Automatic Extraction of Man-Made Objects
from Aerial and Space Images
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Geometric versus Texture Detail in 3-D Models of Real World Buildings

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Abstract

The creation of three-dimensional CAD models of real world objects and their rendering using photorealistic texture are current topics of investigation. In the case of buildings and other objects of urban environments the need for this technology is evident from various applications. The primary source material consists of images which serve for both the reconstruction of the object's geometry and the creation of texture.

Depending on the scale of the digital source images and on the specifics of an application one may require more or less detail of the geometry. The use of photorealistic texture enhances the perceived detail even in the absence of a detailed geometric model; however one needs to overcome correspondence problems between texture and geometry, which partly may be caused by issues of illumination.

We present in this paper a progress report on one aspect of urban models, namely the reconstruction of roofs. To improve the automation of datacollection we propose the fusion of digital map data and aerial images. We discuss an affine matching procedure. In addition we illustrate the correspondence problem between geometry and photo-texture.

Our initial experiences are based on results from two test sites, one in Vienna and the other in the city of Graz.

1 Introduction

Photo-realistic rendering of CAD models taken from real-world objects 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 3D graphics solutions. Powerful computing environments exist which can process large amounts of textural data. 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. A primary source for realistic rendering is of course the photograph itself. Therefore it is useful to investigate methods to create and merge phototexture and CAD models of city scenes.

In the case of building roofs the exploitation of aerial images appears applicable to both, the geometric as well as textural information. The photo-texture of facades of buildings has to be derived from terrestrial photographs. The benefit of this method is the high degree of detail which is carried in the texture data and may not be present in the geometric data set. This is obvious when considering the structure and color of roof tiles, the texture and color of windows on facades and similar examples.

Succesfull creation of vast repositories of urban 3D models will depend on one's ability to reduce the cost of data when compared with conventional stereophotogrammetric methods. This can be accomplished by means of automation. We show in this paper that the existing two-dimensional digital map, as part of the urban geographic information system, can envolve into a 3D model. This leads to a correspondence problem between map, digital image and real world object. We report on first experiences combining a 2D GIS with aerial photographs to create a detailed 3D model of buildings, as well as to render them with a high degree of realism. An item of concern is the trade-off between geometric detail and realism.

A severe correspondence problem may disturb the quality of the CAD model, when textural detail is not mapped correctly, perhaps because of missing geometric detail. In the case of roofs this may concern the chimneys and skylights; facades show baywindows, entrances and other architectural details, which are not part of the CAD model. In this case, the phototexture will be mapped incorrectly and reduce the quality of the rendering result.

Our initial experiences derive from two test-sites in Vienna and Graz. Aerial images, digital map data and partially terrestrial photographs have been available to create the photo-textured rendering of a CAD model of the sites. The test-site Vienna presents a simplified geometry model without detail and a moderate resolution of texture data; in Graz we focus on the modeling and rendering of roofs and include chimneys into the geometry of the model. We also report about a fusion experiment between digital map data and the aerial image information in an effort to automate the creation of a sufficiently detailed geometric city model.

2 Test Sites

2.1 Vienna

The test-site Vienna is situated in one of the down-town districts of Austria´s capital and contains a city block of 58 buildings (Fig.1). True color aerial photographs at a scale of 1 : 7000 were available for the roofs´ phototexture. The facades´ texture was extracted from terrestrial images at a scale of 1 : 700. The analog film was scanned at a pixel size of 20 μm with 24 bit color resolution. The digital image data were resampled to a suitable resolution for an online application. The three-dimensional CAD model of the site was compiled from the digital map and a photogrammetric acquisition of the roofs. A low level of detail was available. The contrast between a flat shaded rendering

