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Automated update of building information in maps using color aerial imagery

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ABSTRACT
Automated detection and reconstruction of buildings are topics of high interest these days, and they bear quite a number of problems to be solved. The use of approximate building data can support the procedures; however such data has to be checked regarding its actuality and correctness. This contribution gives an overview on building detection and reconstruction investigations that are part of project ATOMI. The project’s long-term aim is to contribute to the production of a realistic 3-dimensional landscape model of Switzerland. A quality assessment of the available approximation data, an overview on several detection and reconstruction methods with encountered difficulties and an evaluation of the results shall lead to a better understanding of the whole subject matter. The achieved accuracy of single standing buildings is sufficient in order to use the results for map update, but town centres or connected groups of buildings cannot yet be processed with sufficient accuracy. A full version of this article can be found in Niederöst (2001) or at http://www.photogrammetry.ethz.ch/general/persons/markus.html.

1. INTRODUCTION
All presented investigations and procedures in this paper are part of project ATOMI (Automated reconstruction of topographic objects from aerial images using vectorized map information), a cooperation between the Federal Office of Topography (L+T) and the Institute of Geodesy and Photogrammetry at ETH Zurich. The aim of the project is to update vector data of road centerlines and building roof outlines from 1:25,000 maps, fitting it to the real landscape, improve the planimetric accuracy to 1 m and derive height information (one representative height for each building) with 1-2 m accuracy. This update should be achieved by using image analysis techniques developed at ETH Zurich and aerial color imagery of scale 1:15,800. The results should not only allow the automated update of the map content, but with the introduction of the third dimension, the data is also intended to be used as a base for a realistic 3-dimensional landscape model of Switzerland (Eidenbenz et al. 2000).

2. EVALUATION OF BUILDING APPROXIMATIONS
VECTOR25 is the digital cartographic model of Switzerland, which in geometry and content is based on the topographic 1:25,000 maps. It represents the natural and artificial objects of the landscape in a flexible vector format and is suited for the use in geographic information systems. The dataset is produced and distributed by the Federal Office of Topography in Wabern / Switzerland. VECTOR25 is generated semi-automatically using the scanned 1:25,000 map. The planar accuracy of the objects is about 3-8 m and corresponds to the map accuracy. The major characteristics of the dataset are defined by the fact that it is a generalized dataset which is not actual. The major effects of generalization and of a map being a snapshot at a certain date should not be underrated when using VECTOR25 as approximation data. The main differences are location, size, orientation, shape (level of detail) and the case when several buildings are combined to one object in the map data. Further aspects that have to be considered when using map information as approximate data are the 2-dimensionality of VECTOR25 and the actuality of the data. A quantitative and qualitative analysis of about 900 buildings in two different datasets showed the big influence of map generalization on the building approximations. Only about 6% of the buildings correspond closely to the reference data. The cases where only the location, orientation or size is wrong make about 25% and usually should be possible to update. More difficult are the cases where the shape is wrong. Remarkable is the high percentage of buildings where no VECTOR25 is available at all. With almost 20% of the buildings having no approximate data it is very important to provide a method for the detection of those buildings, too. For those reasons the use of map data for approximations is an advantage that must not be overrated.

3. USED DATA
Two datasets were used for the search of generally applicable methods for building detection and reconstruction. To allow general applicability, only stereo overlapping imagery was used: Image scale 1:15,800, RGB color (no infrared information), resolution 14 microns, ground pixel size 0.22 m. The height information was calculated with automated DSM generation in commercial software (DPW 770 by LH Systems or Phodis by Z/I Imaging respectively), the rasterwidth was 2.0 m or 1.0 m respectively. In addition the so-called DHM25, a terrain model covering the whole area of Switzerland with a rasterwidth of 25 m, could be used. This product is distributed by the L+T. The accuracy is about 2.5 m for the low parts of Switzerland and 10 m for the Alps.
4. BUILDING DETECTION METHODS

During the research, several approaches for the detection of blobs and particularly of buildings were developed and tested. Building detection with unsupervised classification is described in Niederöst (2000a). The radiometric information and texture from an RGB orthophoto are combined with height values of a normalized DSM \( n\text{DSM} = \text{DSM minus DHM25} \). A new method for blob detection with exclusive use of a DSM (no terrain model necessary) can be found in Niederöst (2000b), too. The height information is sliced into height bins. If through a consecutive chain of bins an object is found at the same location, a blob is detected. Important are the following two questions: Which height information is used to separate objects above ground from the terrain? How can the buildings be separated from trees that are also higher than the terrain?

