CREATING AND USING 3D CITY MODELS

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Abstract

City modelling is a topic which has been on the agenda for a long time and two main approaches from different angles in this field can be identified. GIS experts have attempted over the years (in collaboration with programmers) to build information systems for cities by means of combining graphical information with related metadata. Architects also started to get involved in this field. Most of them came out of academia and they were mainly interested in the spatial aspects of a city model. So they created their own “city models” for different purposes in different ways. Today crucial questions concerning the creation of a city model are resolved. The question is no longer “How to do a city model?” but “What to do with it?” The visions of the automatic generation of the 3D geometry of a city out of high resolution digital aerial images are a reality now. It shifted away from academia into the “real world” and into the “real cities”.

These new developments decreased the cost for creating and maintaining a 3D city model of a complete city significantly. But still there is a substantial amount of money necessary in this field so the cost/benefit analysis must be clearly visible. This paper wants to give an overview about current applications and uses in this field.

The implementation into daily work becomes more and more important. The question: “what to do” with all the accumulated data and the benefits out of a 3D city model are shown with examples (Graz and Vienna city models).

Keywords: city modelling, collaborative modelling, digital design, architectural education

СОЗДАНИЕ И ИСПОЛЬЗОВАНИЕ 3D ГОРОДСКИХ МОДЕЛЕЙ

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Аннотация

Городское моделирование - тема, которая была на повестке дня в течение долгого времени, и два основных подхода под различными углами в этой области могут быть идентифицированы. Эксперты GIS попытались за эти годы (в сотрудничестве с программистами) строить информационные системы для городов посредством объединения графической информации со связанными метаданными. Архитекторы тоже начали вовлекаться в эту область. Большинство из них вышло из университета, и они главным образом интересовались пространственными аспектами городской модели. Таким образом они создали собственные “городские модели” по-разному для различных целей. Сегодня критические вопросы, касающиеся создания городской модели, решены. Вопрос теперь не о том, "как сделать городскую модель?”, а "что с ней делать?” Проникновение автоматического генерирования трехмерной геометрии города из цифровых аэроизображений высокой разрешающей способности – теперь реальность. Это переместилось из университета в “реальный мир” в “реальные города”.

Новые разработки значительно уменьшили стоимость создания и обслуживания трехмерной модели целого города. Но все еще остается существенная сумма денег, необходимая для этой области, поэтому результаты анализа стоимости/выгоды должны

быть ясно видны. Эта статья дает краткий обзор текущих применений и использования в этой области.

Применение в каждодневной работе становится все более важным. На вопрос: “что делать” со всеми накопленными данными и преимуществами трехмерной городской модели дается ответ в примерах (городские модели Граца и Вены).

Ключевые слова: городское моделирование, совместное моделирование, цифровое проектирование, архитектурное образование

Introduction

City modelling is a topic which has been on the agenda for a long time and two main approaches from different angles in this field can be identified. GIS experts have attempted in collaboration with programmers over the years to build information systems for cities by means of combining graphical information with related metadata. Architects also started to get involved in this field. Most of them came out of academia and they were mainly interested in the spatial aspects of a city model. So they created their own “city models” for different purposes in different ways. Today crucial questions concerning the creation of a city model are resolved. The question is no longer “How to do a city model?” but “What to do with it?” The vision of the automatic generation of the 3D geometry of a city out of high resolution digital aerial images is a reality now. It shifted away from academia into the “real world” and into the “real cities” These new developments decreased the cost for creating and maintaining a 3D city model of a complete city significantly. But still there is a substantial amount of money necessary in this field so the cost/benefit analysis must be clearly visible. 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 and the implementation into daily work is shown with examples (Graz and Vienna city models).

