# PHOTOREALISTIC TERRAIN VISUALIZATION USING METHODS OF 3D-COMPUTER-GRAPHICS AND DIGITAL PHOTOGRAMMETRY

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## ABSTRACT:

Photorealistic, i.e. highly sophisticated visualization of the terrain is an important tool for flight simulation or, like in this paper, for the evaluation of changes resulting from planning for land consolidation or afforestation in rural areas. Basic input components for the visualization of these areas are land use data from a geographic information system (GIS), information about the terrain surface given by a digital elevation model (DEM), as well as aerial and terrestrial photographs. Mapping digital orthoimages as texture onto the terrain surface is a first step towards photorealism. A new approach is proposed which is based on the replacement of unfavourable effects like shadows, displacements or occlusions caused by three-dimensional (3D) objects in the orthoimage by information from other images or from adjacent regions employing methods of digital photogrammetry. Using the resulting improved orthoimage together with methods of 3D computer graphics for the modeling and rendering of the 3D objects leads to highly realistic visualizations of the scene.

## 1. INTRODUCTION

Photorealistic visualization of the terrain by means of methods from 3D computer graphics is used in many disciplines (cf. Foley et al, 1990, for an overview). It is an important tool for flight or battlefield simulation, the planning of roads or buildings and also in the movie industry, to mention only a few. The application more closely examined in this paper is the visualization of changes within rural landscapes resulting from plannings for land consolidation or afforestation. It can be used to evaluate the plannings as objective as possible as well as to promote the results in the public.

Most of the disciplines mentioned above aim at highly realistic landscape visualization in real-time. Until now real-time is not possible for photorealistic presentation of existing landscapes, but it can be assumed that future generations of high-end graphical workstations will be able to achieve simultaneously the goals photorealistic presentation and real-time.

Up to now different kinds of simplifications are necessary. If the goal real-time has to be met, e.g. for flight simulation, the geometric and radiometric modeling can not be done as accurately as necessary for highly realistic visualizations. If the goal photorealistic presentation is more important, e.g. in movie industry, real-time effects only can be achieved using pre-calculated views. This means that animation is possible, but real-time calculation of the views is not.

When methods of computer graphics are used for visual interpretation of planning tasks for rural areas, photorealistic representations are demanded. Real-time computing, however, is not an important issue.

The paper is organized as follows. In section 2 the data used for the scene description and in section 3 the modeling strategy together with basic results are given. The enhancement of the orthoimage used as texture and the photorealistic visualization of 3D objects are presented in sections 4 and 5. Concluding remarks and an outlook are given in section 6.

## 2. DATA FOR SCENE DESCRIPTION

Photorealistic visualization requires high effort for geometric and radiometric modeling of the scene, i.e. it strongly depends on the available data representing the landscape as good as possible. Using data bases for DEM and land use based on GIS is a proper starting point. However, 3D models for objects projecting from the terrain surface like buildings or trees are not yet available in existing DEM and GIS systems, although there are some considerations to achieve this goal (Fritsch/Schmidt, 1994).

Data acquisition must be done seperately for the terrain surface and the 3D objects. The best possible data source is often photogrammetry, because from aerial and terrestrial photographs both geometry and texture of the objects can be taken. Automatic data capturing with methods of digital photogrammetry like image matching and image understanding is increasingly practicable for this purpose (Grau/Tönjes, 1994, Collins et al, 1995, Lin et al, 1995).

In the task of planning for land consolidation digital data are used more and more (Stark/Eder, 1992). DEM, stereomodels from aerial photographs of large scale, land use information and digital orthoimages are available. For this paper existing digital data (DEM and GIS) as well as color aerial photographs of scale 1:4000 were used. These data were provided for a land consolidation project around the village Marchertsreuth in Bavaria. By scanning the aerial photographs and calculating digital orthoimages rectified textures were generated.

For 3D objects whose vertical sides were as usual not visible in the aerial photographs, it was necessary to take additional terrestrial photographs. In rural areas these are in principal farm buildings, woods, hedges and trees. As these terrestrial images are taken for the derivation of digital texture information, the use of a CCD-Camera is suggested. For this paper an analog camera was used. Digital information was received by scanning the photographs (photo-CD).

