Creating and Using 3D City Models

Traditional 3D City Models vs. Google Earth and Virtual Earth

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Abstract. City modelling is a topic which has been on the agenda for a long time. Today crucial questions concerning the creation of a city model are resolved. The vision of the automatic generation of the 3D geometry of a city out of high resolution digital aerial images is a reality now. These new developments decreased the cost for creating and maintaining a 3D city model of a complete city significantly. This paper wants to outline the ‘history’ of 3D city models and show recent developments in this field. An overview about current applications and uses in this field in Austria and the implementation into daily work is shown with examples (Graz and Vienna city models). Additionally the new developments like Street View in Google Earth or Bird’s Eye in Virtual earth are discussed in relation to their 3D ‘relatives’.

Keywords: 3D City Models, GIS; Google Earth, Virtual Earth.

History of 3D Computer City modelling

The beginning of 3D city modelling lies clearly in academia. One of the main reasons for that was that working with 3D geometry was an expensive and time consuming task. Very powerful computers and graphic cards were needed to get results. Additionally it was very unclear at that time if the benefits would exceed the effort so it was a kind of a playground for the academics. It started with rather crude urban mass models of parts of university campuses or parts of cities. Most of them were static mass models and used as an educational experience. Sometimes these models were without the roofs and no texture on the facades. Early on it was quite clear that the use of this kind of 3D models was very limited. Because of the unclear data sources, different systems and the lack of a database they existed in themselves but could not be used for any further development.

The next generation of early 3D city models were more interesting and done with a different focus – still in many different ways. The VRML BATH model (Center for Advanced studies, Vasilis Bourdakis & Alan Day, 1997) was focusing on interaction. The aim was to find out how to utilise VRML models in urban planning with an easy-to-use interface to allow non experts to understand the implications of proposed changes to their city. The VR Glasgow model and the Glasgow Directory (ABACUS, University of Strathclyde, Tom Maver, 1985) combined 3D geometry with contextual information on the web. The Graz Digcity model (Dokonal & Plösch, 1999) was exploring on an educational level the creation of the geometry itself and was exploring the concept of the LOD’s (Level of
Details) and the connection with a database.

In some cases universities managed to get funding for more ambitious research projects like ‘Digital City Vienna – Pilotproject’ (IFOER, Vienna University of Technology, Voigt & Walchhofer 1998) In this project the urban-spatial development possibilities in variants could be subjected to a spatial discussion. During special workshops with experts and politicians interactive changes to the 3D geometry on an urban scale could be made by the use of a high-speed graphic computer.

The DIGCITY project at Graz University of Technology

One of the early academic examples of a 3D city model was done at Graz University of Technology. Out of many reasons it failed to create a complete city model of Graz but was quite successful on an educational level. The project itself is well documented and has been presented at several conferences on this topic.

Parallel to our work on the Digcity project at university we were in discussion with the municipality – department of survey about the Graz city model for their needs. As mentioned above the first attempt of the city to commission a company to create a city model out of their data failed because of inconsistent basic data. Because of the fact that Graz was awarded Cultural Capital of Europe in 2003 the city decided to invest a substantial amount of money into the creation of a 3D city model.

At Graz University of Technology the Institute for Computer Graphics and Vision (ICG) (Prof. Franz Leberl) (Institut für Maschinelles Sehen und Darstellen, had a strong research tradition on object recognition, object reconstruction, virtual reality and augmented reality. The company Geodata (an offspring of ICG) was commissioned to setup the new 3D city model for the City of Graz by means of using the systems and routines developed by VRVis (Zentrum für Virtual Reality und Visualisierung Forschungs-GmbH) at the ICG. Our experiments with the Digcity project enabled us to give a valuable contribution towards some aspects of the creation of this model.

They use different technologies to succeed in the task of the semi- or full automatic creation of 3D computer city models. From the evaluation of High Resolution Digital Aerial Photos to Laser Scanning to create the city blocks or 3D façades. ICG researched also on other methods like automatically calculated texture maps out of a sequence of images for the textures. This is an interesting aspect for the creation of the textures for a city model. It is frequently difficult or impossible to take photos of a building without elements in the foreground (e.g. persons, vehicles, vegetation) and these methods try to eliminate the foreground objects in the picture.

For the Graz model it was not possible to do the laser scanning due to financial restrictions and the company had to work with more or less the same basic data as all the attempts before. So it was very logical that they were experiencing similar problems like us and the company that had been commissioned for the earlier model. They got in contact with us because they got to know our work and we were discussing the problems involved in the creation of the model. Because they were no architects and planners but programmers and surveyors we really had an impact on their decisions.

After our discussions with Geodata they
developed additional routines to improve the quality of the model e.g. to use the cadastral map to get the offset between eaves and exterior walls. The importance of the distance between eaves and the exterior walls which always happens when buildings have sloped roofs are a key factor. It defines the spatial aspects. Neglecting this offset especially in dense and small streets give a completely wrong impression of the urban space and is only tolerable for bird’s eyes views.

The outcome of the Graz 3D city model for 2003 can be experienced by means of VRML models, which are downloadable from the website of the city of Graz. These results were very questionable because the last step to remove errors caused by the data resources has not been done due to time and money restrictions. So the impact of this model on the daily work and its use as a planning resource or a tourist information system was not very successful.

