

**Dubravka Bošković, Srđan Popov, Miro Govedarica**  
(Faculty of Technical Sciences,  
Novi Sad, Serbia)

## **SITE VIEW RECONSTRUCTION USING 3D MODELING TECHNIQUES**

**Abstract.** We describe concepts related to generating 3D scene based on data acquisition and 3D modeling. The purpose of combining these techniques is creation of a scene which reconstruct site view when data are complete, or a probabilistic study of site view when data are only partial. 3D digital spatial model for the area of the Campus of the University of Novi Sad has been created, which uses digital terrain model as a basic layer. Various other raster and vector layers have also been added to facilitate spatial data interpretation, including 3D model layer which presents artificial objects. For the realization of this 3D scene it is necessary to acquire data using different technologies for data acquisition like photogrammetry, remote sensing, GPS survey and laser scanning.

**Key words:** 3D scene, 3D modeling, site view reconstruction, visualization

### **1. Introduction**

This paper mainly describes concepts related to 3D visualization which include generation of 3D scene created from various spatial data such as digital elevation model (DEM), raster and vector data and 3D model of artificial objects. There are various tools which allow creation of such 3D scenes using adequate data. There are also various techniques for 3D modeling of the artificial objects which form a separate layer of the scene. Such techniques include aerial and terrestrial photogrammetry, laser scanning, CAD modeling etc. One of the purposes of such scenes is site view reconstruction which can be used for urban planning. Digital spatial model has been created for the area of the Campus of the University of Novi Sad.

### **2. Geospatial Data Visualization**

The term visualization implies transformation of data from a symbolic into a geometric representation, interactive data manipulation and their display, graphic rendering and animation. From the perspective of GI systems, visualization enables spatial data to be presented in ways that enables the human perception system to identify spatial patterns in the process of solving spatial problems or decision making [8].

Geographic visualization, or geovisualization refers to a set of tools and techniques supporting geospatial data analysis through the use of interactive visualization. Geovisualization emphasizes knowledge construction over knowledge storage or information transmission [1]. To do this, geovisualization communicates geospatial information in ways that, when combined with human vision and domain expertise, allow for data exploration and decision making processes [5].

Forms of three-dimensional input data are DTM, DSM, DEM and TIN [12]. DTM (Digital Terrain Model) is a static representation of continuous surface of the Earth with a large number of vertices for which X,Y and Z coordinates are known, in an arbitrary coordinate system. DSM (Digital Surface Model) is a raster based description of the terrain, which also

includes objects on the terrain such as buildings and vegetation. DEM (Digital Elevation Model) is a digital representation of a continuous variable over a two-dimensional surface by a regular array of  $z$  values referred to a common datum. DEM is a superset of DSM and DTM and it consists of three elements: block, profile and vertex. TIN (Triangular Irregular Network) represents terrain model as a continuous surface made of mosaic of triangles which do not overlap and whose vertices are chosen elevations.

In the process of geovisualisation there are two types of representation: 2.5D and 3D. The main difference is that in the 2.5D representation only one elevation value is defined for each pair of coordinates, so details can not be displayed. That limitation is overcome by setting up several points (elevations) to the same position, which represents 3D model. To be considered a 3D model, the system must be capable of handling data as more than a surface, it must handle data as an object. An example is a topographic map over a geologic map.

Objects of interest can be represented in the form of three-dimensional models. Those models can be a rough representation of reality or they can have details and textures to become photorealistic. Techniques of multidimensional terrain visualization allow a continuous analysis of three-dimensional model to the viewer. That can be a change of the point of view, effect known as fly-by or fly-through, which adds spatio-temporal dimension to the visualization.

3D visualization models have a variety of applications in geography and urban studies: site location analysis, emergency facilities planning, design review, marketing, etc. While they are generally used to simply visualize the built environment, there are early signs of them being used as 3D interfaces to more sophisticated simulation models.

