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REQUIREMENTS FOR PHOTOREALISTIC 3D MODELLING OF URBAN AREAS

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Abstrac:

The creation of photorealistic 3-D digital models of urban areas is based on several source data, different techniques to acquire, refine and maintain these data and powerful computersystems, which allow to perform the required operations. The current contribution describes the most important requirements for the complete modelling of urban areas and the use and maintainance of these data. We therefore show the concept of a digital workstation, which combines the functionality of several well known elements like photogrammetric image set up or digital texture mapping and the concept of a geo-server which will guarantee remote and local acess to these data with acceptable performance.

Kurzfassung

Dreidimensionale digitale Stadtmodelle nehmen einen immer breiteren Raum in unterschiedlichsten Bereichen wie Stadtplanung, zivile Sicherheit, mobile Telekom-munikation oder Unterhaltung, Informations- und Bildungswesen ein. Trotz einer sich stark entwickelnden Computer- und Datenübertragungstechnologie sind eher Fallstudien und kleinräumige Projekte vorherrschend, für photorealistische Darstellungen ganzer Städte stellen sowohl die Datenerfassung wie die Verarbeitung und Visualisierung der anfallenden Datenmengen eine nach wie vor schwierige Aufgabe dar. Wir gehen nun davon aus, daß ein Gesamtsystem zur Erfassung, Verwaltung und Übertragung der Stadtmodelldaten konzipiert werden muß. Dieses Gesamtsystem wird im folgenden beschrieben.

Introduction

We present a progress report of our current work to create, maintain and prepare for remote and local use fully threedimensional photorealistic textured digital models of cities. These 3-D Cityscapes are currently a widely discussed *upgrade* from strictly twodimensional geographic information systems (GISs) [Förstner et al. 1993]. Data sources for the 3-D city model of course include the existing GIS, the aerial photographs, which are periodically produced on behalf of the citie's authorities and photographs taken from street level in order to cover facades of a citie's buildings [Gruber et al. 1995a]. In addition to the GIS data and aerial and terrestrial images we are involving the DEM of the terrain, which represents the shape of the bald earth. Each data set consists of different types of data, needs different amounts of disk storage and has to be prepared and tuned for the requirements of the user. These efforts shall result in a complete 3-D database of urban areas. In addition the concept of this *information system* will be subsumed into a *multimedia system*. The goal is to take advantage of the emerging information and telecom-munication technologies to create a large market for 3D urban data bases with geometric and thematic information, generated at low cost and accessible at high speed by a broad range of local or remote end-users.

Such 3-D data will not only present the geometric relationships in a city, but also permit to create photo-realistic renderings for various decision-making and planning tasks and will involve into various new applications like civil security, transport, leisure and entertainment, education and training, tourism, publishing, etc. (cf. Fig. 1).

Fig. 1: Part of photorealistically rendered scene of a city block in Vienna

Although the last ten years have seen the development of applications of 3D urban data bases (essentialy for urban development or mobile radio networks planning), the growth of the market has been slow. Two bottlenecks have been identified by today's end-users:

- **quality-cost ratio is too low**, especially because of the labour-intensive creation of the 3D data base (including the creation and processing of photorealistic texture);

- **limited accessibility of the data base by end-users**, essentialy due to the lack of a structure capable of organizing the data and capable of providing network access to remote users.

Both bottlenecks need to be overcome, if the broad acceptance of fully threedimensional data bases of urban areas shall arise. The need of advanced techniques to acquire source data, create photorealistic textured models of a citiy's buildings and objects and to maintain and distribute these data is evident.

Geometry vs. Texture

The photo-realistic rendering of CAD models from real-world objects, e.g. the buildings and structures of a city, is a very current topic since a high degree of naturalism of a computer model is highly desireable. Such naturalism is needed to create broad appeal for digital 3-D graphics solutions. In the case of urban environments the need for so-called photo-realistic city models is evident from numerous applications such as urban planning, architecture, entertainment, disaster preparedness etc.

