CityGML

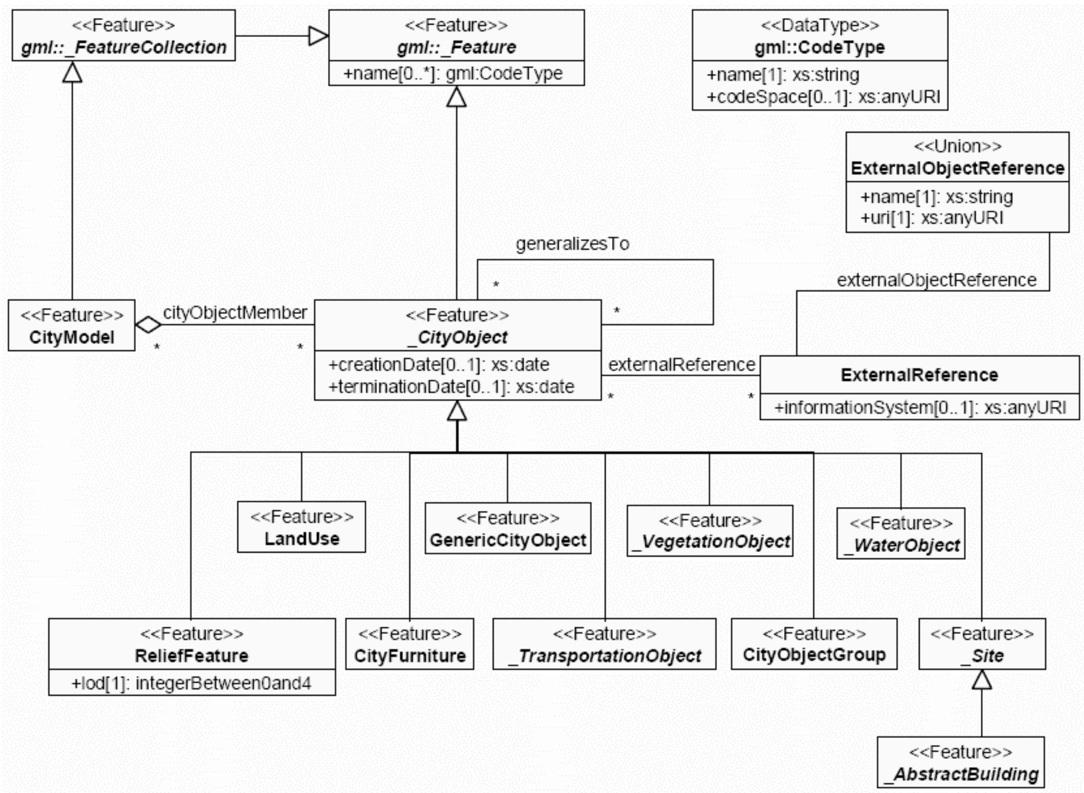
Keywords: CityGML, toposcopy, modeling, infrastructure, 3D topography

1. INTRODUCTION

3D spatial information is becoming widely used in the last years. At the moment we are facing an important paradigm change of spatial information; from 2D to 3D. The interest for 3D geographic tools such as Google Earth and Microsoft Visual Earth is growing. Intensive 3D developments are taking place in all the large GIS manufactures. In 2008, the majority of the large GIS software companies announced extended 3D functionality within database technology (e.g. Oracle Spatial 11g), GIS Software (ESRI ArcGIS 9.2) and spatial data processing (SAFE, FME). The new technology also brings challenges. With the growing possibilities to collect, use and integrate 3D spatial data from various fields, the critical question arises how to organise, integrate and exchange 3D spatial data of urban space. Currently, companies working on various projects experience various problems in sharing and managing of 3D information. Different file formats, software, models and tools are only few of the problems mentioned while discussing heterogeneity challenges. An appealing example for 3D data integration from different sources is the work on infrastructure projects. One of the main problems is the lack of common data models in which data created in different specializations can be represented together. Furthermore, due to differences in semantic or geometric properties, no guarantees are given that the set of data from one GIS or CAD system are usable in another (Coors 2003, Emgard &Zlatanova 2008a, Oosterom et al 2006, Tegtmeier 2007a). Several international standards and industry specific formats have been developed for geometric and semantic description of natural features as well as design features both above and below the earth surface. Two major problems can be observed here: 1) the formats and data models are often domain specific and 2) the geometry representation is mostly two-dimensional. For example, NADM (NADM2004) and