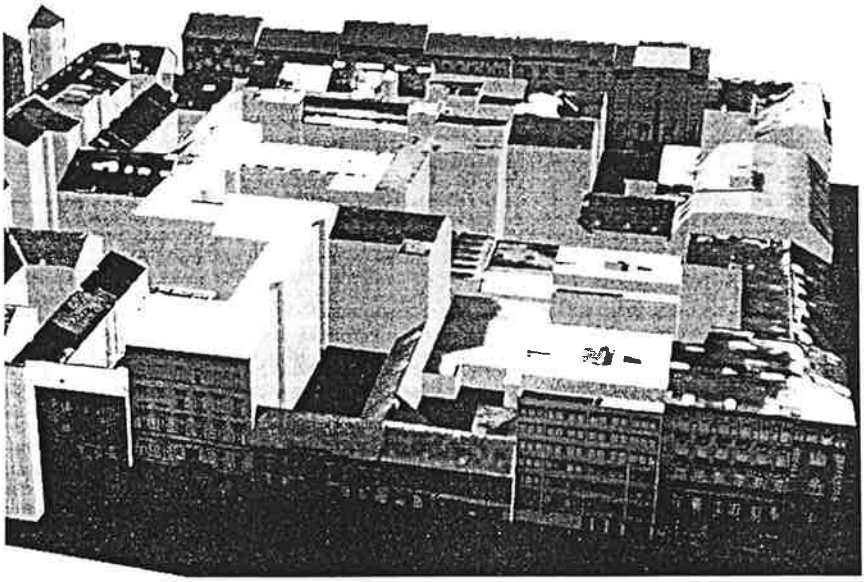


Fig. 1: The Vienna test–site, a city block of 58 buildings. Roofs and facades facing the streets are textured from aerial and terrestrial photographs

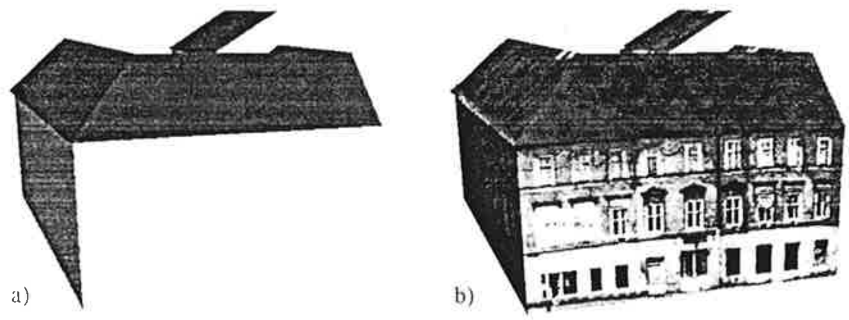


Fig. 2: A simple building from the Vienna test–site, a) flat shaded and b) rendered with phototexture

of the building shapes with a photo-textured visualization shows that photo-texture is a useful addition to the geometric data. The color and quality of the buildings, number of levels and situtation of windows and entrances is documented (cf. Fig.2). The missing detail within the geometric model does not disturb the quality of the model because of the moderate scale and resolution. In other words, the level of geometric detail and of the texture resolution supports the correspondence between CAD model and photographic reality.

2.2 Graz

The city of Graz maintains a 2.5 D geographic information system in the format of a Siemens-SICAD-GIS. The entire city is covered by recent color aerial photographs. A set of five true color aerial images at a scale of 1 : 3500, a digital map data set and a 2.5 dimensional data set of roofs, including chimneys and skylights was thus selected for the Graz test-site, which is situated in the downtown of the city (cf. Fig.3). Our investigation initially focuses on the modeling and photo-realistic rendering of the roofs, including architectural details. Such detail is dictated by the quality and resolution of the aerial photographs, which do show elements like chimneys and skylights, but also eaves and even the texture of the rooftiles (cf. Fig. 4). In addition to these object details the images contain shadows and different brightnesses as an effect of the illumination by sunlight. The two-dimensional digital map represents the planimetry of the buildings´ footprint; this does generally not correspond with the shape of the roofs.

Our work serves to understand the problem of automatically creating a geometric model of a roof, and of creating photorealistically textured representations of these roofs with the many complications arising from various aspects of the problem domain.

