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Modeling a French Village in the Alps

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Abstract

Digital models of real world objects are the basis of Augmented Reality, they support simulation, planning, testing, decision making and can guide automated processes. The creation of a digital model of a French village in the Alps challenged current technology for two reasons: First, the total time available was 3 days. Second, the source material consisted of uncalibrated amateur photographs taken through the window of a helicopter. The digitized photos were used to create both the geometric and texture models. This paper describes the work flow within the digital modeling procedure, combining skills of photographic image orientation, 3-D CAD, texture processing and visualisation techniques. It is at the intersection of photogrammetry, image processing and computer graphics, dealing simply with various elements of „digital visual information".

1. Introduction

We report on the 3-D model of a village situated in the French Alps, not far from the Mediterranean Sea. A number of 41 small buildings, each not more than two or three stories high, is located in a basin as shown in *Figure 1*. On a given Thursday, our group received an inquiry by telephone from France whether we would be able to create a 3-D computer model from aerial amateur photography within 5 days. When we agreed we found out that we had to do this work in 3 days. We received the source material on the subsequent Monday, and delivered the 3-D model 3 days later, on Wednesday evening. The source data consisted of small-scale vertical photogrammetric images, collateral data and a number of amateur 35 mm photographs taken from a helicopter. The purpose of the 3-D model was for planning of strategies and for training of disaster-preparedness. The source data had to be developed into a fully 3-dimensional and photo-realistic digital model of the village. The very short time available for the project was a result of unsuccessful attempts by other groups to create the model, and of a hard deadline for the French customer to use the data.

Previous attempts at modeling the village, undertaken in France and in the US, had failed. This was largeley due to the inability to cope with the geometry of 35 mm amateur photography taken from a helicopter. It was our major contribution

- to have the ability to process such photographs; and
- to operate a complete suite of procedures for 3-D modeling of real-world objects.

The 3-D model was delivered in time. This paper reports on the current procedure available to perform this work which combines skills in photogrammetry, image processing and computer graphics. This combination reflects our view proposed previously (see Leberl et al., 1994) that increasingly, one will have to abandon the traditional split between image processing and computer graphics and to adopt a view of „digital visual information".

Figure 1: The village seen from south (oblique 35 mm photograph, taken from a helicopter)

2. The Source Data

The source data of the test site consists of a stereo pair of conventional black and white aerial images at a small scale (1:30000) and a cadastral map of the village; both data sets are more than 10 years old and therefore not valid in each detail of the object. In addition to these data a set of 35 oblique color images had been made from a helicopter. These images were taken by a small format SLR camera with an uncalibrated lens and a coarse knowledge of its focal length. These images present the object at medium scale of 1 : 4000 (see *Table 1*).

The quality of the images varied because of different film materials (black and white vs. color negative), different image scale (1 : 30000 vs. 1 : 4000), different camera types (calibrated aerial camera, 23 cm by 23 cm format vs. 24 mm by 36 mm small format and uncalibrated SLR camera) and different camera orientations (vertical vs. oblique).

Since the source data were inconsistent with one-another, the modeling process had to start with an unusual procedure to obtain some geometric accuracy across the entire scene and to merge the height information of the terrain derived from the vertical images, with detailed geometric

Data	Type	Scale	Quantity
aerial vertical	b/w images	1: 30 000	1 stereo pair
aerial oblique	color images	1: 4 000	35 photos
cadastral map	line graphic	1: 2 000	1
collateral data	text data	none	several GCP

GCP = Ground Control Point

Table 1: Source data of the test site

information from the oblique small format images. Of course the color-photorealistic texture also derived from the small-format imagery

3. Photogrammetric Operations

The photogrammetric set-up was based on conventional stereo-image set-up of the vertical stereo image pair in order to establish an initial global geometry of the digital model. According to the image scale and the graininess of the emulsion a coarse accuracy of 1 meter was reached (see *Figure 2*). Based on this framework we performed a so-called photogrammetric „bundle adjustment" of all source images, vertical and oblique. This is a mathematical process by which each photograph is viewed as a perspective bundle of rays connecting object and image-points. These bundles are then oriented and shifted until they all intersect at object points. The final result of this „adjustment procedure" leads to a geometric accuracy of better than ± 0.3 meter. This means that the oblique images could be successfully used to refine the geometry of the digital model. Objects' details like windows and doors could be mapped, but in the interest of time, were not actually modelled.

