An analysis of 3D Symbolic Representation of Geographical Information and Visualizing 3D Building Models with CityGML

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Abstract
In 3D GIS, all geographic phenomena and spatial entities need to be represented by the corresponding 3D symbol models. So establishing a complete set of 3D map symbolic database with expression becomes critical in technology development of 3D map visualization. Based on the theory of map information transmission, an analysis of 3D symbol is presented in this paper. Scientists and engineers have discovered the value of the Google Earth application and Keyhole Markup Language as a medium for research and teaching in earth science, life science, and environmental science. Google SketchUp, on the other hand, has been used for 3D modelling. This paper deals with the development of 3D model of a building. This work was done to experiment the use of Google Earth by developing 3D model of BISAG building and mashing it up with Google Earth using Google SketchUp, KML and Google Earth API.

Keywords
3D Visualization, CityGML, Google Earth, Google Mash up, KML/KMZ.

I. Introduction
Few years ago satellite images & GIS were not publicly available but they were only used by the government organizations. With the growing popularity of web mapping applications, it has become possible to serve such scientific data to users outside the building walls of such organizations. Google Earth applications are capable to meet the daily GIS requirements of the growing number of GIS users, for which it provides an easy-to-use, consistent, low-cost platform that has been widely accepted and praised by users.

Latest version of Google Earth is now capable of displaying high-quality 3D building models. Currently several cities around the globe feature some 3D rendering in Google Earth under the cities in 3D program. More and more higher quality city building models are being incorporated in to Google Earth regularly.

In India, Department of Science & Technology, Survey of India (SOI) and the Ministry of Urban Development (MOUD), had come together to make the data based on 3D city model available for the city of Delhi. A research project was commissioned by Department of Science & Technology (DST) for creating a 3D city model of Chandni Chowk area of Delhi for various purposes including detection of illegal constructions. The project was carried out jointly by DST and the Russian Academy of Sciences.

This research conducted by BISAG, a Government of Gujarat organization, is an experiment to check the feasibility & issues in the development of the 3D models of Indian cities & their convergence in various Levels of Details (LOD) models in KML (Keyhole Markup Language) document & mashing up with Google Earth. This paper comprises the details of the technology & the tools used for the development of 3D models from LOD0 to LOD3 & conversion of them into KML which is an XML-based language schema for expressing geographic annotation & visualization on three-dimensional Earth browsers & mashing up of 3D models on Google Earth.

II. Related Work
Google Earth and Google’s acquisition of SketchUp has created tremendous interest in 3D modelling of the cities. Microsoft’s acquisition of the 3D visualization company GeoTango and Microsoft’s Virtual Earth were also providing 3D capabilities.

The solution of the above problem is CityGML, which is designed as an open data model and XML-based format for the storage and exchange of virtual 3D city models. It is implemented as an application schema of the Geography Markup Language 3 (GML3), the extendible international standard for spatial data exchange and encoding issued by the Open Geospatial Consortium (OGC) and the ISO TC211. CityGML is based on a number of standards from the ISO 191xx family, the Open Geospatial Consortium, the W3C Consortium, the Web 3D Consortium, and OASIS. [1]

The 3D model of the building (BISAG, in this case) is created on the basis of its actual architecture and using available sketches, plans and CAD drawings. Actual photographs of the buildings are used to add texture over the 3D model of the building. For 3D visualization of buildings, languages such as CityGML and KML are used. Google earth is using COLLADA objects and KML export files to display 3D models. From the background reading, it was decided that to use the 3D visualization techniques on the 3D model of BISAG, it was necessary to develop the 3D model of the campus buildings in Google SketchUp, and then through the Google Earth one can fully utilize the complete model.

A. Tools & Technologies
- Google Earth Pro 4.3: Google Earth is a virtual globe, map & geographic information program.
- Google Sketchup Pro 7: Google Sketchup is a 3D modelling tool.
- KML 2.2: Keyhole Markup Language is an XML-based language schema for expressing geographic annotation & visualization on existing or future web-based two-dimensional
maps & three-dimensional Earth browsers.

- CityGML 1.0.0: CityGML is an open data model & XML-based format for the storage & exchange of virtual 3D city models.

### B. CityGML & KML

The CityGML is an innovative concept that aims at transferring and exchanging the information and the data of the 3D model of a building or a city. The biggest advantage of CityGML is that it can contain complex 3D data along with semantics that is associated with the data, where as in the past the models of the city or the buildings were like pure graphical 3D models. Nowadays in Google Earth along with the geometry of the building, it is necessary to include the semantics and the topology in the 3D Models. CityGML is implemented as an XML application schema of the Geography Markup Language 3 (GML3) which is an international standard for spatial data exchange and because of this it is compatible with other OGC standards. For the 3D visualization of the buildings on Google Earth, CityGML is therefore considered as a rich 3D information base format with which we can easily derive the 3D formats [3].