## 3. MODELING STRATEGY

Sophisticated scene modeling is the most important task to reach photorealistic visualizations. The main components of the modeling strategy proposed in this paper are shown in Figure 1 (the input data are shown in the first row).

The 3D scene can be geometrically subdivided into the terrain surface as described by the DEM and the 3D objects projecting from the terrain. In 3D computer graphics objects like the terrain surface usually are described as triangular strips or as quadrilateral meshes. In general the data structure of a DEM is very similar and can easily be transformed to this description. However, tiny structures are not contained in the DEM information. A geometric description of these structures requires a huge effort of data capturing and modeling.

As photographs of the terrain represent besides radiometric information implicitly many geometric terrain features, mapping texture information based on digital images is a good idea (Eder et al, 1993, Leberl et al, 1994). It clearly increases the degree of realism for landscape visualization.

Mapping texture information to the geometry of 3D objects aims at the same advantages (see also section 5). Therefore the basic modeling components, shown in the second row of Figure 1, are the terrain surface combined with a digital orthoimage and the 3D objects combined with the photo textures attached to their vertical walls.

The view in Figure 2 is a first result based on this information. Similar visualizations have already been introduced by various authors (Grau/Tönjes, 1994, Faust et al, 1994). Tools for mapping of digital orthoimages or satellite images onto the DEM are also integrated into various GIS.

As terrain visualisation by methods of computer graphics should be independent of the orientation and date of the