3 Using the Digital Map to obtain the Rooflines of Buildings

The fusion of the digital map and the digital images is based on a new affine matching algorithm [Pinz et al., submitted] which compares two token sets, the shape of one building from the map and the detected line segments in the digital images (cf. Fig.5). These line segments have been obtained from the Burns line algorithm [Burns et al., 1986], which allows a large number of tuning parameters. To start the matching procedure, the map detail is projected into the digital image using the exterior orientation of the camera. The orientation parameters of the photographs must be complemented by the terrain elevations, which is known from a DEM. This defines the position of a building's footprint at the ground level.

The transfer of these data to the level of the roofs requires an estimate of the height of the buildings to calculate the shift in the image plane. The estimate can be less accurate the more a building is situated near the center of the photograph. The direction of the shift is radial from the known nadir point of the photograph. The result of an automated matching procedure is shown in Fig.6. Each of the five edge images is matched with the digital map of one building. The correspondence between image and map varies due to several reasons. We have to accept that the digital map represents the "foot print" of

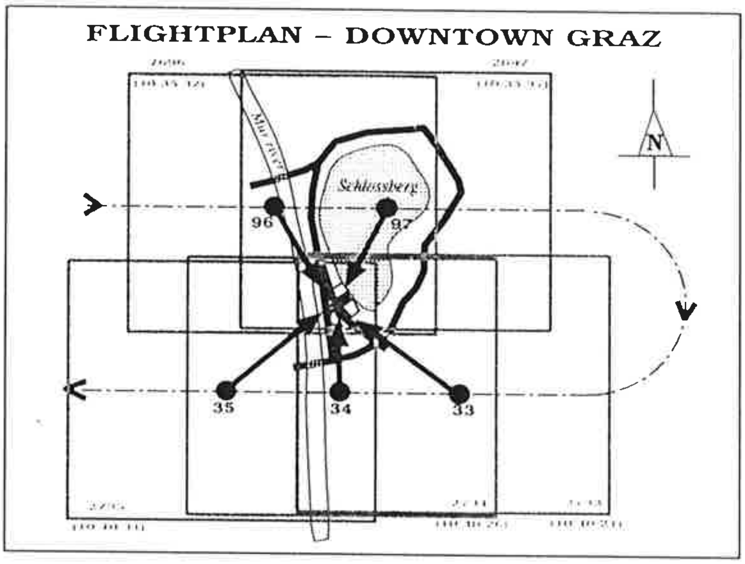


Fig. 3: The Graz test–site. A set of 5 true colour aerial images was selected to cover a quintuple overlap in the historic district. The buildings are on the foot of the Schlossberg, adjacent to the Mur–river

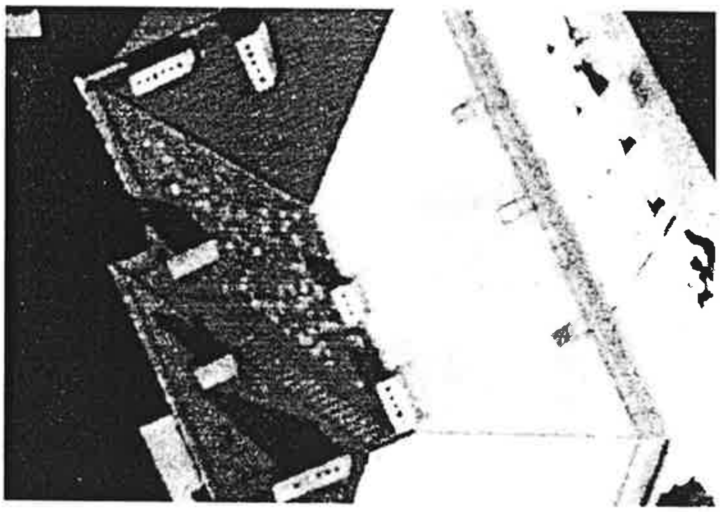


Fig. 4: Detail of one aerial photograph, showing the roof with chimneys, skylights and even the structure of the roof tiles