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 task and needed very powerful computers and graphic cards. 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). By means of a digital, three-dimensional work-as-executed model the urban-spatial development possibilities in variants can be subjected to a spatial discussion throughout workshops making interactive use of a (very expensive) 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 (DIGCITY, Dokonal, Plösch 2000). (Fig. 1)

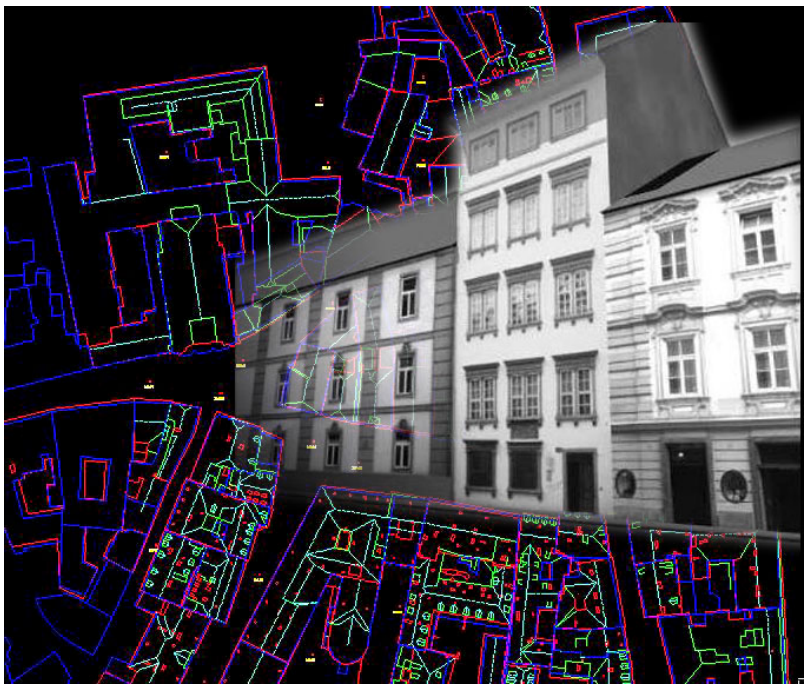
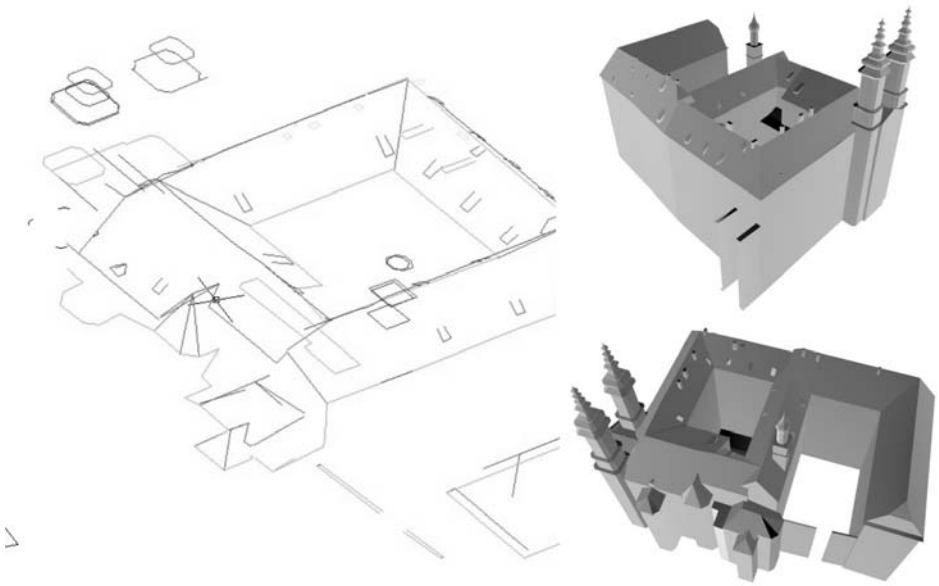


Fig. 1. Digcity

Out of many reasons it failed to create a complete city model of Graz but was quite successful on an educational level. Additionally the project was able to give a valuable contribution towards certain aspects when the city decided to invest a substantial amount of money into the creation of a 3D city model for the year 2003 when Graz was awarded Cultural Capital of Europe. Because of that I give a short outline of the structure of the project – the project itself is well documented and has been presented at several conferences on this topic (see references). (Fig. 2(a,b) (Dokonal, Plösch 2000))



a) b)

Fig. 2(a,b): a) basic data; b) model of building - without textures

Main goals:

- the creation of a 3D City Model of Graz with the support of the students in the study fields of Architecture and Urban Design;
- the educational aspects involved in the work on the model;
- the idea is learning to use and understand all aspects of the city model - like spatial aspects, constructional details, reliability of sources - by being involved in the creation.