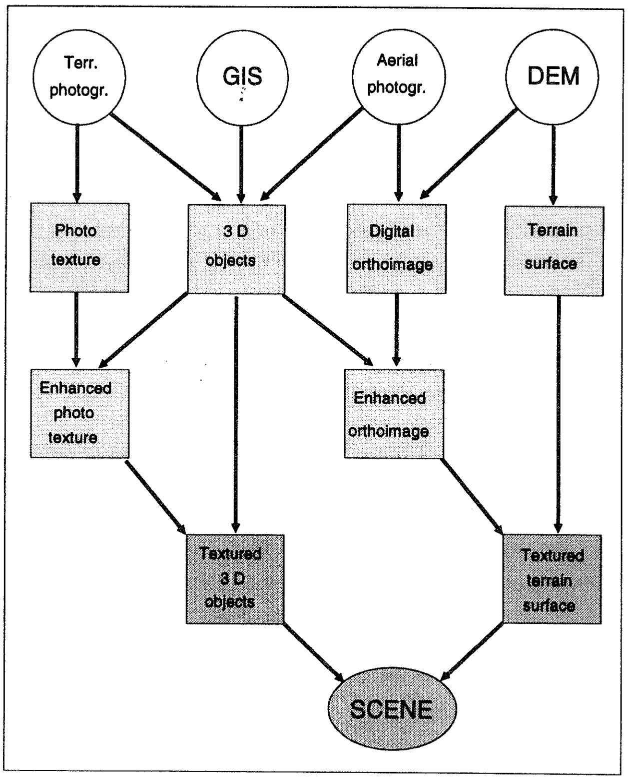

Figure 1: Components of modeling strategy

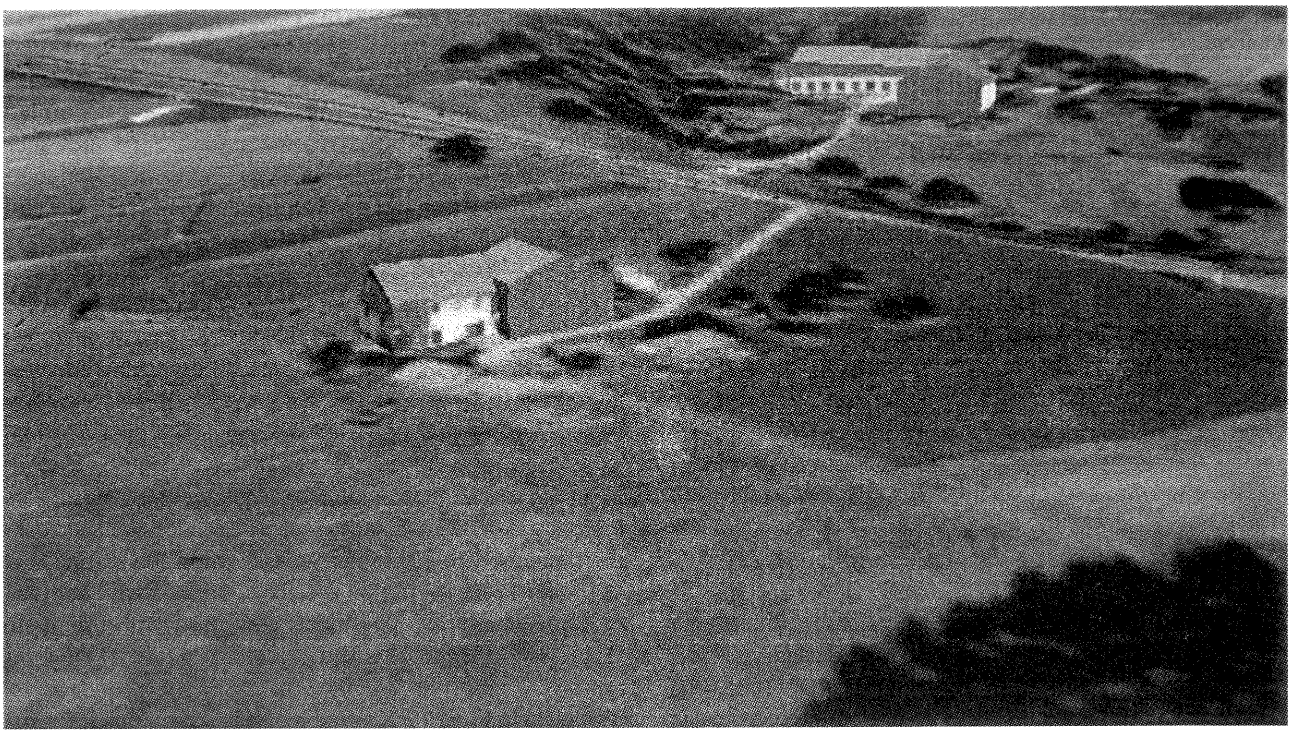

Figure 2: Visualization based on a digital orthoimage as well as 3D modeling and photo textures for the buildings

photographs, using digital orthoimages and photo textures has some disadvantages:

- Shading and shadows within the photographs depend on the position of the sun at the time of exposure.
- The content of the orthoimage shows a distinct seasonal situation.
- Depending on the exterior orientation of the camera, 3D objects are displaced and occlude parts of the terrain surface or of other 3D objects.

Some disadvantages when using digital orthoimages as texture information can be seen in Figure 2: Shadows cast by the wood in the lower right corner of the scene; displaced fruit-trees around the farm-buildings. These problems can not be solved entirely through 3D modeling of the objects, because their influence is active also in regions of the orthoimage near to these objects.

Thus restoration of the orthoimage texture from shadows, displacements and occlusions is necessary to reach the goal of a photorealisitic landscape visualization (cf. section 4). The 3D objects can be handled similarely (cf. section 5). The results of these modeling steps are enhanced orthoimages and enhanced photo textures. Mapping them onto the geometric elements leads to textured terrain surface and 3D objects which build up a highly realistic scene.

## 4. ENHANCEMENT OF THE ORTHOIMAGE TEXTURE

To enhance the quality of the orthoimage texture for visualization purposes some of the situation-dependent effects in the orthoimage have to be replaced. All striking effects (shadows, displacements, occlusions) are caused by objects projecting from the ground. Thus, the replacement of these objects is the most important task. It can be subdivided into the recognition of 3D objects, the determination of areas affected by the 3D objects and the replacement of the affected areas (cf. Fig. 3).

