Accurate Mapping of Buildings in Digital Orthophotos

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ABSTRACT:

The goal of this research project is the development of algorithms for accurate mapping of buildings in digital orthophotos. The algorithms presented in this paper are based on several components: digital terrain model (DTM), digital building model (DBM), and digital photos including orientation information. In this paper the DBM will be generated mainly by using digitized roofs and the DTM. The DBM will be used for generating masks using the Z-buffer algorithm. Masks mark areas in the digital photo that contain elements of the bulding (e.g. walls, roofs, etc). The final accurate digital orthophoto is a combination of orthophotos from "rectified buildings" and "rectified terrain surface".

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1. INTRODUCTION

The generation of digital orthophotos has reached a high level of maturity and is used by several mapping institutes for country-wide orthophoto production. The compatibility of digital orthophotos with GIS, that enables further processing, is another advantage of the digital technique over the analogue solutions.

So far only little importance has been paid to improve the geometric quality of orthophotos concerning images of the mostly artificial 3D-objects on the terrain surface. Currently no orthophoto system is available that enables accurate mapping of buildings in large scale applications [Kraus, 1993]. This problem is caused by the inadequate description of the shape of the buildings by the digital terrain model and the applied algorithm (Fig. 1).

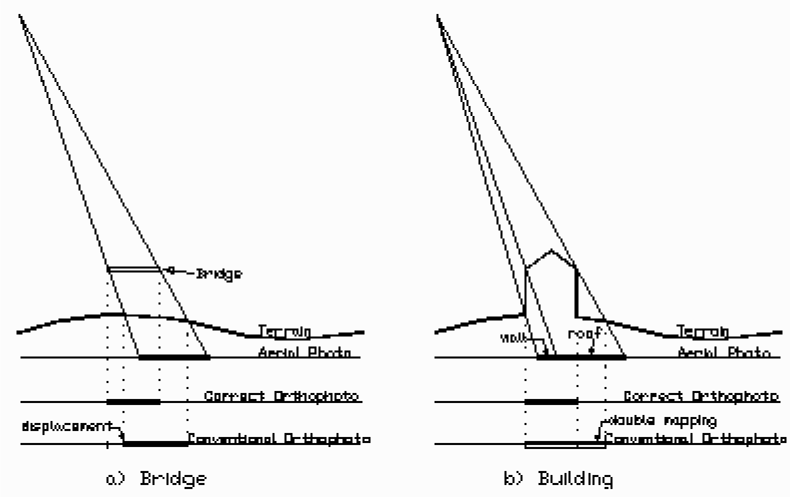

Fig. 1: Correct and conventional orthophoto of bridge and building

Fig. 1a shows the terrain surface modelled by the DTM and a bridge. Since the shape of the bridge is not modelled at all; the bridge will be displaced as can be seen in layer "conventional orthophoto". The proper position is marked in layer "correct orthophoto". In Fig. 1b the building is included in the DTM. This approach results in a correct position of the roof pixels in the orthophoto, but has the disadvantage of double mapping in hidden surface areas.

The percentage of erroneously mapped pixels in today's orthophotos mainly depends on the density *d* and height *h* of the buildings. Assuming a building density of 12.5 % (1/8) and a mean height of 20 m using a small angle objective (c=208 mm) and flying height over ground of 1250 m, 8.2% of the pixels are false. It is a high rate for spatial analysis in a GIS (Tab. 1).

d=1/	h=10 m	h=20 m	h=30
4	30.7%	62.2%	94.4%
8	4.0%	8.2%	12.4%
16	0.5%	1.0%	1.5%
32	0.07%	0.14%	0.20%

Tab 1: Influence of building height and building density on the percentage of erroneously mapped pixels

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2. THE DIGITAL BUILDING MODEL

This paper presents a method to overcome these problems. Additionally to the DTM a model defining the shape of the buildings will be introduced. This digital building model distinguishes between roofs and walls. Walls are vertical plane surfaces and therefore invisible in the orthophoto. Metric (coordinates) and topological information is required for the DBM.

In the process of data capturing for the DBM in most cases it is sufficient to digitize the roofs only. The walls can be compiled from the roofs and the DTM. Furthermore it is presumed that eaves and terrain (modelled by the DTM) are boundaries of walls. Therefore the DTM must be computed first (Fig. 2a). For bridges an approximate thickness can be defined if the bottom side of it is invisible in the stereo digitizer (Fig. 2b).

In developing countries many buildings in new urban regions are of similar shape. For these homogeneous mass buildings a "topology-builder" [Gruen, et al, 1993] can be used in order to facilitate data capturing (Fig. 2c). For modelling of complex buildings (2d) either a mathematical model (if known) or a description of the shape in form of mass points is required. The latter method affords postprocessing like triangulation with geometric constraints [Chen, et al, 1994]. It is important to model the real shape of a building although it is sometimes easier to create a new but wrong shape of the building with a CAD-system.