Starting point of the project:

- the wish to create “sustainable“ computer models of the city (sharing and reusing of work done at our university);
- therefore bring added value“ for students (and teachers);
- use the potential of mass university (no money but many students);
- use the need for 3D-city models in architectural education (a lot of students design projects are situated in the city therefore there is a lot of interest in getting digital data);
- bundle and coordinate all these needs and efforts.

Principle project structure:

- the city model is based on models of individual buildings;
- every single building consists of drawings with a predefined layer structure;
- every source of information and every modification of the data sources has to be documented on a data sheet which is an essential component of the project;
- all the information is stored in a database and can be retrieved using a web interface.

Main data sources:

- photogrammetric evaluation of aerial pictures;
- aerial pictures;
- terrestrial survey;
- site analysis including pictures of the façade;
- available detailed computer models of special buildings.

Levels of detail (Lod‘s):

- girding surfaces of every individual building (LOD 1);
- additional information from aerial pictures (LOD 2)(dormers of roofs, chimneys);
- space defining elements of the facade (LOD 3)(balcony, bays ...);
- detailed computer models of special buildings (LOD 4) (if available).

(Fig. 3 (Dokonal, Plösch 2000))

Fig. 3. Parts of DIGCITY facades

Semi – Automatic created 3D model commissioned by the City of Graz

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. 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 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.

This was an important factor for us because we always thought that the DIGCITY project should contribute towards the best possible 3D-model of Graz. We did not want to do the same thing again so we wanted to work with the best available data. It was always clear to us that every automatically created model would still need a lot of refinement if it is based on the existing basic data.

At Graz University of Technology the Institute for Computer Graphics and Vision (ICG) (Prof. Franz Leberl) (Institut für Maschinelles Sehen und Darstellen, http://www.icg.tugraz.at/pub) had a strong research tradition on object recognition, object reconstruction, virtual reality and augmented reality. The company Geodata was commissioned to setup the 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. (Fig. 4)

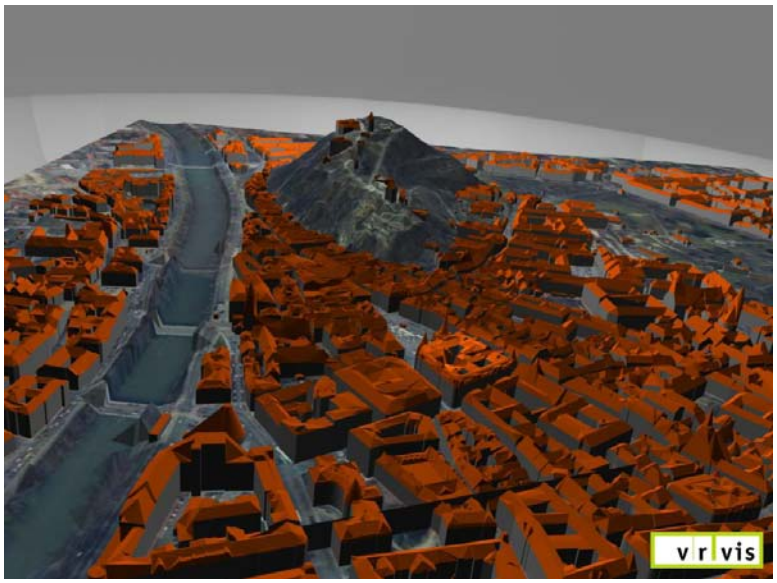


Fig. 4. Some results of the 2003 vrvis model, VRVIS

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. 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.

But 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 that we had when we did the Digcity project. So it was very logical that they were experiencing the same problems we had before. 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 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 (http://3d.graz.at/). These results were very questionable because the last step to remove errors caused by the data resources has not been 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 has 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 the 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. (Fig. 5)

Fig. 5. From Multi purpose map towards the 3D model, MA 41 Vienna

The Workflow which is now established at the Municipalities Department of Surveying is shown in Figure 6. 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 you can see in Figure 7. The range goes from environmental planning to detailed projects.