For a coarse detection the height information in a photogrammetrically derived DSM is sufficient. Detection problems occur when buildings stand close to each other or close to vegetation. A problem is the vegetation that has to be separated from man-made objects. If no laser or infrared data is available, this task has to be solved under exclusive use of the RGB information of the color image. A good opportunity to avoid the measurement of training areas is presented by the Hotelling transform (Wahl 1987, Gonzalez & Woods 1992), commonly known as eigenvector, principal component or discrete Karhunen-Loève transform. The method is used in remote sensing to reduce the number of channels and the redundant information by elimination of the channels which have low eigenvalues and thus do not contain significant image information. Unsupervised isoclustering with 3 input channels (arithmetic combination of red and green channel, 2nd and 3rd principle component calculated from RGB) resulted in a very good separation of man-made objects from vegetation without use of training areas. The user interaction was reduced to a minimum.

5. BUILDING RECONSTRUCTION METHODS

Automated building reconstruction has been done by many researchers in recent years, and a number of very interesting procedures was developed. See e.g. Brenner (2000) or Ameri (2000) for a comprehensive overview or Baltsavias et al. (2001) for recent developments. In project ATOMI the aim is to reconstruct the coarse shape of the buildings. In a first attempt (Niederöst 2000a), the buildings were reconstructed on the base of a color orthophoto, derived color channels, edge magnitude and orientation as well as height information from a DSM and a DTM. Score functions were then used to do a step by step adaption of location, orientation and size. One building height was derived from the DSM. A more general approach using both aerial images is described in (Niederöst 2000b). Those roof parts that represent the coarse shape of the building were determined in an unsupervised classification. With reconstructed 3-D edges and height values from the DSM, the surface equation of each roof part was calculated. Reduction of each roof part to 4 keypoints and addition of the walls by projection onto the DHM resulted in the building model. While the orthophoto-based approach was rather slow, the reconstruction of main roof parts was not generally applicable. For those reasons the method with 3-D edges and blob outlines was developed. It is based on use of the building outline from the nDSM that is determined during the blob detection process. Reconstructed 3-D edges are employed, too. The principle is to do a step-by-step correction of the approximate data: Translation, rotation, scale, correction of single sides, height and roof shape determination.

6. EVALUATION OF THE PROCEDURES

Common property of the developed methods is that they work for simple, single standing buildings, whereas in a town centre, where buildings are connected or standing very close, the procedures fail. The main factors influencing the quality of the results are the used image and height data. When researching for a generally applicable procedure, one has to be aware that the radiometric properties of aerial color images vary to a large extent, depending on the season, daytime, weather, and used film. Thus, the method for vegetation detection has to be independent of such parameters. Major attention has to be paid to the used surface model, too. The present research has been restricted to the standard data acquisition practiced by L+T up to now. A DSM that is automatically derived from a stereo model with photogrammetric methods always contains an amount of incorrect height values, especially at steep slopes (e.g. building walls). Laser surface models are widely used because of their resolution and reliability, and their use would significantly improve the quality of the results.

The orthophoto-based method and the approach with blob outlines were automatically compared to a manually measured reference data (approx. 900 buildings). The reconstruction of separate roof parts turned out to be not generally applicable, and therefore those results were not used in the comparison.

Generally, the update of a map based on the building reconstruction results is possible. But the planar precision of the results is not of high accuracy. Considering the quantitative measures that where used for analysis - e.g. total relative shape dissimilarity (Henricsson & Baltsavias 1995) - many of the reconstructed buildings are not precise enough. Reasons for these inaccuracies can mainly be found in the used data (low ground resolution) and the used height information (no laser data). For buildings contained in VECTOR25, the outline given in the approximate data was used. This shape is usually affected by the map generalization. All new buildings were assumed to have 4 corners, which is quite a strict simplification. Despite of those inaccuracies it could be shown that the achieved results in suburban areas are sufficient for update of a 1:25,000 map (Fig. 2).
8. CONCLUSIONS

It was shown that the automated reconstruction of coarse building models from one stereo model (image scale 1:15,800) is possible. A priori knowledge about the buildings was available, but a comparison of the approximations with manually measured reference data showed that their value for building reconstruction must not be overrated. The main problems inherent in the used input data (imagery, DSM) were discussed, and a general solution for vegetation detection was introduced. Some developed methods for building detection and reconstruction were briefly outlined. Finally, the results of two developed methods were compared and the usability of the results in suburban areas was showed.

REFERENCES