Both planners and the general public can use geovisualization to explore real-world environments and model “what if” scenarios based on spatio-temporal data. While geovisualization in the preceding fields may be divided into two separate domains, the private domain, in which planners use geovisualization to explore data and generate hypotheses, and the public domain, in which these planners present their visual thinking to the general public, planning relies more heavily than many other fields on collaboration between the general public and planners. Planners use geovisualization as a tool for modeling the environmental interests and policy concerns of the general public. There are two examples: 3D photorealistic representations are used to show urban redevelopment, and dynamic computer simulations are used to show possible pollution diffusion over the next few years. The widespread use of the Internet by the general public has implications for these collaborative planning efforts, leading to an increased participation by the public while decreasing the amount of time it takes to debate more controversial planning decisions [6].

### **3. Tools for 3D Scene Generation and Visualization of 3D Objects**

Virtual Globe is a 3D software tool based on network technologies (mainly Internet) which presents geospatial data models on spherical surface of the Earth or any other planet. Spatial data model imply partial or complete digital representation of a planet based on a set of characteristic geometric parameters. Data about terrain, such as altitude are added on this representation of a planet and it represents basic layer for the visualization. After adding terrain data, various satellite and aerial imagery are added on the model in order to create an impression of three-dimensional world on the two-dimensional screen. Some of the software tools in the category of virtual globes are Leica Virtual Explorer and Google Earth and they were used for the creation of 3D scene of the Campus.

Standard functionalities of software tools for 3D display of spatial objects and visualization include changing dimension of spatial objects, their rotation, moving toward the

object, turning on and off specific layers, adding labels and new layers etc. It is also possible to read the coordinates at every point of the scene or view the attributes of specific vectors or 3D objects on the scene (for example, for a certain polygon which represents spatial extent of a city, attribute data such as its name, area, perimeter or number of inhabitants can be displayed).

Leica Virtual Explorer Architect (LVE) [10] is created for the modification, labeling and organization of geospatial data in three-dimensional scenes with the purpose of geovisualization and analysis. 3D functionality of LVE is complete. It allows all necessary functionalities for a 3D display and supports all necessary data formats. LVE enables: display of all basic 3D data types (DEM, TIN, CAD) absolutely georeferenced, display of raster data (orthophoto, terrestrial, aerial and satellite imagery), relatively or absolutely georeference and display and editing of vector data.

LVE gives a good solution to the scene manipulation and animation. It allows the following functionalities: 3D navigation, creation of flight path and creation of animation. 3D navigation implies various kinds of navigation in virtual world. Creation of flight path implies the creation of a path on which a virtual camera moves and whose position and angles are predefined which creates the flight simulation over the terrain. That is called virtual tour.

On the other hand, Google Earth [2], a virtual globe program, maps the Earth by the superimposition of images obtained from satellite imagery, aerial photography and GIS 3D globe. It displays satellite images over digital elevation model (DEM) data collected by NASA's Shuttle Radar Topography Mission (SRTM).

Google Earth also supports visualization and 3D scene generation, but unlike LVE it contains a specific number of predefined layers which are stored in its database. A user can also add his/her own layer on the scene. In Google Earth's database there are informations about the terrain, borders, high-ways, airports, railways, settlements, parks, important buildings such as schools, hospitals, banks, restaurants, hotels etc.

#### 4. Realization of 3D Scene of the Campus

3D scene for the Campus of the University of Novi Sad was generated both in LVE and Google Earth, and such scenes were compared. The basic idea is to add all necessary layers on default LVE and Google Earth's scene.

