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Visualization Project of Roman Cologne – How to Make VR models Available for Scientific Work

Abstract: The visualization of the Roman city of Cologne, as an interdisciplinary research project, combines the knowledge of building archaeologists, archaeologists, designers and computer scientists. The aim of the project is to create innovative methods and techniques that cope with highly detailed 3D models of historic sites such as the Roman Cologne, making them available as real-time visualizations for interactive scientific work. Our research started by analyzing archaeological evidence, publications, and drawing conclusions from analogies. Our building archaeologists and archaeologists produce scientifically reliable reconstructions of well-known ancient buildings of Cologne. These results, documented in drawings, are later transferred into high-detail 3D models by our designers and arranged to create the overall city model. Finally the models are converted into Collada. The Collada 3D asset exchange schema is an XML based open standard of the Khronos Group (http://www.khronos.org/collada/). Collada is a 3D asset exchange format used by a real-time application created by our computer scientists. In the future these highly-detailed real-time visualizations will be linked with archaeological databases to improve the usability of VR models in scientific work.

Introduction

Three institutions are involved in the interdisciplinary research project "Visualization of Roman Cologne". The Archaeological Institute at the University of Cologne, supervised by Prof. Dr. Henner von Hesberg, provided the scientific input with the necessary reconstructions and contextual knowledge. The Köln International School of Design at the Cologne University of Applied Sciences, under the aegis of Dipl. Des. Michael Eichhorn, was responsible for building the digital 3D models and developed methods of dissemination for these models and the associated knowledge. As a technical partner under the direction of Prof. Dr. Jürgen Döllner, the computer graphics group at the Hasso-Plattner-Institut (HPI) at the University of Potsdam is developing a solution for the real-time visualization and exploration of Roman Cologne. The project has been mainly financed by the RheinEnergie-Foundation – Youth/Profession and Science, Cologne. Further financial aid and scientific support has been granted by the Roman-Germanic Museum, Cologne (RGM). HPI has been partially funded by the German Federal Ministry of Education and Research (BMBF) as part of the InnoProfile research group '3D Geoinformation' (http://www.3dgi.de/).

The Challenge of Reconstruction

As a fundamental task, various detailed digital 3D models of single Roman structures and building complexes have been created to setup the overall virtual 3D city model representing the ancient town. The reconstructed models differ in their level of detail. Only the well-known buildings are modeled on a highly detailed level, the others as simple shapes acting as replacement characters. The models are constructed on the basis of detailed research, carried out by building archaeologists and archaeologists of the Archaeological Institute at the University of Cologne. The scientific work takes into account the analysis of previous publications, the actual archaeological evidence, and the recent finds of the local department of antiquities (RGM). In addition, analogies to well-known buildings are used to create new scientifically reliable reconstructions. These models are designed as single units, which are to be embedded into the 3D virtual city model of Roman Cologne. This was done on the basis of a digital modern terrain model, which is modified by archaeologically gained data. Other projects present their results as detailed renderings, predefined animated sequences or QuickTime VR visualizations, mainly serving as information material in an exhibition or e-learning context, for web sites and to suit the needs of visitors in museums. Examples of this approach are the visualisation for Pompeii and Herculaneum, from Capware Digital Worlds (http://www.capware.it), the various projects of Digital Archaeology (http://www.digitale-archaeologie.de), or the web presence of the Roman colony Colonia Ulpia Traiana, Xanten (http://www.apx.lvr.de/), commissioned by the Archaeological Park and Regional Museum Xanten. Their virtual models are often the final product in the scientific process. In our workflow the digital 3D models are used differently. They are already used during the scientific process to validate the results immediately in the third dimension. The 3D models provide this potential and they should be used much more often in archaeology and building archaeology in order to develop new approaches, to verify or falsify scientific theories, and to enhance the scientific process.