4. Collecting Geometric and Texture Data

Digital image data were the source of the geometry of the terrain and the geometry of the buildings. In addition, the images also were the source of the photorealistic texture. Because of the difference between vertical and oblique aerial image data, the modeling procedure had to extract that

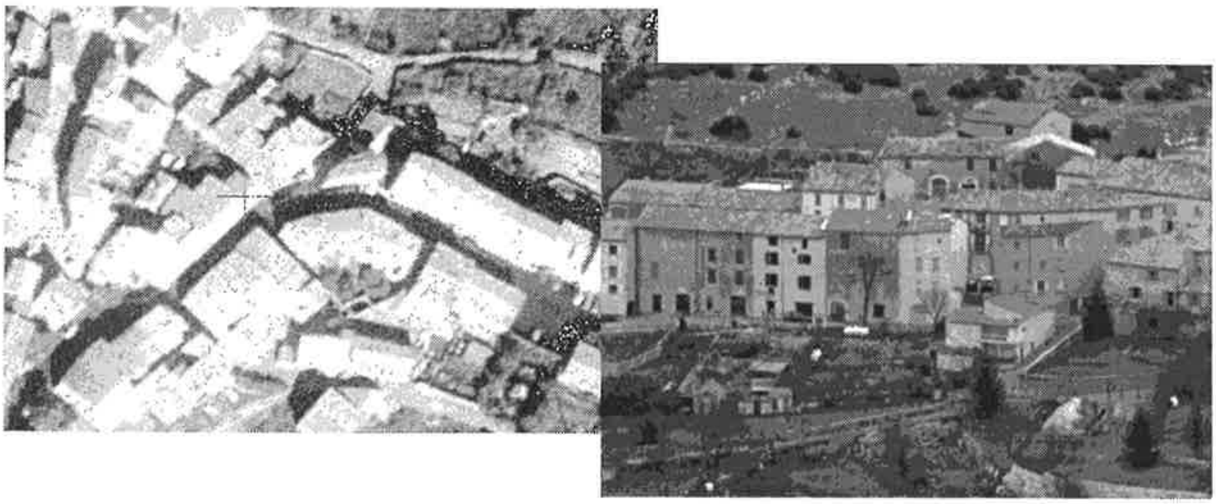

Figure 2: Source image data of the testsite. Vertical aerial image, scale 1 : 30000 (left) and oblique aerial image, scale 1 : 4000 (right)

information which was useful in each data set. The black and white vertical images were used for the terrain and for coarse building boxes and roofs. One will not be able to map building details from these vertical images. Work for this project had to be done manually since the unique source data could not be processed by automated tools, for example the building model extractor by Lang et al. (1993).

The oblique images were used to refine the geometry of the buildings, to increase the level of detail and to correct mis-interpretations from the prior modeling effort. Finally, photorealistic texture was derived from the oblique images by calculating texture coordinates. These establish a relationship between the 3-D CAD geometry and the 2-D image geometry of the photographs. This step of texture modeling may be seen as a correspondence check between geometry and texture and is supported by photogrammetric software specifically developed for this purpose (Gruber et al., 1995a). The key function is the local refinement of texture coordinates in parts of the model where 3-D geometry and photo-texture contradict one another (Gruber et al., 1995b). This may occur when set-up parameters are uncertain, or when unknown distortions take effect, or when photo-texture is extracted from source images which were not part of the set-up procedure so that camera pose and position are only approximately known.

Beside checking the correspondence between photo-texture and geometry, the image data also served to consider obstacles, occlusions and shadows. This work was done manually using well-known software like Photoshop from Adobe.

5. Merging CAD Data and the Digital Terrain Model (DTM)

Digital terrain models (DTMs) are widely used descriptions of a terrain's geometry. We know two data-structures, the „regular grid" which allows a structured storage of

