Reality-based 3D City Models

CyberCity-Modeller and Database

For geomatic applications and realistic visualization the latest urban cartographic databases contain 3D building models. Based on the application scale and requested details, CyberCity AG creates 3D city models from aerial / satellite imagery and laserscanner data.

By Daniela Poli

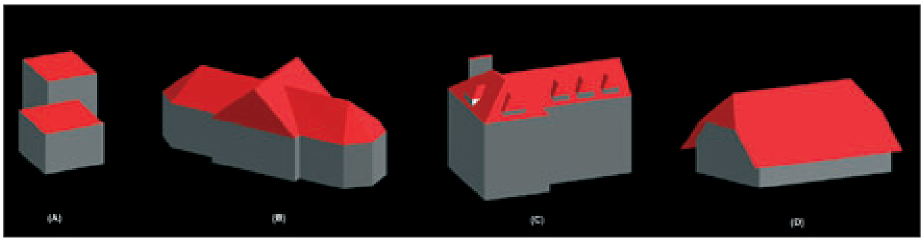


Figure 1: Different levels of geometry complexity.

Introduction

Today the demand for the generation and realistic visualization of 3D urban environments is growing in many geomatic applications. First there was the move from a 2D to a 2.5 D representation of the reality with the introduction of terrain models.
Now GIS users are looking for the description of buildings as 3D vector data in order to create a virtual environment which is more and more similar to reality. The third dimension represents a fundamental information for efficient disaster simulations (like earthquakes and flooding), urban and environmental planning, and building monitoring. Other examples are telecommunication planning, pollution distribution analysis, microclimate investigations and security evaluation.
In the field of visualization, the added value provided by a 3D object in comparison to the corresponding 2D plan is incommensurable. By flying through the 3D city models (see the interactive model of Salzburg, Austria, (1)) the user can recognize the location and get a true impression of the presence of the buildings around him. For tourism purposes, realistic models with a high level of rendering are recommended.

Building Geometric Complexities

According to the application and the project scale, the 3D city models must fulfil specific accuracy requirements in the geometry and in the texture. Memory size is an essential issue too. At CyberCity three different levels of geometric complexity are generated for city models, see Figure 1: (A) block models, (B) main roof structure and (C) detailed roof structures. Of course, the more details, the higher the resolution of the input data.
The data source can consist of stereo aerial images, satellite stereopairs and laserscanner data. In practise, detailed roof structures can be generated from aerial stereo images with a scale 1:9,000 or smaller or from dense laserscanner measurements with the support of orthophotos. Examples can be found in Figures 2 and 3. With the highest possible resolution for satellite images available on the market (Quickbird's pixel size is better than 70cm) main roof structures can be modelled. In addition overhanging roof structures (D) can be generated by combining the information from the sky with the planimetric building footprints.

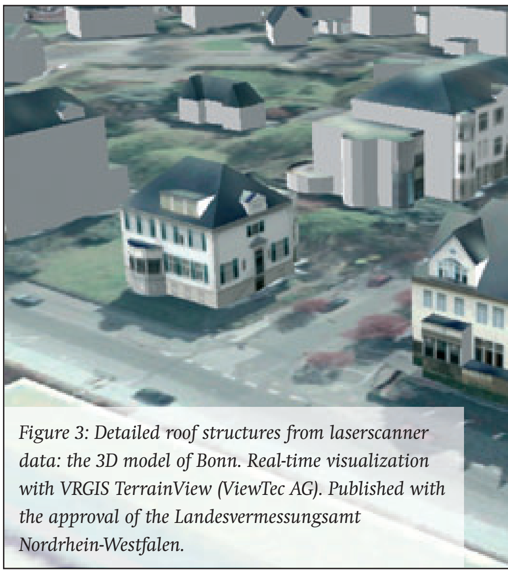


Figure 3: Detailed roof structures from laserscanner data: the 3D model of Bonn. Real-time visualization with VRGIS TerrainView (ViewTec AG). Published with the approval of the Landesvermessungsamt Nordrhein-Westfalen.

CyberCity Approach

Using a reality-based semiautomatic photogrammetric approach, CyberCity generates 3D city models from aerial images, laserscanner data and satellite images with its dedicated software CyberCity-Modeller (CCM).
The modelling approach is the following. In case of aerial and satellite images, see Figure 4, the relevant roof points are first measured three-dimensionally in a photogrammetric station following specific rules, then they are imported as a point cloud and automatically fitted with roof faces. For common types of roof that follow geometric constraints like right angles and parallel lines, intelligent measurement rules were developed to reduce the number of points that are required to be measured to create an object. Therefore this point cloud coding reduces manual labour and keeps the independence of the photogrammetric workstation for 3D measurement and building generation.
The vertical building walls extrude from the intersection of the roof polygons with the Digital Terrain Model or alternatively through

Figure 2: 3D City Model from aerial images: Los Angeles, with detail in Little Tokyo. Automatic texturing using aerial images Real-Time visualization with the VRGIS TerrainView (ViewTec AG).

from Aerial and Satellite Data

Figure 5: Methods for façade texturing.

back-projection of the building footprints from the cadastre. In the latter case, overhanging roofs are automatically generated. Special modules for quality control allow the improvement of the geometry due to inaccuracies in the measurements, for example right angles, parallel lines, planar faces, and correction of overlappings and gaps.