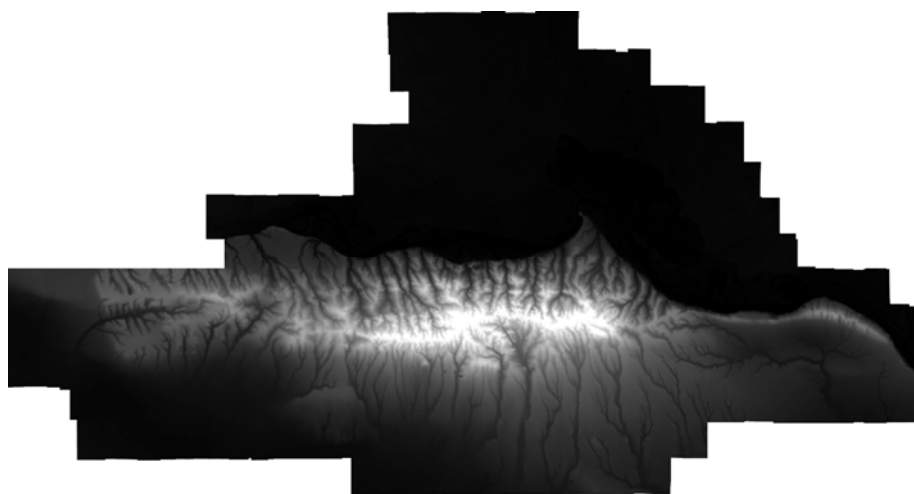


Fig. 1. DEM of Novi Sad and Fruška Gora, resolution 5m

The first layer to be added in LVE is Digital Elevation Model (DEM) which gives a third dimension to each geographic coordinate and creates a three-dimensional model. We used DEM for the area of Novi Sad and Fruška Gora that was created using the photogrammetric procedure based on aerial imagery and its resolution is 5m (figure 1) [9]. DEM is not added in Google Earth's scene because it has its own predefined elevation model which is less accurate than the one used for the LVE scene.



**Fig 2.** Aerial orthophoto of Novi Sad a) 1:1000 b) 1:5000

After DEM is placed on the scene, various raster layers are added. This includes satellite images with lower resolution and airborne images with higher resolution. Airborne orthophoto images are shown in Figure 2. Figure 2.a shows orthophoto 1:1000 (resolution is 10cm) of the part of Novi Sad which does not cover the whole campus area, therefore orthophoto 1:5000 (resolution is 50cm) of Novi Sad and surrounding area should have been used (figure 2.b).

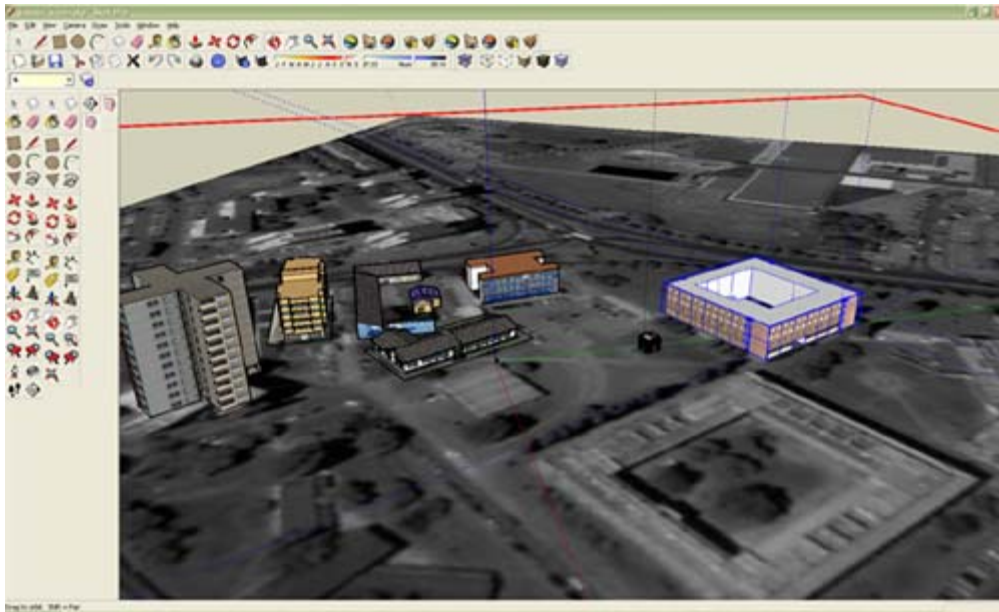
### **5. Realization of 3D Model Layer of the Campus**