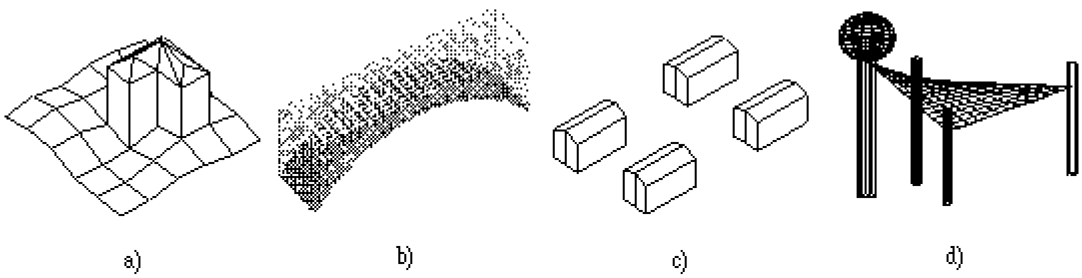

Fig. 2: "simple-building" and "complex-building"

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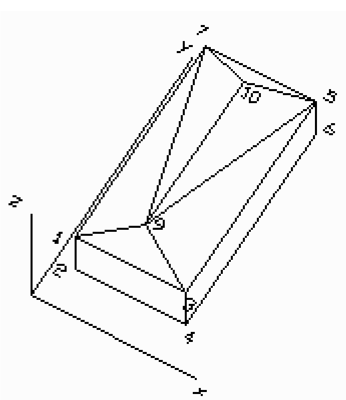
3. DIGITAL BUILDING MODELS AS APPLIED FOR ORTHOPHOTO GENERATION

The data structure for the storage of buildings is based on coordinate lists and topologigal information. For this purpose graphic primitives in form of triangles and quadrangles are used [Fig.3]. Triangles are applied to model roof details whereas quadrangles represent walls (generated by DTM and roof). This is the simplest format [Loidolt, 1987] to generate a DBM. The DBM will be used for the rectification of roof pixels and for the generation of masks by Z-buffer-algorithms [Rauber, 1993].



Coordinate-List

1	x_1, y_1, z_1
2	x_2, y_2, z_2
3	x_3, y_3, z_3
4	x_4, y_4, z_4
5	x_5, y_5, z_5
6	x_6, y_6, z_6
7	x_7, y_7, z_7
8	x_8, y_8, z_8
9	x_9, y_9, z_9
10	x_{10}, y_{10}, z_{10}

Topological Information

WALL	
1	1 3 4 2
2	3 5 6 4
3	5 7 8 6
4	7 1 2 8

ROOF	
1	1 3 9
2	3 9 5
3	9 5 10
4	5 10 7
5	10 7 9
6	7 9 1

Fig. 3 Coordinate-list and topological information

The Z-buffer is a matrix, that stores for each building pixel of the digital photo its object distance. It is just an intermediate product for the determination of hidden surface areas. In most cases the interference of DTM and building is low (put simply: buildings are rarely hidden by terrain surface) therefore the Z-buffer can be computed independently from the DTM. This simplification also results in faster processing. The corresponding index matrix assign values of 0 for terrain surface, 1 for roofs and 2 for walls to pixels (Fig. 4).

For a geometric correct computation of the Z-buffer both DTM and DBM have to be considered. For this purpose the object distance of building pixels, but also its distance from the terrain surface must be computed. Thus it is possible to minimize computing time and recognize the buildings hidden by terrain.

Next the digital photo will be masked pixel by pixel with the index matrix (Fig. 4b). The results are two digital photos. The "terrain-photo" contains terrain surface pixels but no building pixels, whereas the "roof-photo" contains building pixels but no terrain surface pixels. Wall pixels are not relevant for the orthophoto, therefore they are ignored in both photos.

For the generation of the "terrain orthophoto" any available orthophoto system (e.g. SCOP.DOP [Ecker, et al, 1993]), using the terrain-photo as input, can be applied. The "roof orthophoto" must be computed by a separate program using the digital building model. In Fig. 5 the program recroof fulfills this task. The combination of both orthophotos results in an orthophoto with correctly mapped buildings and terrain, but with no information (blank) in hidden surface areas (Fig. 4c). By merging overlapping orthophotos derived from different images by raster algebra, a final orthophoto with no blank areas can be obtained.