It is also possible to introduce geometric attributes like area, volume and compute them automatically for any buildings of interest. More technical details are described in (3).

The accuracy of the 3D models is dependent on the image scale (governed by the flight altitude) and is about 0.1 - 0.2 m using a representative fraction scale of 1:5,000.

Concerning satellite images, CCM can handle orientation data in Rational Polynomials Coefficients (RPC) formats and apply corrections with different functions, such as shift, rotation, and affine.

Roof and Façade Texturing

In CCM roofs are textured automatically using aerial images, orthophotos or satellite images. For façades, three methods are followed, according to the available data and the rendering level to be achieved, see Figure 5. If no data (aerial or terrestrial images) are available, it is possible to map each façade choosing the most suitable texture in the available library. This method can be automated for groups of façades but produces models which are not reality-based.

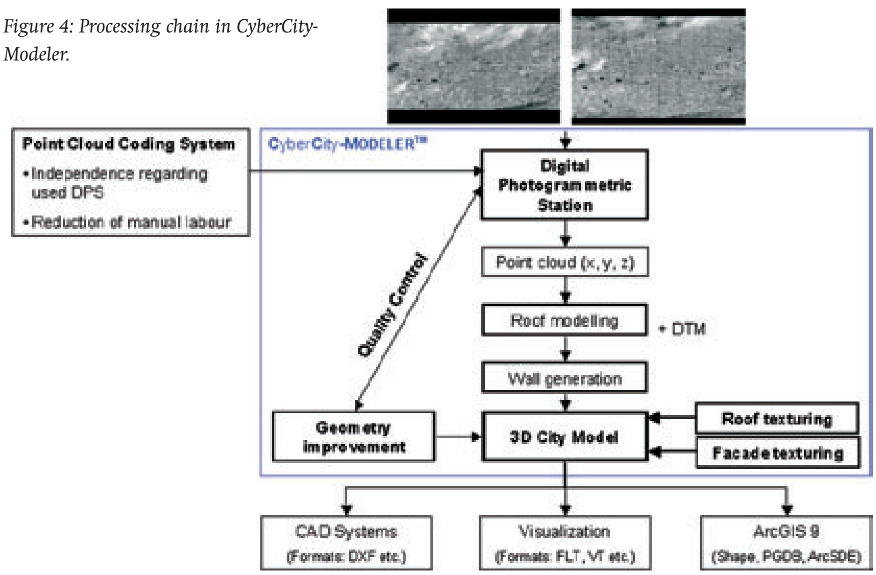
Following an alternative approach, in CCM it is possible to extract the façade textures from the aerial images previously processed for the extraction of the building structure or from high-resolution oblique aerial images. If the orientation is not known, usually in case of oblique aerial images, the images can be oriented by measuring six tie points in the 3D model and in each image.

Once the orientation is known, the software automatically projects each façade or polygon to the images. Among the available textures for the selected façade, the software chooses the best one according to the number of pixels and the occlusion grade through neighbouring buildings. If the texture selected automatically by the software is not entirely pleasing, the user can view the available textures from the other images interactively on the polygon in the 3D model and choose the preferred one.

Each façade image can also be opened directly in an image processing software for editing and retouching to remove any obstacles or correct the radiometry. The changes can be seen interactively on the 3D model. Thanks to the high degree of automation, large size 3D city models can be mapped with realistic texture in a short time with this approach.

The last and most realistic option for façade texturing is the manual mapping of terrestrial photographs with high resolution and quality; the quality and rendering achieved are very high. The images are oriented by selecting the face of the polygon in the 3D model and the

Figure 4: Processing chain in CyberCity-Modeler.



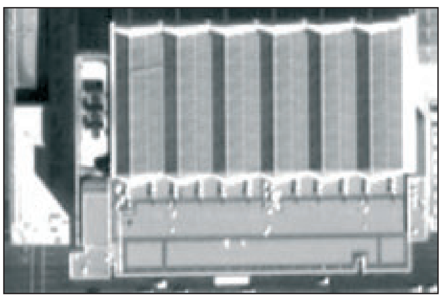


Figure 6: Details in Quickbird images (Courtesy of Eurimage S.p.A.)

Example of 3D landmark: the Brandenburg Gate, generated using terrestrial LiDAR data and textured with high resolution digital images. © 2006 Harman/Becker Automotive Systems GmbH, CyberCity AG.

corresponding corner points in the images. Occlusions and obstacles like cars, trees and people are retouched in a post-process to provide a superior façade texture.

Case Study

One of the last results achieved at CyberCity is the generation of a 3D city model from the high resolution satellite sensor Quickbird. Downtown Phoenix, Arizona, was modelled from a Quickbird stereopair kindly provided by Eurimage S.p.A., Italy (1).