CityGML defines the classes and relations for the most relevant topographic objects in cities and regional models with respect to their geometrical, topological, semantical, and appearance properties. “City” is broadly defined to comprise not just built structures, but also elevation, vegetation, water bodies, city furniture and more. Included are generalization hierarchies between thematic classes, aggregations, relations between objects and spatial properties. CityGML is applicable for large areas and small regions and can represent the terrain and 3D objects in different levels of detail simultaneously. Since either simple, single scale models without topology and few semantics or very complex multiscale models with full topology and fine-grained semantical differentiations can be represented, CityGML enables lossless information exchange between different GI systems and users [4].

KML file specifies 3D models, textual descriptions, placemarks, images, and polygons etc features for display in Google Earth or any other 3D earth browser implementing KML encoding. Latitude and longitude are always provided for each place. In addition to that heading, tilt, altitude etc are provided to make the camera view more specific. KML files are distributed in KMZ files. KMZ files are zipped files out of which one of the file is “doc.kml” and its extension is “.kml” [5].

Example of KML:

```xml
<?xml version = "1.0" encoding = "UTF-8"?>
<kml xmlns = http://www.opengis.net/kml/2.2>
  <Placemark>
    <name>New York City</name>
    <description>New York City</description>
    <Point>
      <coordinates>74.006393, 40.714172, 0</coordinates>
    </Point>
    <Placemark>
      <kml> [5]
```

CityGML is related to the information of the virtual 3D city models while KML is more about visualizing the information. CityGML designed to provide information about the objects themselves. A CityGML dataset may have different visualizations where objects may be selected or highlighted according to different thematic criteria resulting in multiple KML files [4].

### C. Flow of Events

The following figure displays all the stages related to visualization of 3D models on Google Earth.

![Flow of the Development Process](image)

**Fig. 1: Flow of the Development Process**

### D. 3D Modelling of the BISAG Campus

Various different domains like BIM, GIS, CityGML and Computer Graphics (Movies, video games etc) require 3D modelling. Google Earth is capable to provide various views of the earth to the users like imagery, terrain elevation and also it is possible to visualize the landscapes which can include the 3D Models of the buildings and cities. The interoperability of the Google Earth’s repository is more compatible with the models prepared by this tool as compared to other 3D authoring tools. Hence 3D models of the buildings are developed in Google SketchUp for the purpose of mashing up in Google Earth. CityGML defines different Levels of Detail (LOD). LODs are required to reflect independent data collection processes with differing application requirements. Further, LODs facilitate efficient visualization and data analysis. In a CityGML dataset, the same object may be represented in different LOD simultaneously, enabling the analysis and visualization of the same object with regards to different degrees of resolution. Furthermore, two CityGML data sets containing the same object in different LOD may be combined and integrated.

- The LOD0 is essentially a two & a half dimensional Digital Terrain Model (DTM), over which an aerial image or a map may be draped.
- LOD1 is the well-known blocks model comprising prismatic buildings with flat roofs.
- In contrast, a building in LOD2 has differentiated roof structures & thematically differentiated surfaces. Vegetation objects may also be represented in this.
- LOD3 denotes architectural models with detailed wall & roof structures, balconies, bays & projections. High-resolution textures can be mapped onto these structures. In addition, detailed vegetation & transportation objects are components of a LOD3 model.
- We get LOD4 model by adding interior structures for 3D objects into LOD3. For example buildings are composed of rooms, interior doors, stairs & furniture [2].
According to above mentioned different LODs, we have developed the 3D models of the BISAG in LOD0, LOD1, LOD2 & LOD3 as follows:

### Table 1: Levels of Detail

<table>
<thead>
<tr>
<th>LOD</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOD0</td>
<td>REGIONAL MODEL</td>
</tr>
<tr>
<td></td>
<td>2.5D Digital Terrain Model</td>
</tr>
<tr>
<td>LOD1</td>
<td>CITY MODEL</td>
</tr>
<tr>
<td></td>
<td>Block Model, No Roof Structures</td>
</tr>
<tr>
<td>LOD2</td>
<td>CITY MODEL</td>
</tr>
<tr>
<td></td>
<td>Roof Structures, Optional Textures</td>
</tr>
<tr>
<td>LOD3</td>
<td>SITE MODEL</td>
</tr>
<tr>
<td></td>
<td>Detailed Architectural Model</td>
</tr>
<tr>
<td>LOD4</td>
<td>INTERIOR MODEL</td>
</tr>
<tr>
<td></td>
<td>Walkable Interior Spaces</td>
</tr>
</tbody>
</table>

### III. Representation of Bisag Models in CityGML

CityGML data Generation depends upon data, i.e. it is already a 3D model or not, source data formats & aggregation of the data entities to the identifiable objects. CityGML standards are represented with the help of Unified Modelling Language (UML). <<Geometry>>, <<Feature>> and <<Object>> are those identifiable objects which are derived from the abstract GML type, ‘AbstractGMLType’. The model is converted using an XML namespace and then an XML schema is prepared.