Particularly, complex virtual 3D city models provide valuable means and synergy effects to visualize archaeological sites such as Cologne, where antique structures were continuously transformed by the subsequent settlements and can hardly be recognized in the current cityscape. The most important advantage of this approach is the ability to show and control systems and connections in urban design or in building complexes of vanished structures. For example, the relationship between the Capitol Temple in Cologne and its small altar *(Fig. 1)* (Neu 1984), or the altar and the two-storied porticos used like stands in the temenos of the Ara Ubiorum (Irmler 2004). These connections cannot be appropriately shown by 2D drawings or descriptions only.

Furthermore, drawings can easily be verified in the third dimension, since 2D drawings often show only a part of the reconstructed buildings and, thereby, many questions are usually factored out.

Fig. 1. Capitolian Temple Cologne, east elevation with altar (1st half of the 2nd century AD).

To achieve the best conditions for scientific investigations, the high detailed Cologne 3D model is visualized by a real time application. This allows us, for the first time, to take advantage of the flexibility of the real time 3D environment, facilitating scientific exploration and analysis, and to use highly detailed models without perceptible loss of performance. In the past, it was only possible to create the desirable highly detailed models for predefined, pre-rendered images and films, or to build less detailed models

Fig. 2. Two-storied portico, Ara Ubiorum, Cologne. Wireframe view and the shaded building (late 1st century AD).

for the flexibility of real-time animation. The combination of both is the innovation and significant achievement of our project. It is the intention of our project to develop a simple and powerful tool for a broad audience of scientists and to create an intuitive, effective, well structured user interface for this research tool.

Highly Detailed Modeling

Within the production chain, the designers rank second. All objects are modeled with 3D graphic applications, e.g. 3dsMax or Cinema4D DCC (Digital Content Creation). Our work is based on 2D CAD drawings provided by the experts in building archaeology and created with VectorWorks. Next they are imported into the DCC software and positioned correctly in the 3D space. The DWG format is particularly suitable for data exchange. By this procedure we achieve the high and detailed accuracy of our models. Thus the huge amounts of lines in the model represent a heavy challenge to computers. Therefore the drawings have to be optimized in the CAD software. We mainly use polygon modeling for the construction of the objects *(Fig. 2)*.

This workflow provides the best control over the amount of polygons in the final geometry. For example, the accuracy of the curve approximation is always appropriately adapted at the round elements. The form of the objects is maintained exactly with the lowest possible polygon count. By this, we already optimize the models in the molding step for the real-time application. In addition, some objects – particularly organic shapes – are modeled with digital sculpting software, e.g. ZBrush, using a pen tablet. Therefore the geometry shows a somewhat "painted" structure rather than a "constructed" one. The small details of these objects can be stored also as Height Maps (Bump or Normal Mapping). Large elements, such as walls, are used both for real-time application and renderings. We produce the small ornamental elements such as capitals in several versions with different complexity. These objects use most of the polygons in the scene. They are, however, only visible if the observer stands directly in front of the building. Depending on the distance of the viewpoint, different versions of the geometry are loaded. Thus, we receive smooth camera movements even in the total view. For this kind of work the consistent use of instances is very important, since many objects can easily be replaced or reduced in a scene. This increases the efficiency of the workflow and extremely reduces the memory use.

The realistic illumination of the scene is also important. We therefore use global illumination, which simulates a daylight situation, resulting in more authentic depictions. It also gives an impression of the size of the buildings and strengthens the 3D effect. We saved this precalculated lighting in the surface textures for later use, thus time consuming illumination calculations can be avoided in the real-time application. This was planned to provide colored surface textures for many elements, especially for this reason. The archaeologists prepared the necessary color templates. The visual appearance of the surface is developed on the basis of the templates. Apart from scientific reliability and comprehensibility, the simulation also needs a high aesthetic quality. Since this aspect is very important in Roman architecture, we aim at recreating the sensual effects in the virtual city.