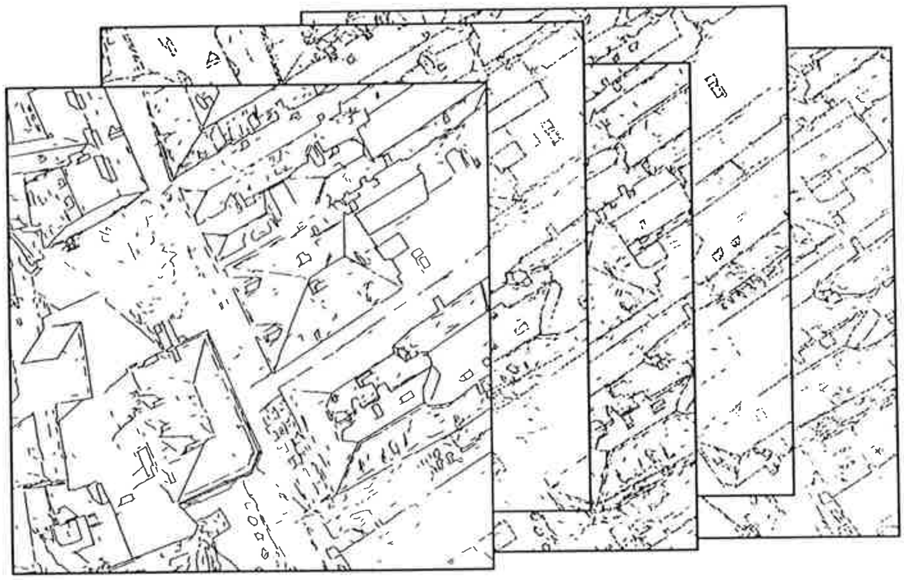


Fig. 5: Detected line segments in the digital images

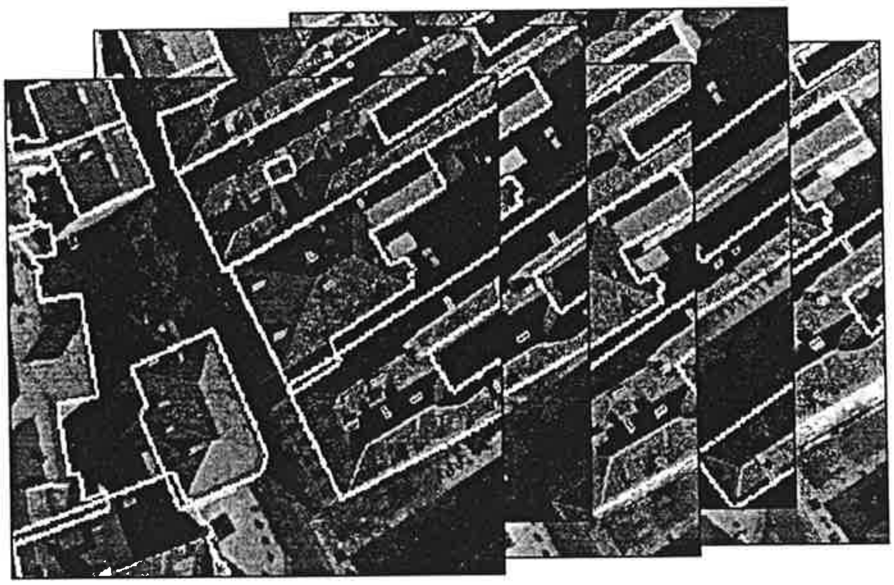


Fig. 6: Result of the affine matching procedure: the 2D digital map combined with the image data

the building and not the shape of the roof-line. This produces a shape that differs from that shown in the image. However, both shapes will find entry into a city-model.

In addition the roof exhibits details such as chimneys and skylights, which cause shadows and occlusions. This may confuse a matching algorithm. The roofline and the building's footprint describe the "building box"; however, the shape of the roof must still be computed, either by stereopsis, by shape-from-shading, by symbolic computing, using the linear features on the roof.