According to the LODs of the buildings the UML diagrams of the building models which are the most detailed thematic concept of CityGML, are prepared. After that the model is developed from LOD1 to LOD4 and hence different components of the 3D model are represented in different LODs. The UML diagrams of LOD1,
LOD2 and LOD3 models of BISAG have been prepared and also the XML schema definition of the same has been done. While creating the UML diagrams of various LODs of model of BISAG, following important concepts of the CityGML have been kept in mind on the basis of Open GIS standards:

- ‘AbstractBuilding’ is the main class in CityGML which has many properties related to LODs of the 3D building model. In case of LOD1, the geometric representation of the volume of the building is considered in XML schema definition of the building model.
- ‘MultiSurface’ & ‘Multicurve Geometrics’ are added to the LOD1 UML diagram to improve this representation in LOD2 & for this purpose, two more classes ‘BoundarySurface’ & ‘BuildingInstallation’ are used. ‘Class’, ‘Function’, ‘Usage’ attributes are used to clearly depict the 3D information in UML diagrams. Now in LOD3 UML diagrams the openings like doors & windows in the surface of the building model are provided in addition to LOD2 UML Diagrams. In this case ‘BoundarySurface’ objects are represented as thematic objects.

Table 2: Semantics Themes on the Basis of LODS of Class [1]

<table>
<thead>
<tr>
<th>Abstract Building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometric Theme</td>
</tr>
<tr>
<td>Volume of the building</td>
</tr>
<tr>
<td>Surface of the building</td>
</tr>
<tr>
<td>Curved part of the building</td>
</tr>
<tr>
<td>Boundary Surfaces</td>
</tr>
<tr>
<td>Openings</td>
</tr>
<tr>
<td>Rooms</td>
</tr>
</tbody>
</table>

IV. KML Documentation & Conversion in KMZ Format for Its Visualization on Google Earth

After developing the 3D models of the building using Google SketchUp they are placed on a terrain image of those buildings. This terrain image is imported in to SketchUp from the Google Earth. Now these SketchUp files are converted in files with .dae extension which is called COLLADA files. It is an interchange file format for interactive 3D applications. After this a separate folder is created with name “images” in which all the images used as texture in the model are kept. A systematic pattern is followed in naming the images starting from “texture0.jpg” up to total number of images. Along with this folder a file named “textures.txt” is created in which name of all the texture files have to be written in following format <../images/texturenumber.jpg>.

The .dae file is kept in the folder with name “models”. The next step is to author the KML document for the models. This KML document helps the Google Earth in placing the 3D models to their exact location using the details like latitudes and longitudes written in that KML document. It also contains the details like visibility, heading, tilt, latitude, longitude, range, altitude, orientation, scale and link. A text file in which KML is written is saved with name “doc.kml”. After creating doc.kml, textures.txt and modelname. dae files and models as well as images folder, they all are kept in a single folder having the name same as .dae file and then compresses finally using the zip format to a KMZ file.

The KMZ file is the final file in the transferable format which can be exported to Google Earth and which when opened with Google Earth it places the 3D model at the exact coordinates with the real textures that were used while developing it in Google SketchUp. Also the default value of the tilt and camera position is provided in to the KML file using which Google Earth provides the first view of the model to the user. But after that the user can change the tilt, altitude or camera position from the options available in the Google Earth for proper visualization.

Following image shows the 3D model of BISAG (R&D block) placed on Google Earth.

Fig. 6: Visualization of BISAG (R&D Block) Model on Google Earth

The symbolic database system is the basic tool of geospatial data representation in map. In the past, many researchers didn’t focus on 3D map symbols but mostly on 2D map symbols. In 3D GIS, all geographic phenomena and spatial entities need to be represented by the corresponding 3D symbol models. So establishing a complete set of 3D map symbolic database with expression becomes critical in technology development of 3D map visualization.

V. Conclusion

This research work, undertaken by BISAG, a Government of Gujarat Organization, is aimed to the development of the 3D building model & its mash up with Google Earth for the experiment purpose. For this LOD 0 to LOD4 models of the building were prepared & then converted in to the KML document. After this a KMZ document was developed to place them on Google Earth. BISAG has planned to develop the model of its campus as well as Gandhinagar City.
References