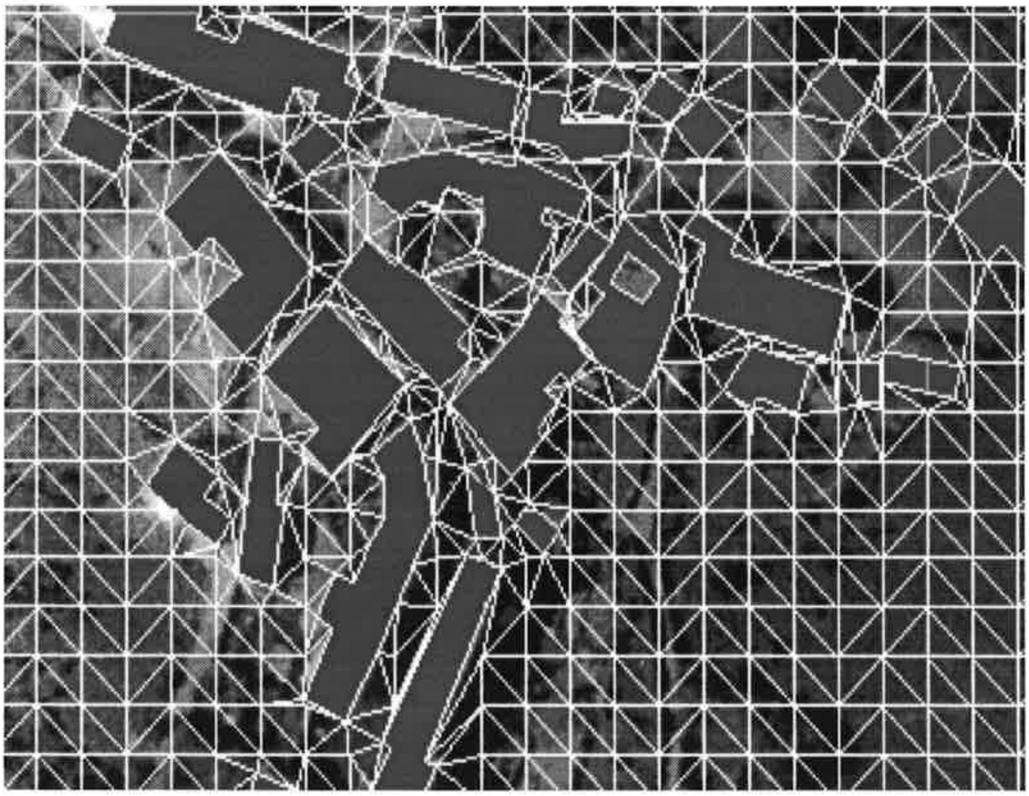

Figure 3: Triangulated terrain data. The buildings' footprints are embedded into the TIN.

height values and quick interpolation; and the „irregular triangulated surface" (TIN). The raster approch supports only unique height values and a strictly defined relationship between the xy-plane and one z-coordinate; this is therefore occasionally denoted as a „$2^1/_2$-dimensional" object. In contrast the TIN description provides a fully three-dimensional data structure with well known algorithms to create, maintain and use the data (e.g. Delauny-algorithm, Voronois' diagram, interpolation, affine transform etc.). The data structure of the buildings and of other objects in the scene is based on similar polygonal faces. Both, TIN data of the terrain and CAD models of features may be treated using one and the same methodology of representation.

The merging of DTM („the bald Earth") and CAD data on top of the bald Earth represents the simultaneous use of both data types in the digital scene and may cause misfits and gaps. Since these data sets are derived from the two different source data sets (vertical and oblique images) we had to consider these deficiencies at more than one place. These merged data sets had to be refined manually and lead us to new ideas for automating these procedures.
In the current work we chose a manual refinement of the terrain data in the form of a TIN based on the algorithm of Delauny and to include the footprints of the buildings. These had to be added into the mesh structure of the TIN (*Figure 3*).

6. Aspects of Visualization

The visualization of the digital model, i.e. the online display of the photo-realistically textured set of data is the goal (*Figure 4*). The use of high end graphics workstations enables one to exploit the capabilities of texture processing graphics boards like the Reality Engine and the Impact board of Silicon Graphics Inc. (SGI). Considering the technical key - limitations of graphics boards one has to keep in mind the total number of graphics simplexes which can be rendered per second and the total amount of photo-texture which is kept resident on the board during visualization. Therefore one needs to tune one's digital data-base to remain within the hardware limitations in order to avoid a response time which is larger than a fracture of a second (at least 30 frames per second have to be computed to guarantee a smooth animation of the scene).

In the present case we need to visualize the

Data	Photorealistic	Texture	Faces
Terrain	Resolution1	Resolution2	
Texture Format	1024*1024	512* 512	3000
File Size	3.00 Mbyte	0.75 Mbyte	
Object Resolution	50 cm	100 cm	
Buildings			
Texture Format	between 64*64 and 128*128		300
File Size	between 12 kByte and 48 kByte		
total (41 Objects)	1.5 Mbyte	1.5 Mbyte	
Object Resolution	5.0 cm	10.0 cm	
Total	4.5 Mbyte	2.25 Mbyte	3300