GeoSciML (GeoSciML 2007) are representing geological observations and features under the surface and the IFC standard (ISO/PAS 16739) is dealing with semantic description of design objects (mostly buildings). The INSPIRE initiative (INSPIRE 2007) deals with harmonization of topographic features while the CONGOO (Pantazis 1997) and Towntology (Teller 2007) project concentrate on city environments. Additionally, various standards describing 3D geometry and occasionally semantics exist such as Multipatch, OpenFlight, X3D, GeoVRML, U3D, KML, LandXML, QUADRI etc, but they concentrate on feature properties related to visualisation only and lack the semantic aspect.

Figure 1: Top-level classes of CityGML (Gröger et al 2008)



In this respect the Open Geospatial Consortium (OGC) standard CityGML (Groder et al 2008, Kolbe en Groder 2003) is the only information model for data exchange of 3D city models. One of the reasons for creating such a model was to enrich 3D city models with thematic semantic information, i.e. information about what real feature a geometric object describes. The information model of CityGML (implemented using GML3) is today the best framework for semantic-geometric relations of 3D objects. Nevertheless, the current version of CityGML still lacks integration of subsurface features such as geology, utility networks and underground constructions (e.g. tunnels). Research and initial implementations are reported in (Emgard & Zlatanova 2008b, Tegmeier et al 2007b). The interest in CityGML is growing. Several viewers allow for visualisation of 3D models and commercial companies are working on CityGML export (Lapierre and Cote 2008). CityGML does maintain a good taxonomy and aggregations of Digital Terrain Models, sites (including buildings, bridges, tunnels), vegetation, water bodies, transportation facilities, and city furniture (Figure 1). The underlying model differentiates five consecutive levels of detail (LOD), where objects become more detailed with increasing LOD regarding both geometry and thematic differentiation.

CityGML uses a subset of the geometry model of GML3 and is based on the standard ISO 19107 Spatial Schema (Herring 2001). In CityGML, *implicit geometry* refers to the principle that “a geometry object with a complex shape can be simply represented by a base point and a transformation, implicitly unfolding the object’s shape at a specific location in the world coordinate system”. *Explicit modeling*, on the other hand, is representing the object by absolute world co-ordinates (Gröger et. al. 2008)

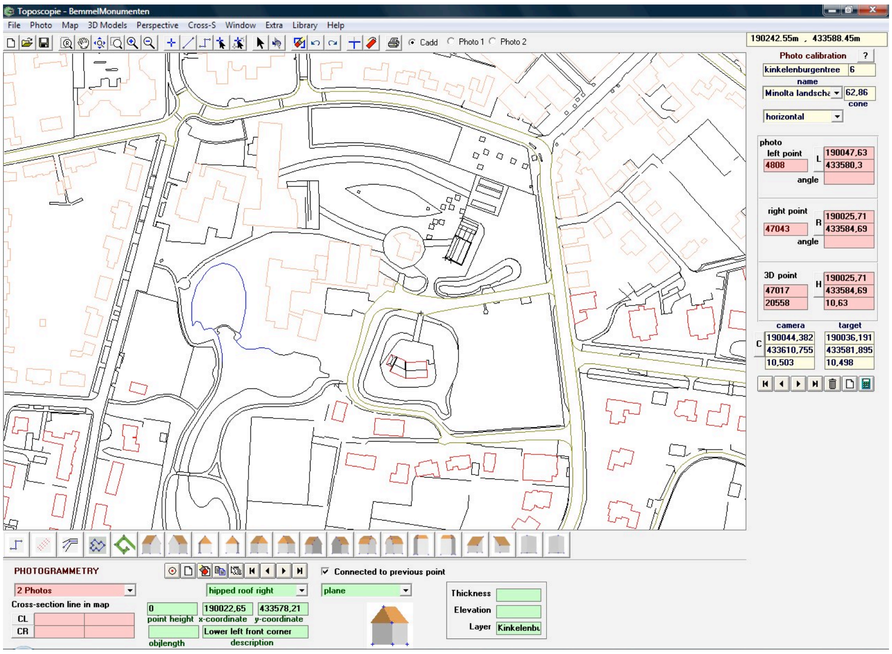
Estimating the potential of CityGML in exchange and storage of 3D data, the project Geo-Information Management for Civil Infrastructure Works (GIMCIW, http://www.gimciw.nl), funded by the Dutch program Space for Geo-information (RGI) has decided to investigate its applicability within the project. This was completed with the help of Toposcopy (a 3D reconstruction software), which was adapted to export CityGML. This paper discusses the performed developments and present experienced problems in transforming existing 3D models (or newly created within Toposcopy) into CityGML.