But the routine that has been developed during the process of the creation of the 2003 Graz model had been ‘state of the art’ and very successful - the company has been commissioned to generate the Vienna model. In Vienna the basic data set was much more reliable and the city works quite successfully with this 3D computer model.

The Vienna 3D city Model and its applications

The city of Vienna has a very good department for surveying with a long tradition and good resources. They manage to update the terrestrial survey in the public street-space and the photogrammetric evaluation of the inner blocks of the complete city every three years. That means that each year one third of the city is surveyed – that means app.140 km²/year. Because of this huge task they have been very keen on innovative methods for the acquisition of geo-data. So for the digital terrain model they use Laser Scanning methods in addition to the terrestrial survey. Quite early they were able to establish a very precise 3D CAD block model of the inner city based on is data. With the evaluation of the aerial
photogrammetry it was possible to add the heights of buildings for the 3D model. With the routines developed from Geodata and VRVis they were able to create the 3D model of the roofs and textures for the facades. At the moment this is only done for important parts of the city.

The Workflow which is now established at the Municipalities Department of Surveying is shown in Figure 2. With this workflow and the structure where the 3D geometry is connected with the GIS databases it is possible to use different qualities of the 3D model for different tasks which is shown in Figure 3. The range goes from environmental planning to detailed projects. Sometimes the 3D city models offer completely new possibilities for the city planning and sometimes it makes existing routines much more efficient.

The production of noise maps for the noise protection is now done in 10 percent of the time with the help of the 3D geometry. The newly added geometry of the roofs in combination with the GIS database gives additional value. For example it can now be estimated how many square meters of roofscape of Vienna have a suitable direction and gradient to be used for solar panels very quickly.

Important tasks for the 3D city model are the help in project design like building extensions on the roof and the analysis of the impact of different projects in an urban setting. The old down of Vienna is listed as World cultural Heritage and the 3D model has been used to generate maps for visibility studies. With these maps you can visualise the areas affected by new buildings and provide the decision makers and the public with additional information. As a
special feature Vienna has several protected vistas and new building projects are tested if they interfere with these vistas. For example the new central train station with its business centre at the location of the existing south train station is a huge project close to the protected vista from the lower Belvedere to the upper Belvedere. In the preparation for the architectural competition the 3D city model allowed the judgment of the impact of possible heights depending on their distance.

The next steps

The demand for quicker and more cost effective ways to create the 3D geometry of a city is getting bigger and bigger. There is a lot of ongoing research to replace some of the tedious manual tasks with automatic procedures. Architects and urban planners have been among the first to deal with 3D computer city models and established the rules for the creation and the emphasis on the spatial aspects, Now there has been a shift towards people coming from the fields of surveying, photogrammetry and programming as the ‘driving force’ behind the creation of these models. Architects and urban planners are now able to use these models for their work.

At the moment Municipalities all around the world realize the potential for their planning departments and the tourist possibilities within these models. Systems like ‘Google Earth’ and ‘Virtual Earth’ - although they started as 2D map solutions - went on to 3D and sparked a new interest into the field. There is a certain footrace between major cities to be the first ‘in 3D’ in Google Earth or Virtual Earth. Cities like San Francisco, Berlin and Hamburg show some results of this race with different success.

We are at the moment waiting for a completely new 3D model of Graz which is now done in a
cooperation of the city with Microsoft for Virtual Earth. Graz is one of the pilot projects for the generation of the complete 3D city model out of High Resolution Digital aerial photos. The Vexcel Company which was founded by Prof. Leberl from the ICG at Graz University of Technology (and recently bought by Microsoft) developed the Ultracam X camera that is used for this task. New algorithms make it possible to generate the 3D model automatically when the aerial pictures overlap 80 percent.

In addition to the 3D geometry new 2D features like ‘Street view’ in Google Earth and Bird’s Eye in Virtual earth seems to have the capacity to give added value to a 3D city model. Especially the Bird’s Eye View where you can have high resolution aerial views from all cardinal points is very convincing. Combined with the 3D geometry they offer new possibilities. There are already results for major American and European cities available. First results for Vienna are already online and the result for Graz should be available soon. If these pilot projects are successful - and there is good evidence that they will be - there is a new chance to generate and maintain the 3D geometry in a cost effective way and even enhance it with 2D information.

Conclusions

In future the availability of 3D city models will be widespread and they will be used for a wide range of tasks. The new generation of these models will be done by a combination of methods. New algorithms allow the automatic creation of the 3D geometry out of high resolution aerial photos. Additionally information is put in with the use of laser scanning for the geometry and details of the facades. On the other hand there is a new strand of a Wiki approach towards City modeling. In systems like Google Earth and Microsoft’s Virtual earth users can start to put in their own 3D geometry using either SketchUp or 3DVia.

The general public will use them in combination with navigation and information and the experts will use them for different kinds of planning issues. Additionally 2D photo information from either a pedestrian view (Street View) or a bird’s eye view (Virtual Earth Bird’s eye view) together with the 3D model have the potential to complement one another.
References

Collections of Links (active in February 2008)
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http://www.icg.tu-graz.ac.at/
http://www.vrvis.at/2d3d/
http://www.vexcel.com/
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