Table 2: Texture and Graphics Primitives

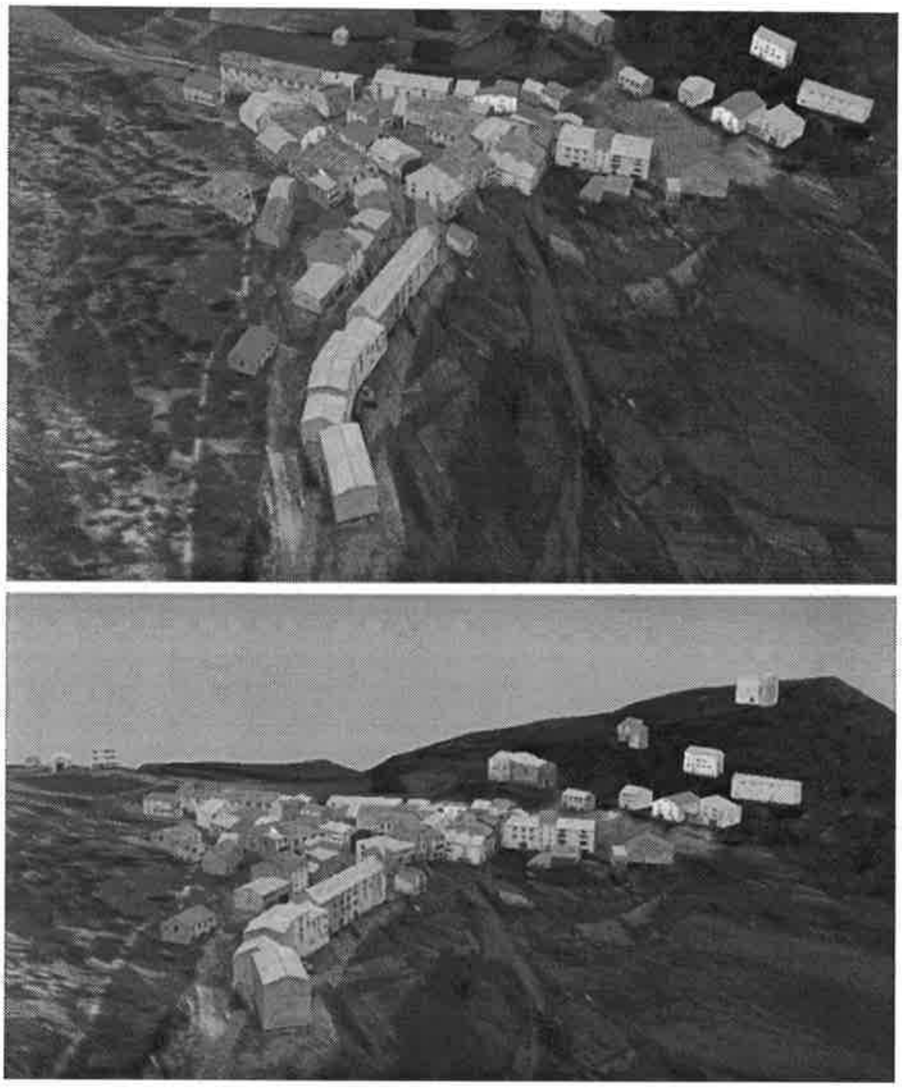

Figure 4: Two views of the „village in the Alps". Note the coarse texture of the terrain to preserve memory for real-time rendering, and a finer texture on the buildings.

scene using an SGI Onyx - Reality Engine² or an SGI Indigo² High Impact computer system. Both platforms have their bottleneck in the data set for the photo-texture of the terrain. Compared to the surface of all buildings we have to manage an amount of digital data which is 10 times larger in case of 3-D polygons and 5 times larger in case of the photorealistic texture. Therefore „tuning" of terrain data is the crucial step for online visualization. A first effort was made by simply reducing the resolution of terrain texture. From a 7.5 Mbyte true-color image a set of 1k*1k, 512*512 and 256*256 texture files was produced. Choosing the 256*256 pixel terrain texture and resizing the texture of the buildings' facades and roofs we could reduce the overall size of photo-texture of the whole database below 1 Mbyte which could be handled by the texture memory of the SGI HI-Impact graphics board. The amount of graphics primitives (i.e. the number of 3D faces of terrain and buildings) remained unchanged (see *Table 2*).

Resolution of the texture of the terrain is about 10 times lower than the texture of the buildings' facades. This was the „price" for a suitable total amount of texture data of the entire database. It is now up to the user to decide if it is convenient to use a certain level of resolution and if the quality of the model is suitable for the application.