### 4.1 Recognition of 3D objects

Approximate information for the shape of 3D objects can be taken from the land use information, e.g. the borders of woods, hedges and buildings. However, for the purpose of land consolidation not all 3D objects are acquired. The fruit-trees visible in Figure 2 are for example not contained in the GIS data nor is their shape. Thus, methods of digital photogrammetry are suggested to determine the position and the shape of the 3D objects.

Automatically derived DEM using image matching techniques applied to large scale stereo models contain bumps that represent the 3D objects. Smoothing or comparison with ordinary DEM (ground DEM) and fusion with orthoimage data improve the shape determination of the objects (Haala, 1994, Eckstein/Steger, 1996). As automatic methods don't work reliable and exactly for complete scenes so far, semi-automatic methods (Lang/Schickler, 1993) can be used (e.g.

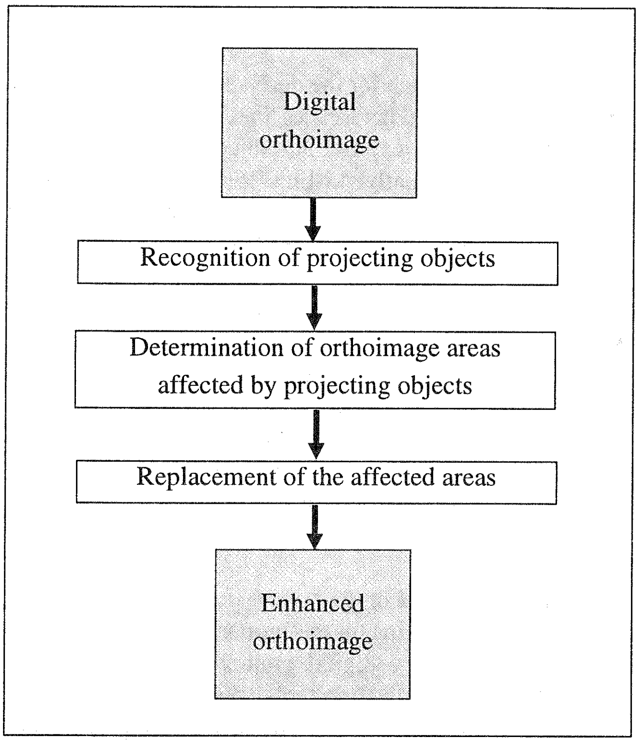

Figure 3: Enhancement of orthoimage texture

fitting the position of 3D objects interactively and fixing the shape automatically afterwards).

### 4.2. Determination of Areas Affected by 3D Objects

The areas of the orthoimage affected by the projecting objects are geometrically restricted by their polygons lying on the DEM surface. The polygons can be calculated using ray-tracing. The rays are defined by the center of projection in the case of displacements or the sun position in the case of shadows and the outlines of the 3D objects.

As the shape of the 3D objects, especially of trees or hedges, is usually not known well enough the polygons of shadows or displacements will not be geometrically exact. Therefore combining the ray-tracing method with image processing methods like region growing or edge detection is suggested. The profit of image processing are geometrically exact polygons. The problem is the determination of the right polygons. One way to solve it for the case of shadows is to illuminate a automatically derived DEM with the given sun-angle, to segment the shadowed areas by thresholding and to use this regions as seeds for region growing in the image (Eckstein/Steger, 1996).

### 4.3. Replacement of the Affected Areas

After the derivation of their outlines, shadowed or occluded regions are replaced by more or less situation-independent image information. For the case of occlusion this information is taken from another image of the stripe or block, where the occluded area is visible. To fill formerly shadowed areas, information from adjacent regions of the same object is used.

Orthoimage pixels that are both shadowed and occluded can not be replaced using pixels of another image, because the shadow will cover the same region considering a short time delay between capturing of the two aerial photographs. Thus first occlusions are replaced, filling shadowed areas afterwards.

The result of this processing is called an enhanced or situation-independent orthoimage. Note that the effects of shading also caused by the position of the sun at the time of exposure are not taken into account. This enhanced orthoimage is used as texture information for all objects lying on the DEM surface. The 3D objects have to be modeled separately.

