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Production of Virtual 3D City Models from Geodata and Visualization with 3D Game Engines. A Case Study from the UNESCO World Heritage City of Bambergs

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1 INTRODUCTION

In cooperation with the city of Bamberg and the TU Kaiserslautern, a research project on 3D-4Dcity models was founded whose results were presented to the public during this year's conference of the UNESCO Organization of World-Heritage-Cities (OWHC Regional Conference 2004).

For the first time, approaches from the entertainment industry - especially from the computer game industry - have been used besides standard techniques for the preparation of 3D city models. They combine an - until this date - unknown presentation quality with the possibilities of an independent navigation in real-time. Consequently, the virtual walk through the historic part of Bamberg turns into an experience even from your home PC.

2 PROBLEM STATUS / STARTING POINT

Starting point for this project was the idea generated in the spring of 2003 between representatives of the city of Bamberg and the TU Kaiserslautern to build a city-model, not "physically" out of wood (as models have been in the past), but to concentrate the efforts on the attempt of constructing a virtual city-model.

Herein the focus didn't lie primarily on the technical side or the question with which modeling software a virtual 3D city structure would ideally be produced, but it was rather essential to define an optimized workflow to generate preferably inexpensive and high-quality 3D models from already existing local geo-data. The use of surface-covering laser scan recordings, which, besides high expenses during the recording and modelling process, presents a gigantic point-density of frequently already collected data and consequently redundant information, was renounced on purpose. Furthermore, it was important to guarantee the ability to apply and transfer the data for various internal and external users. Hence, it was supposed to supply other user groups, besides the local community offices, such as manufacturers of car-navigation-systems, tourism, location-marketing all the way up to facility management, with accurate city models, consequently allowing local data to grow in economic value.

Thus, the following criterions were central factors for the assessment of the existing data and their application as well as for the preparation of the 3D model itself:

Precision of the model preferably in the centimeter-area;

Simple preparation, modeling from existing data;

High aesthetic ambitions and degree of detailing;

Possibility of swift update and extensive modification of the generated model;

Continuation of the geometric data, preferably at low-cost;

Open data-interfaces and compatibility with current software applications.

Furthermore, the produced "raw-model" should offer the following features:

Detailing degree according to current Level-of-Detail specifications (LOD 0-3) [Gröger et al 2004];
Database interface;
Integration into web browsers and mobile devices;
Integration of laser-scan data.

3 PROJECT COURSE

The quite complex project task to create a city model of the historic city center of Bamberg (after all, its expansion as city-memorial amounts to 425 hectares) as exact as possible and above all extensively , required a project arrangement of several work phases. Besides the procurement and preparation of data groundwork, the main work focus concentrated on the model creation and presentation as well as on interactive navigation of a 3D city model of these dimensions.

3.1 Data groundwork / Preparation of the database

A principle difference was made between data resources that have already existed and such that still had to be collected.

Existing data resources, e.g. the digital elevation model of the Federal State's Surveyor's Office, geo-referenced sewer measurement points, street-surveying points of the city-planning office, the digital cadastral map as basis for the building shapes, aerial pictures from several aerial photos strips etc. were checked on topicality and were supplemented by newly recorded data.

Façade photos, exact heights of respective buildings, and unambiguous building identification numbers were non-existent, however still important fundamentals for a 3D city model. Besides this information, it was particularly essential to survey special points of interest more carefully and, if necessary, to detail them more precisely by means of terrestrial laser scan recordings in another work phase.

The purpose of the model creation was the preparation of wire frame data, which contains the digital elevation model, the buildings placed on the DGM, as well as the roof surfaces cut down to the buildings. The subsequently originated CAD basis of the model creates the foundation for further actions and was returned to the city-planning office of Bamberg in DXF data format. For internal use,e.g. in the land use plan, the integration of reconstruction measures, the filling of gaps, the continuing town planning analyzes etc., this optimized database still offers a valuable support of daily planning practice.

To obtain adequately exact databases in the inner part of town, it turned out to be problematic at first, especially since the existing digital landscape model of the Federal State’s Surveyor’s Office of Bavaria (DLM / 50m Raster), proved to be too inaccurate. Elevation leaps like edges etc. were only partially recognized in fragments; moreover, many measuring points laid in built-on areas. Hence, faulty measurements in reference to the real world situation existed with deviations up to 10 m, allowing the DLM data to be usable for un-built areas at best. On the basis of self-surveyed street stretches (by the local city planning office), in connection with further stereoscopic evaluations of non-available areas, a degree of detailing could be attained which enabled the creation of a digital elevation model.