The next section presents briefly the 3D reconstruction software Toposcopy. Section 3 explains how the different objects are coded in CityGML. Section 4 presents some of the results in the pilot project.

2. TOPOSCOPY METHOD AND SOFTWARE

Toposcopy is a 3D reconstruction software based on photographs, 2D map and field managements (Groneman, 2003). The software links a 2D map to photos taken in a horizontal or upward direction through a perspective calculation of 2 or 3 points that can be identified both in the photo and the map. After the data has been processed the map and images form an interactive 3D system (Groneman 2004, 2005).

Figure 2 The interface of Scope with a loaded topographic map



The main program of Toposcopy (www.toposcopy.com) is called Scope. Figure 2 shows the interface with a CAD drawing loaded. The system can also load 2 photos at a time. Besides the general CAD toolbar at the top of the screen, there is a bar with specialized tool buttons that automate the procedures to make ground planes, extrusions and parametric models of buildings. At the right-hand side of figure 2 is the calibration window, where a photo is being linked to the map. Most data are entered by clicking on points in either the photo or the map. The calibration varies according to the available hardware and data. When the camera point is not known, it can be calculated in Scope after clicking on 3 points in the map and in the photo. In such a case the angle of the viewing cone has to be estimated. When the camera point is located with one of the standard land survey methods or is just known in the map the viewing cone can be calculated instead. The orientation is determined with a 3D point that is known in the map and can be seen in the photo. The software is developed primarily for the

Dutch market and therefore the available parametric shapes are designed to represent the most common Dutch building types.

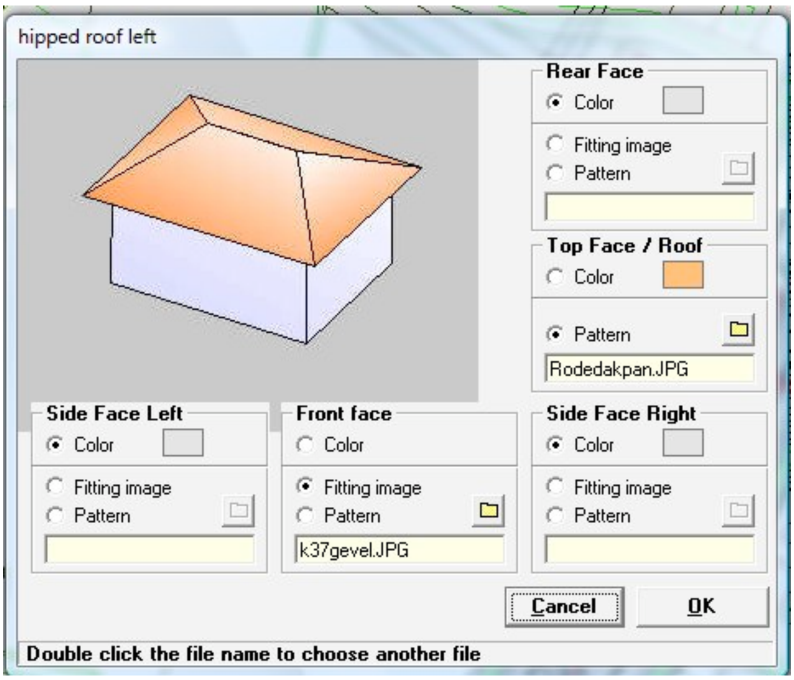
Supposed that the building is symmetrical then one needs 4 to 6 points to calculate the planes (see Table 1). You always need 3 points on the ground and according to the type of building 1 to 3 points to calculate the roof. Usually the first point on the ground and the construction points of the roof are determined photogrammetrically. The others may be determined by clicking on the points in the CAD drawing.