## 5. PHOTOREALISTIC PRESENTATION OF 3D OBJECTS

A great number of different 3D objects is present in real landscapes. Nearly everything is a projecting object, e.g. grass, stones etc. For photorealism, the biggest and most eyecatching objects have to be handled first. Smaller objects are tackled later. In rural landscapes big objects are farms, woods, hedges, trees, fields of cereals or corn.

Experiences have been made modeling farm-buildings and trees. Mapping textures from terrestrial photographs to objects with simple geometry already results in realistic representations of buildings (e.g. farm buildings consisting of six plane surfaces as used for the scene in Fig. 2). In general problems arise similar to that using digital orthoimages. For example trees or bushes in front of the buildings occlude parts of the walls or shadows are caused by projecting roofs or details of the buildings like chimneys (Gruber et al, 1995). The same methods as described in section 4 can be used to get rid of these problems.

For trees sophisticated algorithms like l-trees (Prusinkiewicz,1994) lead to a detailed geometrical description giving photorealistic presentations. However, considering the available computer graphics facilities, they are not practicable for landscapes with numerous trees, hedges and woods.

Therefore, the method of texture mapping was improved using photographs of the vegetation (photo textures). This method is based on the simple geometrical description of a vertical rectangle always facing the viewing position. It is called the billboard method and generates quite realistic trees or avenues (see Fig. 4). The attribute of alpha-transparency is used as additional information within the texture. Transparent pixels can be defined around the outlines of the trees and within the foliage. For its separation from the terrestrial photographs of trees it is only necessary to gua-

Figure 4: Avenue

rantee a distinctly different background color. The transparent pixels can then be separated by image processing tools.

The use of the billboard method for hedges is suggested and will be tested. For objects with big spatial extension like woods or corn fields combining texture information from aerial photographs for the upside and texture information from terrestrial photographs for the vertical sides is the first attempt for visualisation. Further methods with even more effort in geometric modeling will be examined to find out which results are preferrable.

Besides the modeling of the objects, special methods of computer graphics have to be considered to achieve a highly realistic representation. For example, natural phaenomena like depth cueing and fog, or the change of lighting due to clouds can be introduced. Global rendering methods like ray-tracing should be used to make visible effects like shadows or reflexions.

The intensive use of phototextures together with global rendering methods can result in some absurdity, as the direction of the light is implicitly contained within the phototextures through shading.What is more, shadows of trees modeled as billboard planes can be reduced to a line when the angle between the viewing direction and the sun direction is about 90 degree. Thus additionally effort in geometric and radiometric modeling has to be made to reach photorealistic visualizations.

## 6. CONCLUSIONS AND OUTLOOK

The proposed approach for the derivation of photorealistic representations of real landscapes, based on enhanced digital orthoimages and textured 3D objects is useful for the visualization of currently existing landscapes. Changes in the projecting 3D objects like the growing of plants or new buildings can also be represented without special efforts, because the proposed methods can be used.

When results of a planning change the objects represented by the texture of the orthoimage, new methods have to be developed for the photorealistic visualization of these objects. During the course of the planning the texture of the orthoimage more and more will be replaced by the representations of accurately designed objects.

As explained above photogrammetry is the most important method of data capturing for this purpose. The requirements are best achieved by digital photogrammetric systems (DPS). Adding visualization tools could be a self-evident expansion of DPS. These systems need strong graphical power for the stereo viewing of digital image pairs on the one hand and contain the methods of digital photogrammetry mentioned in section 4 on the other hand. The stereo cabability of DPS can be used to represent stereoscopic views of the landscape which will improve the evaluation of planning tasks. Thus synergy can be expected running digital photogrammetry and 3D computer graphics on the same high-end graphical workstations.

Nowadays real time and photorealistic visualization at the same time is only imaginable using high-end graphical computer. But it is predictable that future generations of graphical workstations will be able to meet these conditions. Then interactive planning tasks could be made in real-time at the computer (Ware, 1994) demanded by people using facilities of virtual reality like stereo projection systems.

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