The building heights in the world-culture-heritage area were recorded with the help of laser distance measurements. Therefore, an initial virtual city model could be created in combination with the layout plan information of the digital cadastral map. In addition to the exact position and height information the buildings could also be assigned with explicit identification numbers. Consequently, the ID, consisting of landmark numbers, street keys and house numbers, enables an unified access to each single object that would allow georeferencing of all buildings (nationwide). Furthermore, preliminary meta information about recreation, traffic, and tourism etc.was analyzed and catalogued in this work-step.

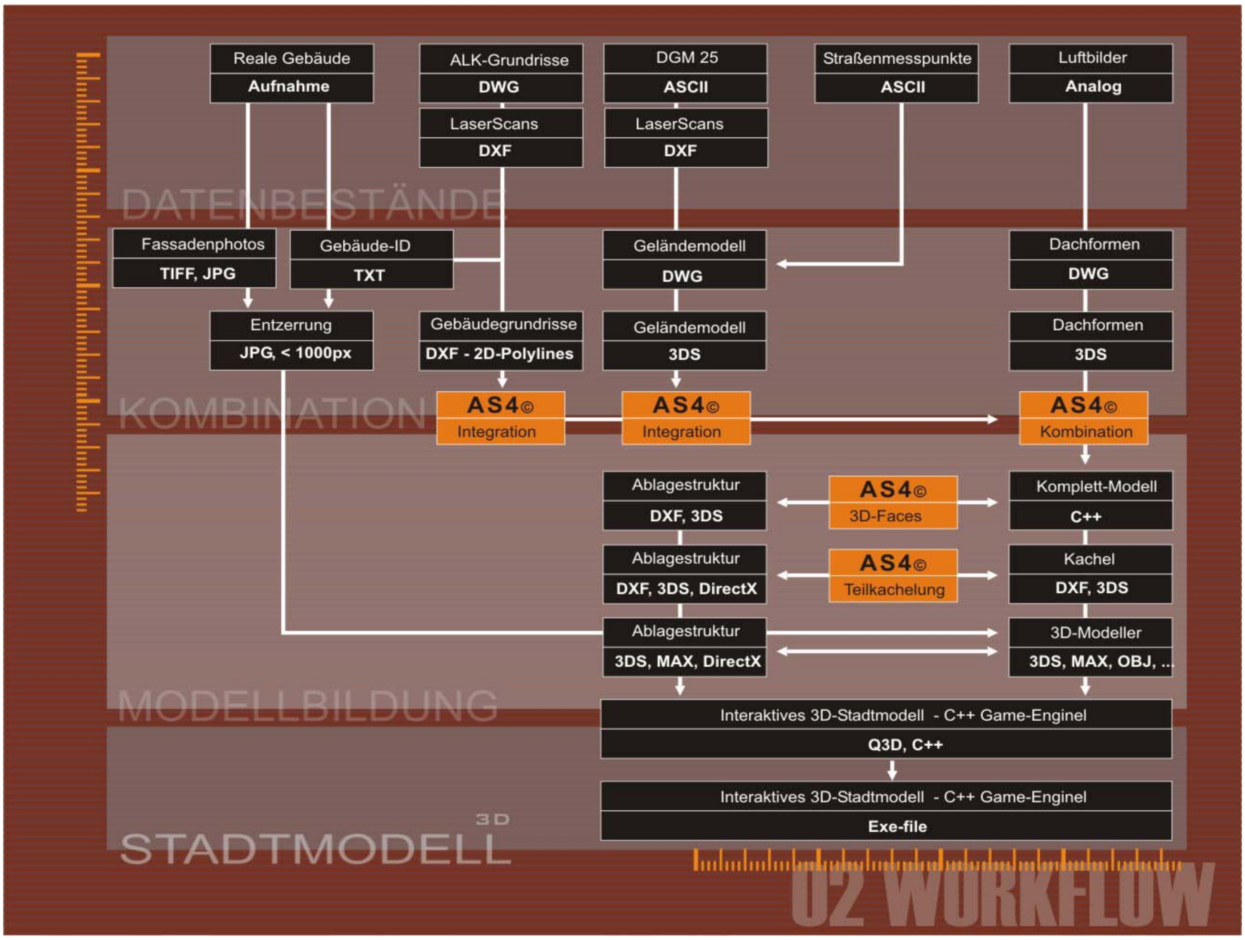

Fig. 1: Workflow of the generation of a 3D city model

The so generated ”block model“ was combined with the digital elevation model in another work step to adjust the shapes to the terrain’s surface. In analogy to further procedures, this step is called ”Level of Detail 1” (LOD 1). The next higher detailing degree (LOD 2), contains additional information such as roof shapes, on-roof constructions etc, which were determined by stereoscopic analyzes of available surface-covering aerial photos. This detailing step, in particular, contributes to an essentially higher recognition factor of the 3D model and decisively improves the orientation within the virtual city structure. Consequently, landmarks and prominent buildings etc. in the city area become noticeable.