Table 1: Planes of house types and 3D points, that are needed to calculate them.

Type of building	Number of planes	Number of 3D points
Flat	6	4
Building with a gable roof	7	5
Building with a hipped roof	9	5
Building with a pyramidal roof	9	5
Building with a shed roof	6	5
Building with a flattened hipped roof	9	5
Building with a gable roof	9	6
Building with a Dutch hipped roof	11	6

The walls can have a color, a texture or a fitting image (see figure 3). The image is mapped on the 3D geometry automatically. The values of the 2D texture co-ordinates are determined with the help of a build-in routine for perspective calculation. The used images can be the original once when the photo is taken more or less perpendicular to the building. Otherwise cutting is required before using it for texture mapping. Repetitive texture can be applied as well. When the size of a plane is known, the number of times a pattern has to be repeated can also be calculated supposing that the pattern represents 1 square meter. All roof planes are treated the same and can have a pattern or a color. The floor underneath the building is always gray.

Figure 3: The fill in sheet of the appearance of walls and roofs



After defining a construction line in the CAD drawing one can model a façade just by clicking on the contour in a linked photo and extruding the formed plane horizontally. Then the façade can be coloured or textured as discussed above. Figure 4 shows that it is possible to combine many parametric models and extrusions in one building.

Figure 4: Parametric models and horizontal extrusions combined

Buildings can also be modeled with a vertical extrusion. These are created from a closed polygon that is formed by drawing or selecting a continuous line or polygon in a loaded CAD drawing. All vertical planes of an extruded model can have a different appearance.

The terrain modeling is usually done with either connected 3D points that form a closed polygon or with an elevation grid.

3. EXPORT IN CITYGML

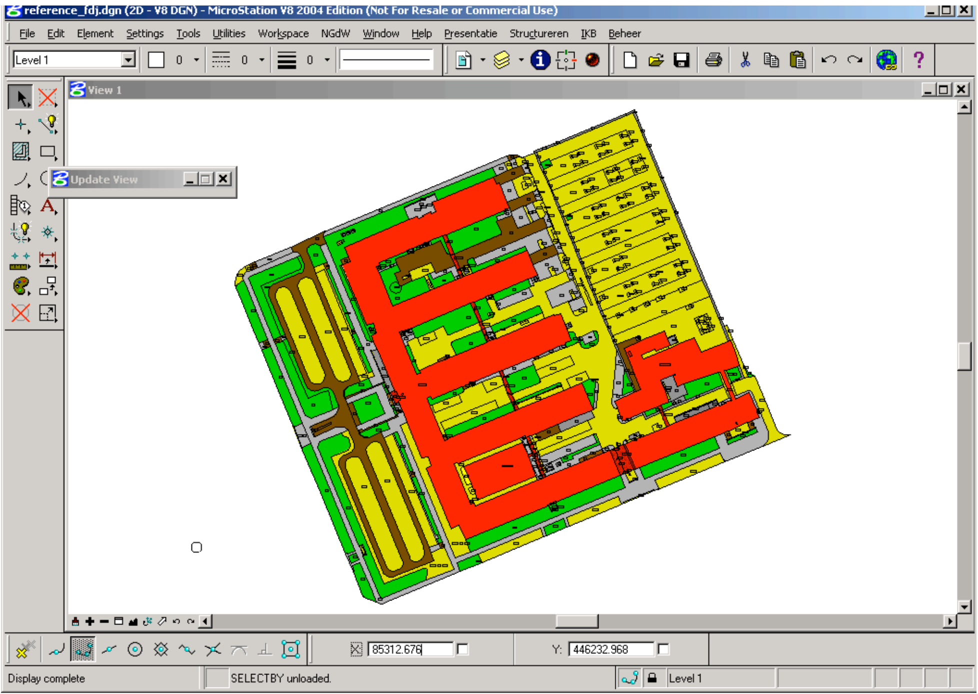
Toposcopy had already an export in DXF (Drawing exchange format) and VRML (Virtual Reality Modeling Language). For the GIMCIW research project an export routine in the new information model according to CityGML spatial schema was added. The new CityGML code is tested in the LandXplorer viewer (www.3dgeo.de), the Aristoteles viewer (www.ikg.uni-bonn.de/aristoteles) and the CityVU viewer (cityvu.3dgis.it). The latter can be used as a stand alone program and as a plug-in.