There are several techniques for modeling 3D objects such as buildings. Some of them are CAD (Computer Aided Design) modeling using standard CAD software packages such as 3D Studio Max or AutoCad, laser scanning [4] of an object and post-processing, and photogrammetry [7,11] both terrestrial (where stereo-pairs are obtained from the ground) and airborne (or even satellite with a newer very high resolution sensors). 3D CAD models of cities are by far the most common example of 3D urban model, with several applications applied to many cities around the world. Laser scanning demands post-processing of scans to purify point clouds and build mash of a building façade, with a resolution of only a few centimeters. Terrestrial photogrammetry can give very good results depicting many details of the façade of a building, while airborne photogrammetry can help determine the third dimension (height) of a building and then polyhedrons or cylinders are drawn from the base upward.

For 3D model layer generation, which presents artificial objects, we used a set of Google tools. The Google Earth has the capability to show 3D buildings and structures, which consist of users submissions using Google SketchUp [3]. Google SketchUp is 3D modeling tool we used to design buildings displayed on Google Earth and Leica Virtual Explorer scene.

It is an easy-to-use conceptual tool with a simple interface. It also allows to import modeling context (orthophoto + terrain model) from Google Earth for modeling reference.

This 3D model of the Campus was developed initially to aid university officials in carrying out their planning. The buildings from the Campus have been modeled with many details and it included the highest resolution photo-realistic textures. Three-dimensional renderings was available for most important buildings and structures around the Campus. Figure 3 shows developing environment in Google SketchUp for the 3D model layer of the Campus which was later put in the 3D scene of the Google Earth and LVE.



**Fig. 3.** Google SketchUp modeling environment

Geometric properties about the objects of interest are determined from photographic stereo images (photogrammetry), GPS survey and laser scanning. Photogrammetry, laser scanning and laser measuring data complement each other. Photogrammetry (accomplished with laser measuring data) is more accurate in the x and y direction while laser scanning and GPS are more accurate in the z direction. In our work we used benefits and the advantages of all systems and integrate it to create a better scene. A 3D visualization is created by georeferencing the aerial photos and laser scanning data in the same reference frame.

We used add-on which allows the user to export the 3D models as a kml and kmz files. That way generated files can be placed in the Google Earth, as a component of 3D scene. This allows accurate georeferencing of 3D models and accurate placement of those models in the presentation software. The result of 3D modeling and the scene creation in the Google Earth are shown in Figure 4.

3D models were also exported in 3DS format (3D-Studio file format by Autodesk), since LVE only support this format for 3D objects. 3DS objects are then manually placed on the LVE 3D scene. We also added three-dimensional models of the trees from the LVE library of predefined 3D objects, to make the scene more realistic. The result of 3D modeling and scene creation in LVE is shown in Figure 5. Such a scene allows a user to zoom in and out objects of interest and to view them from all sides. One of the very convenient capabilities of such software tool is the possibility to create virtual (animated) tours, so the animated tour through the Campus was created for the presentation purposes.

Both LVE and Google Earth scenes enable measuring of distances on the ground or in the air. They also enable measuring of dimensions (height, width, depth) of the 3D objects on the scene, such as buildings. All measured values correspond to the real values of distances and dimensions, and the accuracy depends on the added layers resolutions and accuracy of 3D modeling technique. LVE also displays true X,Y and Z coordinates for every point pointed by the cursor and the position of the viewer (shown in lower left corner of Figure 5). It is also possible to obtain tabular data about 2D (2D vector layers) and 3D objects.