Nevertheless, it became clear rather quickly that as well as with conventional software as with specialty applications, particularly developed for this purpose, the variety of calculating operations for an entire city model could not be achieved. Besides elementary merger errors, the various systems struggled with export problems and unacceptable processing times. This ledour team to develop a software (ArchitecturalSpace©), which, besides the identified requirements, also enables a segmentation of the total area (small-tiling in any grid-width).

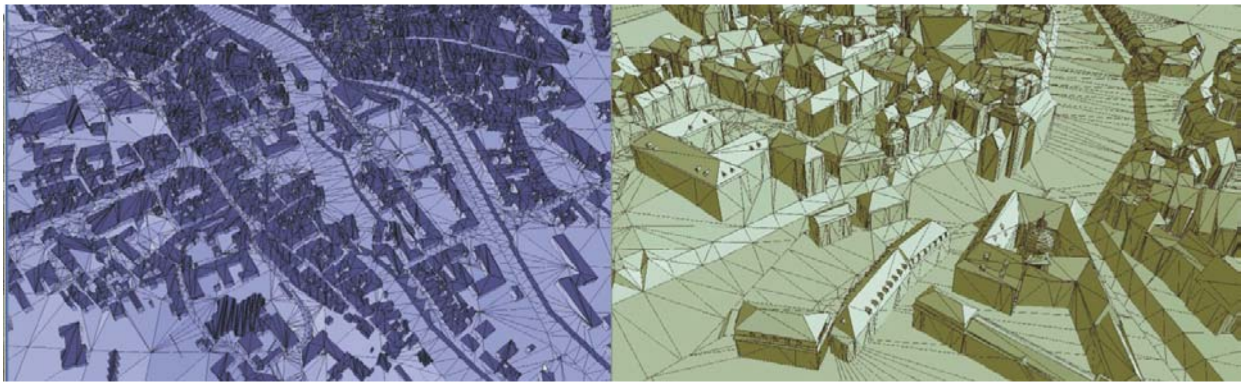

Fig. 2: Detail steps LOD 1 and LOD 2 generated from ArchitecturalSpace©

The highest detailing intensity (LOD 3) was reached by 3D rendering techniques. Façade photos, which were stored in a database, rectified by means of a photo processing program, corrected and modified are mounted (mapped) on the building surfaces. Above all, the photo editing proved to be most labor-intensive during this process. Some buildings are not freely accessible due to their location; facades cannot be photographed orthogonally, or were blocked by scaffoldings, parked cars, vegetation, etc. In order to generate ideal 3D models, such "disturbing factors" must often be edited in strenuous and time-intensive handwork.

Corrected façade mappings Heading 1

4 PRESENTATION OF 3D CITY MODELS

Crucial for the acceptance of 3D city models is primarily the quality of the representation. The detailing intensity achieved with LOD 3, combined with the abovementioned rendering techniques, already allows quite photorealistic scenes. Nevertheless, they offer no more than "static pictures." Each time the model is optimized according to the specific viewpoint in order to control the wealth of details of the representation.

Virtual walks, the so-called "walk-throughs" bring dynamics to the picture. A scene is presented to the observer as an animation, which he may play as often as he'd like, similar to videotape. The route through the virtual model is, however, predetermined. Possible alterations, i.e. scene selection, cruising altitude or even the selection of an alternative route through the city model necessitate considerable work and calculating effort. The modified result will once more be an animation with all above-mentioned restrictions.

Contrary to this, the Desktop-VR presents an extended approach of the three-dimensional representation of geometries. The focus rests less on the large-scale production of photo-realistic still images or virtual round flights through e.g. town-planning situations, but rather on the integration of a multimedia and linked information arrangement with a connection to space/volume. Contrary to independently running film-sequences in high-end rendering, VR-systems allow an individual navigation in the computer-generated world. Besides the established representatives of internet-based visualizing techniques, e.g. VRML, X3D, GML and Java3D, in whose skillful combination enormous potentials may also be found, the focus is directed in a different direction, namely computer games. New approaches for dealing with large quantities of three-dimensional data, which must be processed in real-time, presently mainly derive from just these areas. Consequently, it was obvious to combine these developments with the tasks of city model processing, and to profit from the speed and capability of these ”game-engines“.