Small details, such as ornamented surfaces, can be represented efficiently by textures. The difference to real geometry representations is practically undetectable by the user. The effort involved in the creation of the authentic textures is also relatively high, and the ambition lies in the reduction of the complex geometry data. Normal maps *(Fig. 3)* are particularly suitable for this purpose, thus the high-resolution details are projected on a low-resolution polygonal object. Due to the high accuracy, all buildings are suitable for the production of common animations or large sized prints. Also, the real-time model might be implemented as a movie setting for a real actor in a virtual studio.

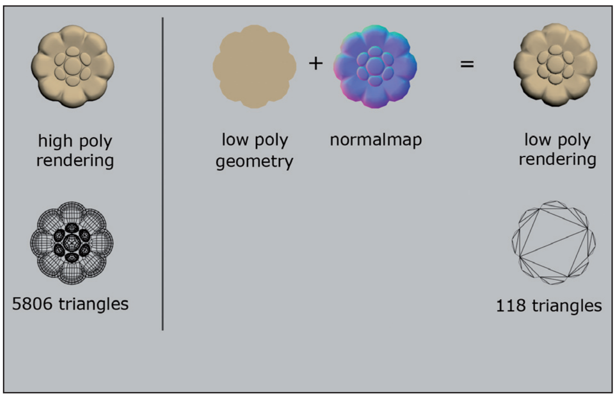

Fig. 3. An example of normal maps usage.

Real-Time Visualization

Applications for real-time visualization of virtual 3D city models can be found in different domains, such as the entertainment industry, e.g. computer games, as well as in professional services, e.g. city planning or car navigation systems. Since we aim for a scientific visualization of archeological virtual 3D city models, our technical requirements differ in the following aspects:

- Free 3D Navigation: In contrast to users of computer games or navigation systems, our scientific users do not accept a navigation that is restricted only to specific areas or viewing angles. Usually, they want to be able to instantly switch between a birds-eye perspective, showing an overview, and a close-up view to inspect the detailed geometry of parts of a building.
- Complex Data: The building models that are used as input rely on archaeological reconstructions carried out by designers using standard modeling tools. They are highly detailed in geometry *(Figs. 4 and 5)* and complex in their material appearance. Therefore, techniques that optimize this huge amount of data for the real-time visualization have to be implemented and applied in pre-processing steps. Again, this is different to computer games, where virtual worlds are created with specialized editor applications, or from virtual city models, where highly detailed models only appear for a few important and explicit modeled landmarks.

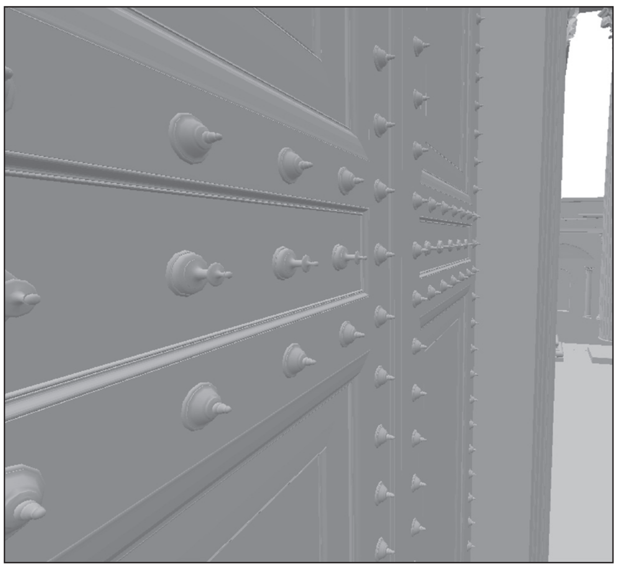

Fig. 4. Aperture of a temple door in real-time environment.

Fig. 5. Corinthian capital in real-time environment.