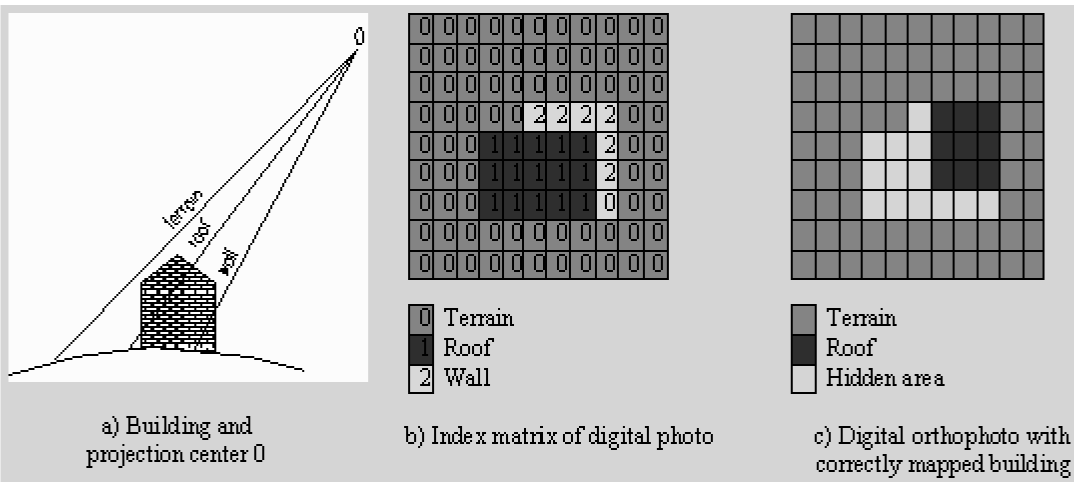


Fig. 4 Situation, index matrix and digital orthophoto

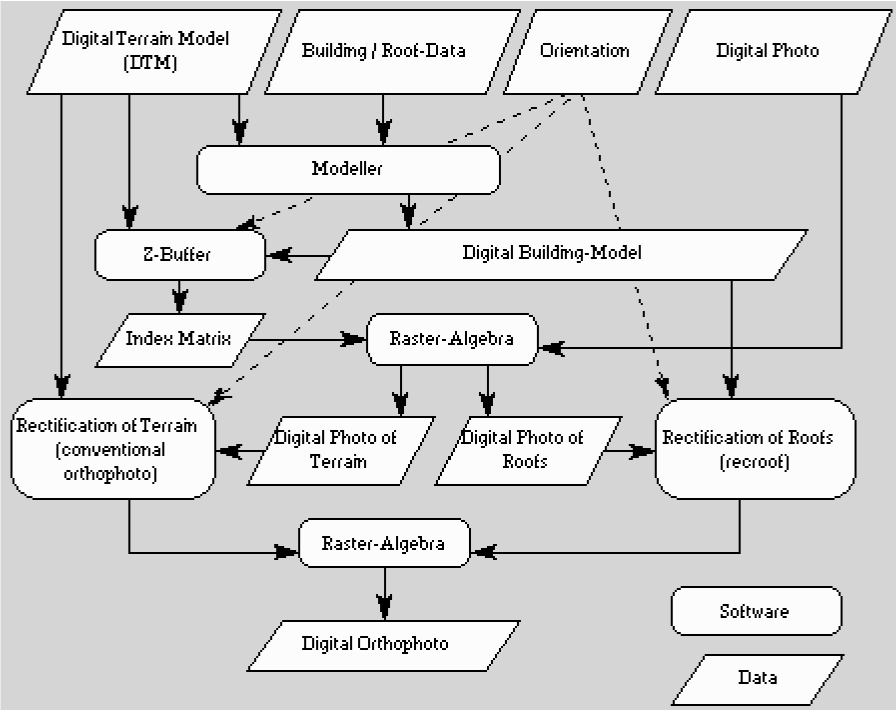


Fig 5: Process of orthophoto generation using a digital building model

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4. OUTLOOK

The most important task to be done yet will be to set up an integrated data capturing system for fast data acquistition of different types of 3D-objects (including DTM-points). A solution based on a digital photogrammetric stereo plotter will be prefered in order to get better control on topology building at the time of data acquisition.

The integration of the digital building model into a DTM will be another investigation. Within the DTM 3D-objects can be stored as enclaves. The data structure presented is also suitable in using DTM technique for virtual reality. Thus sightseeing in a town could be simulated. For this purpose photos of building facades must be integrated [Gruber, et al, 1995].

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5. CONCLUSION

The problems of today's digital orthophoto has been discussed. It could be demonstrated that in central urban areas about 8 % of pixels are mapped erroneously in conventional orthophotos. Considering 3D-objects (buildings, bridges) in the process of orthophoto generation can solve this problem. The algorithm presented in this paper creates a mask for the digital photo applying a Z-buffer algorithm. This mask allows for distinguishing between wall and roof pixels in the digital photo. Thus DTM and roofs can be rectified seperately. Future investigations are needed to improve data capturing and the integration of 3D-objects into a DTM.

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