3.1 Generation of a 3D topographic dataset

In order to allow 2D data of existing topographic maps to be included in the toposcopic database an import routine was programmed. In the Netherlands two data sets can be used as a topographic basis: GBKN (large scale topographic map of the Netherlands) and the TOP10vector (scale 1:10000). Both data sets were tested.

The GBKN is more accurate (created for a scale 1:1000 or 1:2000) and is preferred when linking a photo to the map or when making a close-up view. However, the big disadvantage of the current GBKN is that most objects are drawn with lines that are only partly connected. It is possible to join the lines manually in a CAD program, but that is very time consuming. A Dutch company NedGraphics (www.nedgraphics.nl), has developed a software GEOCAD (an extension running on AutoCAD), which provides elaborated rule-based tools for building of 2D topology. The rules take into account the names of the layers and the topological connectivity of the objects. Using these tools it is possible to clean the data set (resolve overlaps, gaps, create objects) and organize the model in a 2D topological data structure. The GEOCAD tools allow for a completely automatic identification of the objects and their thematic properties. It should be noted that thematic classification of the objects is available in GBKN and can be obtained from the name of the layer. GEOCAD was tested only for a small area of TUDelft campus (Figure 5). This software can be successfully used in the conversion of the current GBKN data sites into the new object-oriented model IMGeo (Krijtenburg et al 2007) for the large scale topographical objects in the Netherlands. The accuracy of the objects is supposed to be from 10cm (high accuracy) to 60 cm (low accuracy).

Figure 5: 2D topologically correct model for the area of TUDelft: all the objects are closed polygons with attributes derived from the GBKN (courtesy NedGraphics)



IMGeo object classification is very similar to the CityGML (as given in figure 1). The top classes of CityGML can be found in the IMGeo schema. Some small differences exist, e.g. CityGML has transportation object as a top class, while IMGeo has 'road' and 'railroad', IMGeo has classes related to administrative boundaries in cities such as neighborhood, municipality, province, etc. (which does not exist in CityGML), etc. Generally, IMGeo objects can be straightforward mapped into CityGML classes. The concept of LOD, however does not exist in IMGeo, as well as the third dimension is not explicitly discussed.

The second data set TOP10vector can also be used for the reconstruction. The TOP10vector dataset consists of a landscape model (DLM) and a digital cartographic model (DKM). The DLM contains of a bas-file that can also be supplied as vlk-file (i.e. polygon file) that exclusively exists of closed polygons. These polygons can easily be converted and coded in CityGML. A GML version of the model is also available (De Vries at all 2001). The disadvantage of TOP10vector is that the intended scale is smaller (i.e. low accuracy and details is considered) and therefore less objects are modeled in the data set. TOP10vector is replaced in 2007 with the new TOP10NL, which is maintained centrally by the Dutch Cadastre (www.kadaster.nl/top10nl_engels). TOP10NL is one of the basic data sets of the Netherlands. Similar to IMGeo, the classes of TOP10 NL can be easily mapped to CityGML. LOD and third dimension are not explicitly discussed in the model.

The GML code of Fig 6 is an example of an object classified as *landuse*. The code between the two horizontal lines has to be repeated for each object on the terrain. In the case study Highway A15 (see section 4), it is repeated a few thousand times. Note that the color is given only once in the *appearanceMember* at the end of the file. Since GBKN and TOP10 are 2D datasets, an intermediate step should be taken to add a z-co-ordinate to each vertex in a polygon to create 3D surfaces). In our case this was completed using ArcGIS and more specifically the 3D Analyst extension. The z-co-ordinate for each vertex is obtained with the help of AHN, the Dutch database of elevation points (http://www.ahn.nl). Of course, if it is not possible to add a realistic third dimension this way, one can fill in a user-defined elevation.