Fig. 4. 3D scene of the campus in Google Earth

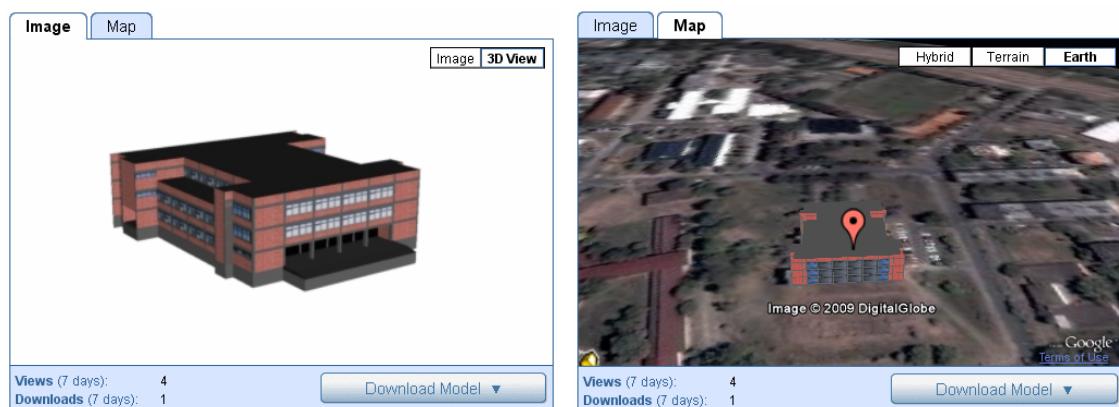


Fig. 5. 3D scene of the campus in Leica Virtual Explorer

Usually, the models have no functionality beyond display (i.e., they are not linked to a spatially referenced database, nor capable of displaying the results of searches and queries performed on them). Models may be navigated by the user or may be static. While the ordinary 3D model offers no functionality to the user except its display values, the incorporation of a geographic information system (GIS) underpinning a 3D display of a model enables users to perform spatial queries of the buildings and build space depicted in the model environment. A GIS, essentially, acts as a spatial database with a graphical interface for performing queries, operations, and manipulations on the data in a spatial plane. 3D GIS models introduce that functionality (if available data permits) to the ordinary 3D model. Users can query the built environment and have the results displayed visually and interactively in three dimensions on the screen. We did not connect our model of the Campus to the spatial database, but both Google Earth and LVE allow such possibility, so it is left for the future development. In that way our model of the Campus will become a full 3D GIS model.

## 6. Publishing 3D Model of the Campus on Google Earth

3D scene of the campus was mainly developed for urban planning and local use. An attempt was made to make 3D models of the buildings in the Campus publicly available in the Google Earth, but since they are very detailed and their size in MB exceeds the limit provided by Google, the models needed to be simplified. Therefore some of the 3D models have been simplified and published on Google 3D Warehouse waiting for the approval by Google to be published on the Google Earth (<http://sketchup.google.com/3dwarehouse>). Models can be found under the keyword “gitis”.



**Fig. 6.** Image and Map view of a 3D building in the Campus in Google 3D Warehouse

## 7. Conclusion

This paper describes concepts related to 3D geovisualization, and presents some of the 3D visualization tools. It also presents site view reconstruction in the form of 3D scene including 3D model layer of the Campus of the University of Novi Sad. Apart from visual presentation and animated tours, this scene offers various possibilities such as real measuring of distances and building dimensions, accurate coordinate and elevation display for each point on the scene, attribute data display for every pointed 2D or 3D object on the scene. All of that can help urban planners and university officials to perform their planning more easily. Further development of geodatabase for the model of the Campus will increase its usefulness and turn it into a full 3D GIS model.

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[dudab@uns.ns.ac.yu](mailto:dudab@uns.ns.ac.yu)

[boromir@uns.ns.ac.yu](mailto:boromir@uns.ns.ac.yu)

[miro@uns.ns.ac.yu](mailto:miro@uns.ns.ac.yu)