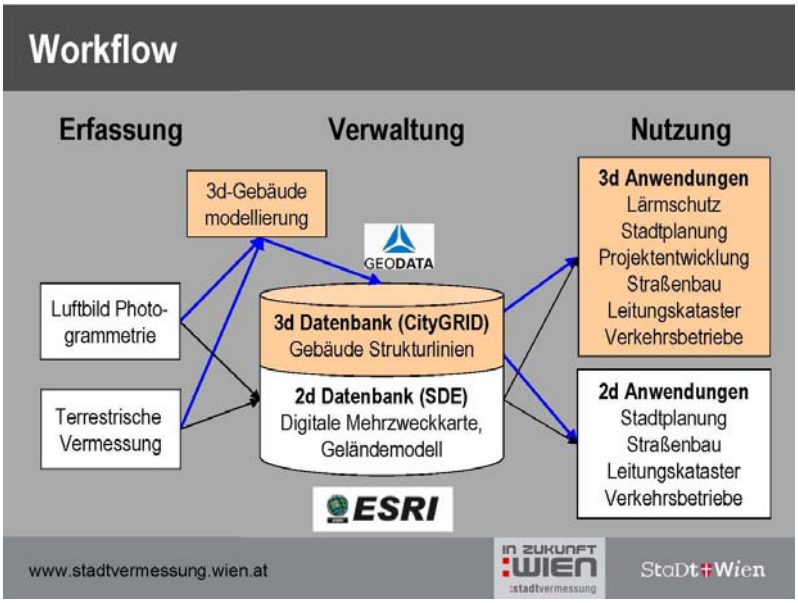


Fig. 6. Workflow

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 new added geometry of the roofs in combination with the GIS database allows for example an estimation of how many square meters of roofscape of Vienna have a suitable direction and gradient to be used for solar panels. (Fig. 7)

Fig. 7. Model Detail depending on the tasks, MA 41 Vienna

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 visualize 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. (Fig. 8)

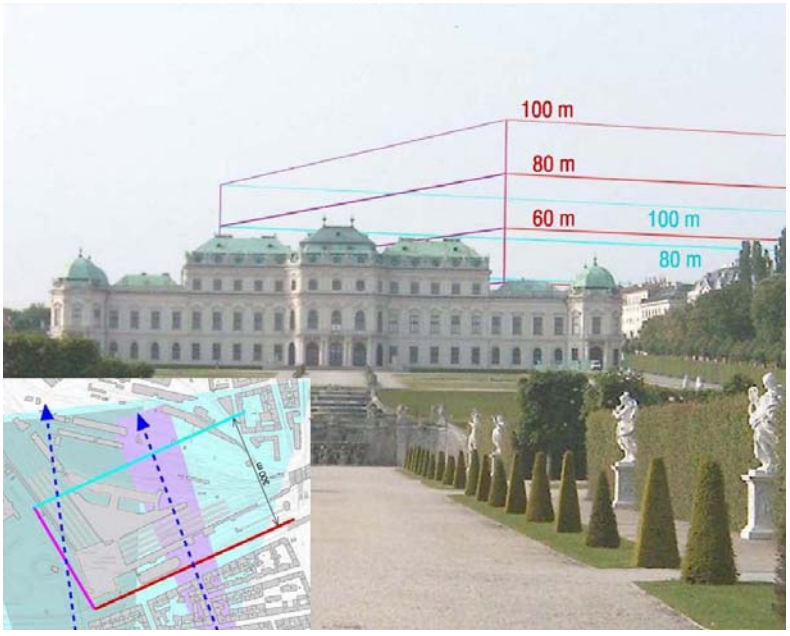


Fig. 8. Vista study for the proposed mass of the Vienna central train station, MA 41 Vienna

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 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 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. The result should be available soon. If this pilot project is successful there is a new chance to generate and maintain the 3D geometry in a cost effective way. In future the availability of 3D city models will be widespread and they will be used for a wide range of tasks. The general public will use them in combination with navigation and information and the experts will use them for different kinds of planning issues.

Collections of Links (active in February 2008)

http://www.digcity.tuGRAZ.at
http://www.icg.tu-graz.ac.at/
http://www.vrvis.at/2d3d/
http://www.vexcel.com/
http://www.georgholzer.at/blog/2007/06/10/die-beste-kamera-der-welt/
http://www.bath.ac.uk/Centres/CASA/bathmodl.htm
http://www.casa.ucl.ac.uk/3dcities
http://www.stadtvermessung.wien.at
http://www.gis.graz.at
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http://www.zukunftsinstitut.at
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(http://cumincad.scix.net/cgi-bin/works/Home)

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