Figure 6: Closed polygons, coded in CityGML of agricultural land (Feature *landuse*)


```
<?xml version="1.0" encoding="UTF-8"?>
<!-- Generated by toposcopie - version: 4.8.0.5762 -->
<CityModel xmlns="http://www.citygml.org/citygml/1/0/0" xmlns:gml="http://www.opengis.net/gml"
    xmlns:xAL="urn:oasis:names:tc:ciq:xsdschema:xAL:2.0" xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:xsi="http:www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http:www.citygml.org/citygml/1/0/0/CityGML.xsd">
    <gml:name> AgriParcelsHght</gml:name>
    <gml:boundedBy>
        <gml:Envelope>
            <gml:pos srsDimension="3">185999.052 432789.533 7.660</gml:pos>
            <gml:pos srsDimension="3">205000.000 441922.431 16.330</gml:pos>
        </gml:Envelope>
    </gml:boundedBy>
      <cityObjectMember>
        <luse:LandUse>
          <gml:name>bouwland 001</gml:name>
            <gen:intAttribute><gen:name>ToposcopyID</gen:name><gen:value>1</gen:value></gen:intAttribute>
              <luse:lod2MultiSurface>
                <gml:MultiSurface gml:id="Bouwland">
                ________________________________________________________________
                  <gml:surfaceMember>  <!-- 1-->
                    <tex:TexturedSurface orientation="+">
                      <gml:baseSurface>
                        <gml:Polygon>
                          <gml:exterior>
                            <gml:LinearRing>
                              <gml:posList srsDimension="3">
                                199931.568 437417.299 11.090  199944.571 437415.890 10.940
                                200000.000 437406.915 11.000  200000.000 437426.223 11.150
                                199973.494 437431.962 11.430  199933.151 437437.650 11.380
                                199931.568 437417.299 11.090  199931.568 437417.299 11.090
                              </gml:posList>
                            </gml:LinearRing>
                          </gml:exterior>
                        </gml:Polygon>
                      </gml:baseSurface>
                    </tex.TexturedSurface>
                  </gml:surfaceMember>
                ________________________________________________________________

                </gml:MultiSurface>
              </lod2MultiSurface>
            </luse:LandUse>
          </cityObjectMember>
    <app:appearanceMember>
      <app:appearance>
        <app:surfaceDataMember>
          <app:X3DMaterial>
            <app:ambientIntensity>0.4</app:ambientIntensity>
            <app:diffuseColor> 0.784 0.808 0.690 </app:diffuseColor>
            <app:target>#bouwland53</app:target>
          </app:X3DMaterial>
        </app:surfaceDataMember>
      </app:appearance>
    </app:appearanceMember>
</CityModel>
```


3.2 Creation of LOD1 buildings

In a map, buildings usually form islands in bigger building sites. When they are treated evenly it causes a topological problem. Therefore buildings are in the DLM of the TOP10vector dataset separately stored in hzn-files. Accordingly in the 3D topographic map coded in CityGML, buildings are also placed as individual objects on top of the terrain formed by all the elements of the vlk-dataset.

It is straightforward to create houses in LOD1 with Toposcopy from the hzn-files. When a CAD drawing is loaded into the Scope program, the houses that are drawn in a particular layer of that drawing as closed polygons, can be imported in the toposcopic database. They are automatically coded as a vertical extrusion. The elevation and height of the group of houses can be filled in. At a later stage these data can be changed for each particular building.

3.3 Textured buildings in LOD2 and LOD3

It appeared that the internal representation of buildings of Toposcopy is very appropriate for buildings in LOD2 and LOD3. Toposcopy works with about the same types of houses as CityGML, i.e. the type of roof is also leading in the Toposcopy classification.