- **Source data acquisition**
  Collection of existing image data (vertical aerial images)
  Creation of new data (oblique aerial images)
- **Source data preparation**
  Scanning of analog image data, creation of a digital image archive of project image data
  Archiving of collateral data
- **Photogrammetric set-up of digital images**
  Determination of camera parameters (pose and position)
- **Reconstruction of man-made objects**
  Photogrammetric stereo restitution of objects, creation of 3-D polygons from 3-D points and 3-D lines, description of objects in a 3-D data structure
- **Reconstruction of the terrain (DTM)**
  Stereo measurement of regular grid of terrain surface points and breaklines or adaptive (progressive) sampling of DTM
  Triangulation of the point data and merging DTM and CAD data of man-made objects (e.g. footprint of buildings).
- **Texture processing**
  Evolving digital images into texture data, including cropping, processing of occlusions and image enhancement procedures.
- **Texture mapping**
  Determination of texture coordinates to relate geometry and texture data to one another (establishment of correspondence between CAD model and photo-texture)
  Using set up parameters of the original photogrammetric set up
  Using mapping functions of the modeling software
- **Tuning and visualization**
  Tuning of photo-texture and geometry for visualization purpose including the creation of different Levels of Detail.
  Visualization of the data base via a graphics workstation.

Table 3: Synopsis of the work-flow to create a photo-realistic 3-D model of a village.

There are not only decisions to be made concerning the pixel size of the photo-texture in the digital model; one also has to realize that several faces of the data base are not visible in the set of source images available within such a project. These occluded faces need to be textured using standard texture or texture taken from other facades, just to avoid visible inhomogeneities. But we know that the characteristic evidence of this photo-texture does not exist and therefore we cannot treat this like our „as-built documentation“ of the real-world object.

7. Synopsis of the Workflow

The creation of 3-D databases may be used for many applications, including civil preparedness or disaster operations. They require a specific workflow and tools and thus need to cope with bottlenecks in time and labour. The available source data will also influence the workflow, the result and the quality of the resulting data base. The test site of this project with its old vertical aerial images and new oblique imagery may be reasonally typical.

The synopsis of the workflow is presented in *Table 3*. It leads to a work breakdown structure with many individual tasks.

These tasks of the total procedure may cause different amounts of labour time, dependent on different types of software or equipment. *Table 4* relates individual tasks to the amount of labour, the opportunity to accelerate by automation and to

Task	Labour	Automation	Workstation
Source data acquisition	not eval.	not eval.	-
Source data preparation	1	5	film scanner
Photogrammetric set-up	2	3-5	DPWS
Reconstruction of objects	3	3	DPWS + 3-D CAD
Reconstruction of (DTM)	3	4	DPWS
Texture processing	5	2	TPT
Texture mapping	5	4	3-D CAD
Tuning and visualization	2	-	GWS

DWPS = Digital Photogrammetric Workstation   TPT = Texture Processing Tool
3D CAD = 3D CAD System   GWS = Graphics Workstation

Table 4: Evaluation of labour time and promise of automation, both on a scale from 1 to 5, with „1" being easy and „5" being difficult. Tools needed are described generically.

the computer-environment which is needed for each process. The evaluation scale ranges from 1 (low) to 5 (high).

In the case of the current project, the total amount of labour (excl. source data acquisition) was about 200 person-hours. More than 60 % of the total amount of time was spent on texture processing and texture mapping. An urgent need exists for tools to automate these tasks, as one may understand from this case study.

8. Conclusion

We are concerned with processes of digitally modeling existing objects. This needs various tools and skills. We report on experiences made during a case study in the French Alps and point out the needs and requirements of a workstation environment. Some selected aspects of digital modeling have been touched according to the nature and properties of the object - a small village. An important factor is the need for a proper method to represent and visualize terrain data in real time. We argue that TIN data structures are better suited for fully 3-dimensional graphics simplexes used within a CAD environment than the raster data structure of conventional terrain mapping in photogrammetry and remote sensing. The quantity of photo-texture for terrain and building representation still presents significant obstacles to real-time rendering. We hope, however, to have shown that an integrating view of „digital visual information" is useful and important, and that work to automate the extraction of geometry and texture from images is important.

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EUSAR'96

Lieber Herr Doktor Klemm!

Anbei übersenden wir das Manuskript zum EUSAR'96 Kongreß. Wir haben den Titel ein wenig angepaßt, da Sie ja auch eine Einleitung zur breiteren Thematik der „Image Enhancement and Evaluation" anregten.

Ich hoffe, der verspätete Zeitpunkt des Einreichens verursacht (noch) kein Problem!

Ihr

Franz Leberl