4 Texture versus Geometry

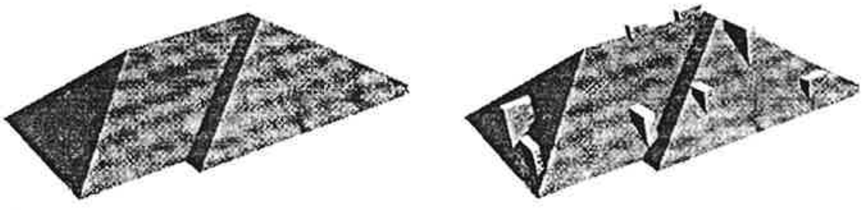
The work with the Vienna test-site addressed the broad problem domain of 3D city models [Gruber et al., 1995], [Leberl et al., 1994]. The next step is to focus on specific details. In this paper we deal with a high resolution representation of the medieval tile roofs of downtown Graz. The digital images describe the tile structure of the roof, the shape of small skylights and the texture of the eaves. This may be included in the textured CAD model. A much larger data set is obtained compared with a standard textured presentation (cf. Fig.7a and 8a). The part of the roof seen from the point of view chosen for Fig.8a does not contain object details which are of geometric importance. The correspondence of the CAD model and the photo-texture seems to be free of errors, at least at this level of detail and resolution. However, moving the viewing position produces the example of Fig. 8b; the geometric detail is inadequate for the quality of the model because contradictions exist between the CAD model and the photo-texture: the chimneys are not included within the geometry, but they are existing in the photorealistic texture.

This issue is resolved by a refinement of the CAD model. The chimneys are included in the scene, resulting in the presentation of Fig.9a. Geometry and phototexture correspond now to one another at the new level of detail. But occlusions and shadows in the image still disturb the visual impression. This defect has to be removed in a postprocessing step. The result is shown in Fig.9b to indicate that a solution exists that will satisfy the visual requirements. Shadows could now be computed for the chosen position of the sun.

While methods for the automated refinement of the geometric model have some tradition in photogrammetry, such tools need to be created for the texture process. A cost effective system for data acquisition must offer a high degree of machine support. It is therefore important that automation for texture processing be developed.

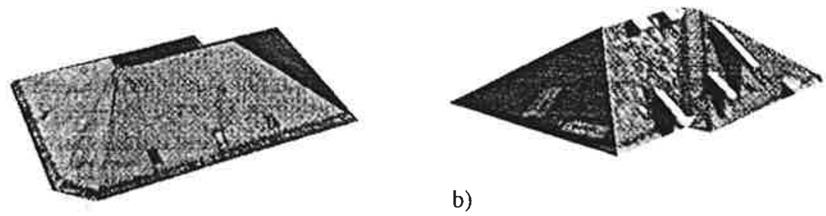
5 Design of a Building and Roof Modeling Module

The entire suite of modules to create 3D models of cities in the computer will have to combine an element addressing the basic shapes of buildings (= "building boxes") and roof shapes. We denote this as "building box and roof modeling" which needs to be augmented by modules for facades, vegetations, suspended structures in streets etc. to represent a complete system to create a 3D GIS. Fig.10 is the outline of a process flow which encompasses the geometric modeling procedure, the texture processing and the merging of both, CAD model and phototexture.



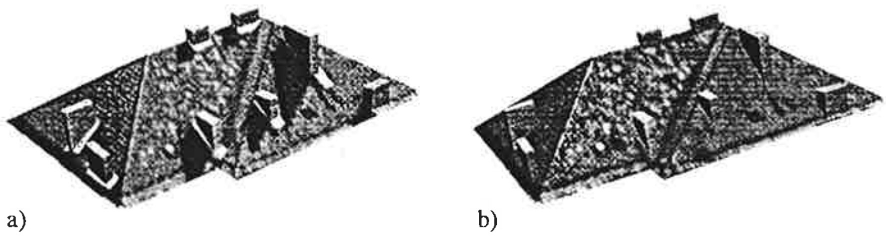
a) b)

Fig. 7: Rendering result of a roof with standard texture using a) simplified geometry and b) enhanced geometry including chimneys



a) b)