We have now investigated the benefit of texture and the relations between texture and geometry. We know that the two sets of data need to correspond even in case of a multi-level-of-detail presentation of the computer model on each different level of the visualization. In [Gruber et al., 1995b] we have presented ideas and a flow diagram of a *building box and roof modeling* procedure, which points out the importance of correspondence between geometry and phototexture.

The need of photo-texture in the threedimensional digital model of a citiy's environment shall be documented within the following set of figures. A simple building from the Vienna City Block (see Fig 1) is presented as wireframe model (Fig.2 a), surface model using different colors for roof and facade (Fig. 2b) and in a more photorealistic manner, exploiting the texture of photographs (Fig. 2c). The quality of the different graphics representations is clear, the range of usabilitiy may also be easily understood:

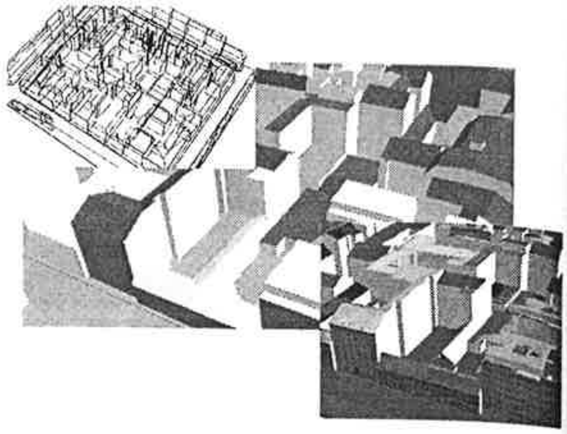

Fig. 2: Different visualization types of the city block in Vienna; left) wireframe representation, middle) surface model and right) photorealistically textured model

- the wireframe model seems to be unacceptable (even the conventional 2D CAD model may be easier to read and manipulate);

- the surface model gives a coarse idea of the buildings' form and may help in some special applications (large area city planning etc.);

- the phototextured model allows an immediate identification of the unique building; the data set is the basis of digital visual information, which is easy to understand and supports the human operators visual sensitivity;

- the fusion of manipulated texture and the detailed geometric model based on primitives also leads to an inadequate, unrealistic impression considering sharp and unnatural edges; so the extension to a combined manipulation of geometry and texture at the intersection of primitives has to be considered to improve the visual impression.

We now argue that photorealistic texture is an essential part of city models. Only this high degree of realism will also open the digital model to a broad useabilty in the growing markets of multi-media and tele-services.

Towards Automation

Creating 3-D models of cities needs a large amount of manual processing. The transition of existing data like GIS or DEM, the modelling of buildings and other objects which are not yet available in three dimensions and the acquisition of missing data like texture from facades of buildings are performed under time and manpower consuming circumstances. Therefore we need to automate these processes on a dramatical scale [Leberl et al. 1994], [Gülch 1992], [Lang et al. 1993]. This automation shall take place on three different levels of the modelling procedure:

- The acquisition of texture data needs to be improved. We propose to develop methods and instruments to create strip images of facades and other objects;

- The extraction of shape information from image data and other source data like the exisiting GIS has to be implemented and adapted also for the automated reconstruction of details like chimneys, balkonies, bay-windows etc.;

- The processing and enhancement of phototexture is in need of significant improvement. Shadows, occlusions and change in hue and intensity occur and need an at least semi-automated solution.

The current status of these demands is very poor and we have insufficient tools to create high quality city models in an acceptable time and for acceptable costs. For sure a broad field of research and development challenges our skills.

Concept of a Digital Workstation

In line with the demand for automation mentioned above we present the concept of a digital workstation which shall provide all necessary functions needed to create three-dimensional models of cities. We include into this workstation-concept also the process of data acquisition and the maintainance, update and use of the data. Especially for remote use and effective distribution of the digital data we have to keep a powerful computer environment in mind. We present the concept of this *geo server*.

The main parts of the workstation concept are :

- Data acquisition of source data like aerial photographs, terrestrial images taken from street level and additional data sources like the existing 2D GIS or hight information via a DTM;

- Data base content creation which shall lead into a fully three-dimensional CAD model including surface information via photoexture;

- Data management in order to maintain, update and distribute already existing data;

- Communication Technology, which prepares the necessary background for quick and full data distribution.