- Interactivity: The final product of this project should not be another viewer application for virtual cultural heritage models. In our opinion interactivity should not be restricted to the navigation of a virtual observer within the model. Moreover, we plan to create interactive virtual objects with features that allow users to explore a wide range of context information, including additional texts, images, perspectives, historic maps, and hyperlinks to related material.

Another important aspect is the data exchange. To improve the usability of the 3D data models for the real-time visualization in a scientific context, an iterative creation process is applied. This approach allows content providers, designers, and technical developers to discuss different construction variants (e.g. explicit geometry vs. normal maps) and to detect visual artifacts early during the recurrent tests. For this, a 3D data exchange format has to be selected to establish the link between the designers and the real-time visualization in the production chain. Widely used formats, e.g. Wavefront OBJ files, VRML, or X3D, only provide a subset of the features needed in our application:

- Support for the DCC tools of the designers (Cinema4D, 3dsMax)
- Support for standard features, e.g. transformations, unique geometry and material definitions, object names, multiple instancing and external references to construct libraries for often used parts
- Support for modern modeling and rendering features (e.g. multi-texturing, bump and normal mapping (Akenine-Möller / Haines 2002), or material shader (Rost 2006))
- Lossless, extensible, and future-proof.

After a short period of evaluation, the Collada format (Arnaud / Barnes 2006) was chosen for the reason of its XML based structure, its open specification, and the support by a number of major hardware and software vendors, acting as active members in the specification board.

The archaeologist is supported by the interactive visualization of the highly detailed Roman buildings in their spatial context by the presentation, discussion, and validation of his or her hypothesis. It allows analysis of the arrangement of buildings related to the ground structure they are built on, their intervisibility, or their connectivity in the path network. Besides these direct graphical insights, our application framework provides a number of techniques to enhance 3D views with interactive secondary context information, including texts with hyperlinks, images, and animations. For example, non-photorealistic rendering (NPR) techniques (Nienhaus / Döllner 2004) can be used to communicate non-spatial aspects, e.g. changes over time or uncertainties in a hypothesis. Additional annotation techniques can provide information about the name, function, or exact extensions of building parts.

Moreover, we are currently experimenting with an integration of Adobe Flash content for the presentation of context information next to the 3D view. This would create a loose coupling between the 3D models and the multimedia context information, permitting an easy update and extension of the material in the future.

Perspectives

To address further needs for scientific exploration and analysis of virtual archeological sites, as a next step, high-resolution textured city models will be combined with database features. They provide contents necessary for archaeological research, such as literature, two-dimensional plans, archaeological documentation, photographs, information about the individual building reconstruction, links to databases with original finds, e.g. for Cologne, the "Arachne" database (http://www.arachne.uni-koeln.de/), information about preserved ruins and so on. The dynamic combination of the real-time virtual 3D models with traditional sources of information, such as plans, photographs, literature and connected databases of findings is a research challenge. We observed that due to the manifold conceptual and technical aspects, only an interdisciplinary team could solve these challenges effectively. The dynamic connection between database-content and the 3D model has been already solved in a proof-of-concept-study by MA F. Wilems under the supervision of Prof. Dr. M. Thaller at the University of Cologne for the Basilika Aemilia. The application of these methods to the city model of Roman Cologne will be investigated in the future. Because the actual state of research is not sufficiently clear enough at this point, we are looking forward to presenting our results at future CAA conferences.

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Illustration Credits

Fig. 1. Reconstruction: J. Bäuerlein, Köln. Visualization: Christopher v. Bronsart, Köln. Rafael Pokorski, Wuppertal.

Fig. 2. Reconstruction: J. Bäuerlein, Köln. Visualization: Rafael Pokorski, Wuppertal.

Fig. 3. Graphic: Christian Rademann, Köln.

Fig. 4. Modeling: Christopher v. Bronsart, Köln. Image real-time application: Stefan Maass, HPI, Potsdam.

Fig. 5. Modeling: Yu-Chung Chen, Köln. Image real-time application: Stefan Maass, HPI, Potsdam.

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