Figure 7: Coding of a plane with an automatically generated specific simple texture

```
<gml:surfaceMember>  <!-- right side surface --> <!-- 49.3-->
  <tex:TexturedSurface orientation="+">
    <gml:baseSurface>
      <gml:Polygon>
        <gml:exterior>
          <gml:LinearRing>
            <gml:posList srsDimension="3">
              190075.570 433655.290 9.513
              190077.650 433660.130 9.513
              190077.650 433660.130 12.577
              190075.570 433655.290 12.577
              190075.570 433655.290 9.513
            </gml:posList>
          </gml:LinearRing>
        </gml:exterior>
      </gml:Polygon>
    </gml:baseSurface>
    <tex:appearance>
      < tex:SimpleTexture>
        < tex:textureMap>..\photos\bemmelmonumenten\brugdijkoost.jpg</ tex:textureMap>
          < tex:textureCoordinates>  0.586 0.497  0.747 0.497  0.747 0.622
                                  0.586 0.619  0.586 0.497 </ tex:textureCoordinates>
          < tex:textureType>specific</ tex:textureType>
        </ tex:SimpleTexture>
      </ tex:appearance>
  </ tex:TexturedSurface>
</gml:surfaceMember>
```

The colors and patterns of walls and roofs are collected in the *appearanceMember*. They are referred to with an ID like in: <gml:CompositeSurface gml:id="TPNT2_146_3"> . Only the texture co-ordinates of specific textures are given together with the co-ordinates of the 3D plane because they are used only once (see figure 7). Some of the thematic and attribute information of a building feature such as height and roof type can be automatically assigned. All data are stored in the GML file.

3.4 Conversion of CAD design files

At the moment only 3D points, 2D and 3D lines and polygons can be extracted from existing CAD design files.

- 3D lines and polygons can be extracted by first converting the CAD file into DXF. This DXF file can be parsed and converted in CityGML.
- 3D points can be imported as space or comma separated text.
- 2D polygons can be imported with the build-in CAD functionality of the Scope program. First the CAD file is loaded in DWG, SHP or DXF format. Then one can choose which layer must be imported and converted in CityGML. One can fill in a ground level and also

a height in case the polygon must be extruded like a LOD1 building. At last one can tell what kind of feature it must be.

4. CASE STUDY: HIGHWAY A15

The study area was selected to be able to show a successful integration of different data sets with existing and design (project) information. The integration of data is intended for citizens. The website is supposed to demonstrate a new way of informing citizens about the planned trace of the extension of a highway (A15). The website has to provide different possibilities to search and overlay data in 2D and 3D browsers. Toposcopy software was used to provide the CityGML files to be used in the 3D environment.

In the study area many data from different sources were collected, processed and stored in CityGML files. All these files can further be combined in one project. In this chapter we will show some of the results and how we managed to get them. When the data are imported in the Scope database it is always easy to export them in CityGML code. Short description of all modeled objects is given below:

1. The existing highway A15 intersection Ressen: The most accurate data of this intersection are stored in a dataset “DTB-droog”, which is a specific dataset for roads, which is maintained by the Dutch department of the maintenance of dikes, roads and bridges and the navigability of canals within the Ministry of Water and Transport management. DTB-droog is a 3D digital topographic database of highways in a scale 1:1000. The data can be obtained as a CAD or a GIS file. In a 3D CAD program the data was exported in DXF. The important layers were as 3D lines and closed 3D polygons imported in Scope by parsing the DXF file. This resulted in separate files with asphalt-pavement, grass and wooded areas. The viaducts of this intersection are modeled and visualized with Toposcopy. Photographs are taken from known points in the “DTB droog”. The viaducts are modeled as horizontal extrusions.

2. The existing railway: The route of the existing cargo railway “Betuweroute” is obtained from the RailInfra company as a string of connected 3D points. These strings are transformed in closed polygons with a width of 4 m and imported in Scope. Other railroad tracks are given in two dimensions. Their elevation is calculated by combining the data with the AHN using ArcGIS and the 3D Analyst extension.

3. Other topographic objects: The vlk-files of the TOP10 vector are made 3-dimensional by combining the geometry data with the AHN (Dutch database of elevation points). This is explained in 3.1. This certainly is a very interesting possibility. However the outcome needs some re-processing. Big trees and other high objects may cause points of an object that lie underneath to have an unrealistic height. To correct this a tool was developed that subsequently smoothes the points, that are obviously too high and makes sure that the same points in adjacent polygons are changed as well. Another problem was caused by the fact that the AHN of the study area is 9 years old and the TOP10 vector quite up-to-date. This causes for example that the local roads crossing the “Betuwe route” are correctly drawn in the TOP10 vector, but the elevation values are wrong and have to be corrected manually.
In the process of making a 3D topographic dataset each layer of the CAD database was transformed to a separate toposcopic database. Using database manipulation these toposcopic databases can be reorganised according the features of CityGML, namely:

- Landuse: Grass-land, Arable land, Orchard, Park
- Vegetation object: Hedge, Tree, Waterobject, River, Lake, Ditch, Jetty
- Transportation object: Road, Railroad, Grass verge, Site, Building site

4. The buildings: A few thousand buildings in Level Of Detail 1(LOD1) have been created. They were not processed in ArcGIS as is explained in 3.2 The ground level varies in the different villages from around 9.6 m to 10.8. The LOD1 buildings were given a uniform height of 8 m. Both the ground level and height can be changed for each individual building. They can easily be found in the database by selecting the building. The only problem we experienced was that many buildings in the 2D TOP10vector CAD drawing were coded as a filled object without explicit co-ordinates. They needed some pre-processing. First they had to be exploded and then the lines had to be re-joined.

Figure 8: View on Bemmel and the highway intersection in a 3D topographic world

As examples a few fully textured buildings have been created in LOD3 (see figure 5). Moreover a church and some farm buildings are created in LOD2. They are coloured, not textured and are modeled with the Toposcopic method (see 3.3).

5. The 2D CAD design objects: Of the proposed extension of highway A15 from Bemmel to highway A12 somewhere between Duiven and Zevenaar several alternatives exist but none was at the time of this study elaborated in 3 dimensions yet. However it was agreed that in our study east of Groessen the new highway would be lowered 6 meters to reduce the noise nuisance. The highway would cross the river with a bridge in contrast to the nearby railroad “Betuwe route”, that has a tunnel underneath the river.

The 2D CAD design file was split up into separate files: asphalt, grass verge, grass talus and a horizontal grass top. The x/y co-ordinates are collected from the 2D CAD design drawing by selecting the lines and joining them to form closed polygons. Sometimes it was easier to draw a new closed polygon and import it in the Toposcopic database (see 3.4).

Where the track of the new highway that is sunken below ground level, split the closed polygons of meadows, agricultural land, building sites, etc, these polygons had to be adjusted. They are connected to the horizontal grass top with a height of 12 m, which is slightly higher than the local ground level.

5. CONCLUSIONS AND FUTURE WORK

The experiments and the initially performed tests have shown that the modeling tools of Toposcopy can be adapted to import a large number of data sets needed for re-constructing of the objects as specified in CityGML. Toposcopy offers some benefits for the modeling of LOD2 and LOD3 as the house models of Toposcopy can be easily decoded in CityGML. Although the progress in automatic 3D re-construction, these LOD's are still some of the most challenging issues in 3D modeling.

Most of the problems in our experiments were related to the existing 2D datasets GBKN and TOP10vector. The highly time-consuming tasks were the creation of correct polygons and resolving heterogeneity issues. In the case of our pilot the highway intersection Ressen was given in 5 different files: the 3D DTB , the GBKN, 2 different design files and the TOP10 that was made 3D with the AHN. They have different levels of accuracy, both in location as in height. It is difficult to combine them in the best possible way.

However, it is expected that the 3D modeling process will be relatively smooth, fast and largely automated when the new models IMGeo and TOP10NL become operational. In cases, when only LOD1 is intended the process should be completely automated. Indeed if LOD2 or LOD3 is demanded, field measurements will be still required.

CityGML seems a promising file format for integrated visualization of different data sets, since the different GML files can be combined in various browsers (and since recently plug-ins). As our tests have shown, CityGML is suitable for modeling existing and design (project) objects. The objects of CityGML are sufficient to represent the Dutch topographic objects as well. Despite some differences in the top classes, the mapping between the two major Dutch topographic data models IMGeo and TOP10NL is easy to establish.

The next steps in the development of Toposcopy tools will be devoted to representing individual trees in CityGML. Toposcopy has a large library of tree images, which after mapping on billboards could help in creating realistic attractive 3D visualizations. Currently CityGML browsers do not provide billboards; therefore the trees have to be modeled as 3D objects. Such 3D models might decrease the speed, while navigating through the model. Therefore it is highly recommendable to address billboard visualizations in the CityGML specifications.

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