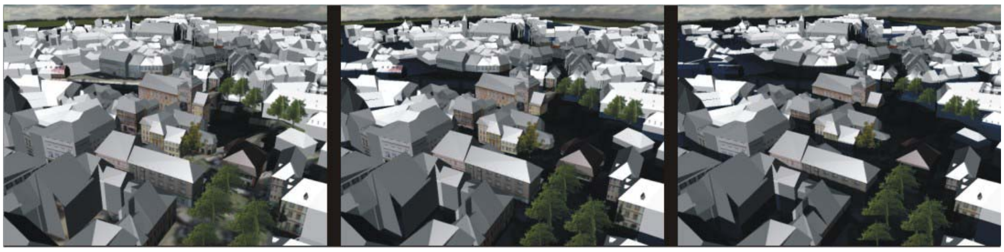

Fig. 4: Flood simulation

5 GAME-ENGINES

3D game-engines offer real-time 3D rendering, coupled with simple and logical navigation assistance and could in particular be utilized for tourism, city and location marketing as well as the reconstruction of vanished historical scenarios. Especially in reference to the performance and handling of large graphic data, the development in game programming has been pressed forward strongly during the last years, using data quantities which are meanwhile comparable with those for CAD programs, or even exceeding those by far in some cases. Merely the effective utilization of game technology for three-dimensional applications outside the entertainment industry (ego-shooter, spaceship-simulators etc) has not yet been achieved until today. Thus, the 3D city model of Bamberg, being based on these techniques, can certainly be regarded as unique.

Fig. 5: LOD 3 – game-engine integration; situations bridge-town hall and view from fruit-market on bridge-town hall

Contrary to products of various software companies, the self-created routines can be adapted to individual needs and be optimized according to their requirements. With this, only the solution for special problems is placed into the foreground and not the general approach, like in other software programs. The generated drawing data is usable as raw data material for further operations in various ways. Since the buildings are available as independent objects, they can receive additional information and titles such as house numbers etc. Moreover, the relatively slim data packages are suitable for visualizing via Internet and mobile devices, which opens a variety of possibilities especially in reference to the new UMTS-net. Besides the accurate 3D representation, precise coordinates, e.g. Gauss-Krüger or WGS84 , are assessable, while new data can be supplemented and existing objects can easily be changed.
Furthermore, there is the possibility to simulate variation comparisons in real-time through the programmable 3D game-engine interface by means of push-button access to prepared, georeferenced single objects. Especially in the town-planning context or in design-sensitive areas, this option is an enormous advantage concerning communication with the public and transparency of the planning decision.

After all, the possibilities of game technologies allow new approaches for the development of 3D city models and can contribute to solving pending (planning) tasks more effectively. On the basis of these techniques, the construction of 3D drawings will become easier, faster, and more flexible in the future, while reality-like scenes – whether they involve existing or planned structures - can virtually be “experienced”.

6 RESULT

The confrontation with the 3D city model topic as well as intensive discussions amongst all project participants have shown that the use of universally employable city-models is considered very helpful and even appears to be unavoidable in the future. Besides diverse possibilities in the planning process itself, potentials are primarily seen in the visualization of spatial contexts of town-planning structures, which are often not perceptible in flat 2D representations. Moreover, the aesthetic attractiveness as well as the high level of detailing will lead to further application of for virtual worldsin urban contexts, adding dynamics as well as fun to the topic “city” itself.

Due to data preparation problems and the consequent high expenditures of the processing and integration into current software applications in particular, questions have been raised increasingly, asking for uniform standards for 3D city models. Furthermore, awareness for the necessity of data administration of existing models must be created. This could be achievable for the communities without any large technological efforts. In this context a 3D monitoring of the city would be desirable in order to document, to archive or to even simulate processes of growth or shrinking, changes of the city shape, etc.

In consideration of scarce city budgets, a 3D city model becomes especially attractive when, besides the diverse internal application areas of the city, external interests are additionally served. Therefore, the focus will rest on an optimization of the workflow, allowing a rather inexpensive preparation of 3D city models, which are actually demanded and also paid by the market due to their quality and breadth of usage options.

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