We discuss below these prominent parts of our digital workstation's concept in more detail and we provide also some aspects of modern usage of „CyberCity" models. A overview of our workstation concept may be seen in Table1.

Part 1. Data Acquisition/Data Base Content Creation

The objective is to design and develop a low-cost collection system for terrestrial images complementing today's collection systems based on aerial photography and to develop a methodology for producing 3D urban data bases with a high level of automation by fusing all available sources of information (aerial images, GIS data, DEM data and terrestrial images).

The data acquisition approach will be integrated in a vehicle-based kinematic imaging system, based on electronic CCD sensors. High resolution image data of buildings facades will be produced in order to allow geometric and radiometric exploitation for a facade's 3D geometry and phototexture [cf. Maresch et al. 1996]. In addition to the vehicle based sensor system we propose to use a rotating camera to map backyard or indoor scenes [cf. Duracher et al. 1996].

The fusion of all available data sets (aerial photographs, digital map, DEM and image data from the kinematic imaging system) shall provide a high level of automation. Basically two complementary approaches will be pursued, each based on a two step strategy : firstly, estimate a CAD model of the building by using aerial images and the knowledge of a building's footprint by the GIS [cf. Pasko et al. 1996]; secondly, the terrestrial images will be used to refine the geometry and, mainly, to give the texture information on the building's facades.

Beside these data acquisition and geometric processing tasks the digital workstation has to offer functions and techniques to improve photorealistic simulation. These thematic processing tasks have to be based on manual texture processing (like Photoshop of ADOBE) but shall rise into innovative techniques to determine surface properties from the images, process shadows and occlusions in a semi-automatic or automatic manner and allow a very effective compression of the texture data using parametric description approaches. This includes concepts for the automatic or semiautomatic segmentation of facade texture, where the *base texture* easily can be reduced to a parametric description and interesting details are kept in full resolution.

Finally we have to consider the necessary correspondence of 3D geometry and photorealistic texture. The need of an accurate set-up of source images and the relation between CAD-model, phototexture and true object needs functions which are well known and are integrated in the concept of a Digital Photogrammetric Workstations (DPWS).

Part 2. Data Management

The data of a three-dimensional urban data base need to be managed in line with the evolving strategies of three-dimensional geoinformation systems (GISs). Various criteria have to be fullfilled to allow spatial analysis, up-date and maintainance of data and to create subsets of the data to meet a user's special requirements.

Compared with two-dimensional datasets we have to keep in mind that a fully three-dimensional CAD model shall be visulized by means of perspective projections. The visible part of the object is now situated within a viewing frustum, which may widely open onto the horizon, if large citiy-areas are rendered.
This means, that in addition to the GIS-recommendations we need strategies to visualize the digital data under the conditions of perspective projections (cf. Fig 3).

Fig. 3: Perspective view of a digital model of a larger part of Vienna (2 km by 2 km)

Including the texture data of buildings, objects and ground surface of the digital model we have to manage a total data set of several hundred Gigabytes. This large amount of data has to be referenced and indexed by a *standard* data manager such as an existing data base management system. In line with [Kofler et al. 1996] we favor the concept of OODB's, where efficient queries, transaction support and communication tools exist and the novel situation of three-dimensional objects and their spatial relationships have to be denoted.

In addition a Level of Detail (LoD) concept has to be implemented, which allows the visualization of parts of a scene in a rather cost-effective manner, according to the perspective enlargement of the specific object.

Part 3. Communications Technology

Based on the data management system, we grow the concept of a *geo server* for local and remote accsess for clients and users with widely available 3D data for added value services. Data will be accessed either as end user' elaborate products or as raw data are required for further processing. These two kinds of data processing will require a flexible broadband transport technology such as currently provided by the upcomming Asyncronous Transfer Mode / ATM.

This provides users both with connection oriented services and with the flexibility of a packed switched service. So the need for variable bandwith will be covered as well as the need for high transmission rates up to 622 Mbit/sec.