Fig. 8: Rendering result of a roof with photorealistic texture, where a) details are visible and mapped correctly (skylights) and b) details are visible but mapped incorrectly due to the missing geometric representation



a) b)

Fig. 9: Rendering result of the same roof with photorealistic texture and enhanced geometry, where a) shadows and occlusions are visible and b) shadows and occlusions are cleaned

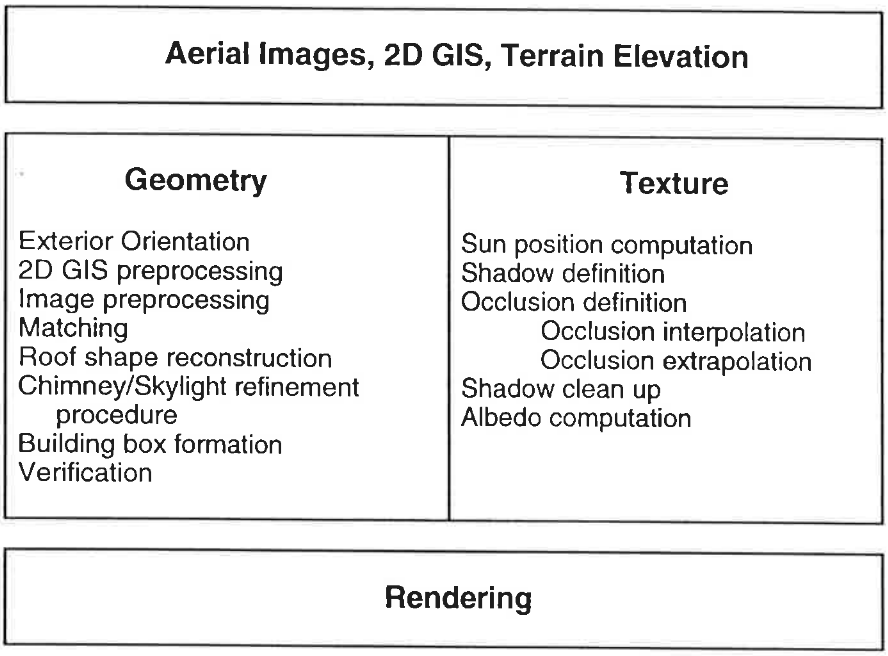


Fig. 10: Flow diagram of the "building box and roof modeling" procedure for geometric modeling and texture processing

6 Conclusions

We have presented a concept for the joint use of 2D GIS data and aerial photography to produce a detailed model of roofs. We demonstrate the importance of sufficient detail with chimneys and other structures. Our approach begins with a novel method of affine matching using so-called "token sets" based on edges obtained by the algorithm by Burns.

The use of photographic texture to render three-dimensional CAD-models of buildings is an important element in the transition from the 2D GIS to the 3D cityscape. We show the pitfalls caused by inappropriate geometric detail, shadows and occlusions.

Therefore a 3D GIS requires close correspondence between geometric and textural details. Lack of correspondence will result in a loss of quality. Currently a large amount of manual postprocessing is needed to create a texture with satisfactory results. We argue that automated texture processing methods are needed as urgently as one needs geometric reconstruction methods. Texture must closely interact with the geometric model so that satisfactory 3D geographic information systems are obtained.

References

Burns B., A. Hanson, E. Riseman (1986) *Extracting Straight Lines,* IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. 8/4 Los Alamitos

Gruber M., S. Meissl, R. Böhm (1995) *Das dreidimensionale Stadtmodell Wien, Erfahrungen aus einer Vorstudie,* VGI, Heft 1+2, Wien

Leberl F., M. Gruber, P. Uray, F. Madritsch (1994) *Trade-offs in the Reconstruction and Rendering of 3-D Objects,* 16th DAGM Symposium and 18th ÖAGM Workshop, Informatik XPRESS 5, Wien

Pinz A., M. Prantl, H. Ganster (submitted) *A new Affine Matching Algorithm for Computer Vision*, submitted to J. of Universal Computer Science, Springer Verlag