The dataset included two stereo images over their testsite in Phoenix, Arizona, together with DTED2 DTM and 30 GCPs measured with topographic surveying. The images were acquired on 9th April 2004 with viewing angles 29° (forward) and –27° (backward). The mean ground resolution was 70 cm. In these images it is possible to distinguish both skyscrapers and residential houses distributed in a regular network. The appearance of a building is shown in Figure 6.

After the image orientation, the roof points in the downtown are about 2 square kilometres. These were measured in stereo mode and transformed into 3D objects in CCM. The roof texturing was added automatically using the original Quickbird images. As the façades were not visible in the scenes and no other data were available (oblique aerial images, terrestrial images), some façades have been mapped with texture available in the software library.

For visualization, the TerrainView software by ViewTec (ViewTec, 2006) was used. A screenshot of the resulting 3D model is shown in Figure 7.

Applications

The textured 3D city models can be exported into several formats and managed in different software according to the application:

- In GIS environments: an interface allows the user to export CyberCity's 3D city models as Shapefiles for ESRI ArcGIS 9. Additionally, the data can be stored in a Personal Geodatabase (PGDB) or managed in a commercial database like Oracle or Microsoft SQL Server using the ArcSDE connection. The 3D data represent an additional layer for further geographic analysis, disaster simulations, microclimate analysis or for homeland security;
- For real-time visualization: the models can be exported in Open Flight (FLT) with different levels-of-detail (LOD) for the textures (as a percentage of the original resolution), and the geometry. The LOD of the geometry composes of a symbol (LOD 1), the block model with flat roof (LOD 2), the main roof structures (LOD 3) and the main roof including all superstructures like dormers, and chimneys (LOD 4). The visualization speed can be additionally improved by using hardware accelerated texture formats. It is recommended to map the terrain with true-orthophotos instead of standard orthophotos to avoid seeing building roofs on the ground near the 3D models;
- For engineering and architecture planning: by exporting the 3D models in DXF formats and working in CAD software, engineers and architects can be used to visualize buildings and urban areas and simulate the impact of planned buildings.

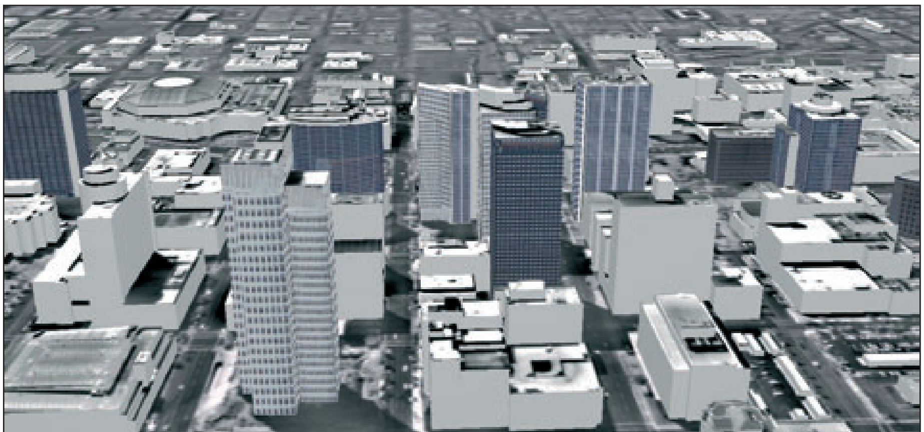
Worldwide Database

Apart from providing services for the modelling of urban environment of interest, CyberCity is generating a database of 3D models of worldwide cities and any geomatic user will be able to buy the 3D model for a selected area of interest.

For the generation of highly detailed and accurate models, CyberCity uses aerial images with a scale 1:8,000 or smaller and accurate aerial triangulation parameters and digital terrain models. The façades are textured with both (oblique) aerial images and terrestrial images for the features of main interest.

The CyberCity database includes or will soon include Los Angeles, San Diego, Las Vegas, Paris and Barcelona. Other cities will follow. For relevant buildings, like stadia, churches, and monuments, detailed 3D models have been generated using terrestrial LIDAR data. A number of landmarks located in Germany is currently produced in collaboration with Harman/Becker Automotive Systems.

Figure 7: 3D City Model of Phoenix, Arizona. Generated and textured with CC-Modeler package. Real-time visualization with VRGIS TerrainView (ViewTec AG). Published with the approval of Eurimage, Italy.



References

(1) Eurimage S.p.A.: http://www.eurimage.com

(2) Salzburg 3D: www.viewtec.ch/techdiv/tvocx/salzburg.html

(3) Ulm, K., 2003. Reality-based 3D city models with CyberCity-Modeler (CC-Modeler) and laserscanner data. VI Conference on Optical 3D Measurement Techniques - Gruen/Kahmen (Eds), Vol.2, pp. 32-39, September 2003, Zurich, Switzerland.

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