End user applications require a common front end that will present available data and processing tools with a friendly and easy to learn graphic interface. In this context we recognise, that Hypermedia servers are a global trend and bring up standardized and transparent access to the data. On top of this existing framework we need only to implement specific extensions.

Results

The result of our analysis is a work breakdown structure which points the different tasks of a total procedure for modelling 3D Cityscapes. We know from the current literature, that parts of this work are investigated and results are presented continuously, e.g. the creation of 3D CAD models of buildings. Other parts are developed not as well as one would wish. This concerns mainly the aquisition of source data for the texture of facades, the processing of photo-texture and the developement of databank-systems to maintain and distribute the data of a full-fledged CyberCity data set.

The synopsis of the workflow leads to a work breakdown structure. In Table 1 we present a list and refer to the computer environment, which is needed to perform a specific task .

Source data acquisition	**var.**
Collection of existing data (vertical aerial images, 2D GIS, DTM, etc.) Creation of new data (images from street level, laser range images etc);	
Source data preparation	**PAS**
Scanning of analog image data, creation of a source data archive;	
Photogrammetric set-up of images	**DPWS**
Determination of camera and camera station parameters (pose and position);	
Reconstruction of man-made objects	**DPWS**
e.g. Photogrammetric stereo restitution of objects, creation of a 3D CAD model;	
Reconstruction of the terrain (DTM)	**DTM**
Triangulation of the terrain surface (TIN) and merging DTM data and CAD data of objects;	
Texture processing	**TPWS**
Evolving digital images into texture data, including cropping, processing of occlusions and image enhancement procedures;	
Texture mapping	**3D CAD**
Determination of texture coordinates to fit texture onto geometry (correspondence between CAD model and phototexture);	
Datamanagement	**OODB**
The entire set of CyberCity's data need to be maintained and distributed (Geo-Server concept);	
Tuning and visualization	**GWS**
Tuning of phototexture and geometry for visualization purpose including the creation of different Levels of Detail (LoDs);	
Legend:	
DPWS	Digital Photogrammetric Workstation
TPWS	Texture Processing Workstation
PAS	Picture Archiving System
DTM	Digital Terrain Model
GWS	Graphics Workstation
var.	various (Aerial Camera, 2D GIS ....)

Table 1 : Elements and equipment for the creation and use of 3D city models (CyberCities)

The combination of the different tools and workstation concepts into one *digital workstation* is the unavoidable next step in improving the skills of creation, visualization and management of photorealistic data of real world objects like our growing cities.

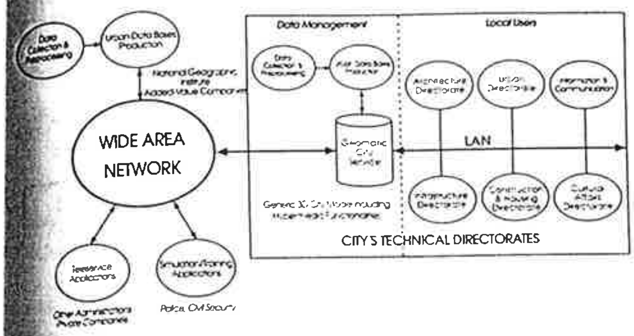

Fig. 4: Synopsis of the proposed *geo server* concept

Outlook

In the context of computer graphics applications the detail of geometry, the existence of texture and the computation of shadows and participating media like fog, clouds etc. is not only an issue of creating the object's model, but also an issue of rendering throughput. We are now at the beginning of a process where hardware and software developements are needed to meet the high requirements of human users in virtual and augmented reality applications and of course in visualization of existing objects and environments using digital methods. The 3D data, equiped with photo-realistic texture and managed via a distributed computer network environment, will not only present the geometric relationships in a city. It will permit to create photo-realistic renderings for various tasks.
Linked with currently growing informaton and service systems (e.g. tele-shopping and tele-banking) the *3D information system* will be integrated into a *multi media system* and - based on the broad appeal of photorealistic data - find its way into commercial use.

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