TOWARDS AUTOMATED MAP UPDATING: IS IT FEASIBLE WITH NEW DIGITAL DATA-ACQUISITION AND PROCESSING TECHNIQUES?

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ABSTRACT

Up to now large scale mapping (scales > 1:10,000) is done nearly exclusively with aerial photographs. New digital camera systems will replace these analogue systems in the near future. This paper describes an approach for automated detection of houses, using a data set of the High Resolution Stereo Camera - Airborne (HRSC-A). The system provides multispectral information with a resolution of 15 cm (3000 m flight altitude) and Digital Surface Models with a resolution of 50 cm, depicting elevation in steps of 10 cm. The elevation and spectral information supplied by the sensor was used for this study. New object-oriented approaches allow the interpretation of these high resolution data sets. The combination of a new approach (multiresolution segmentation, hierarchical networks) and the multispectral high resolution data of HRSC-A with its accurate Digital Surface Model shows very promising results.

1 INTRODUCTION

Geographic Information Systems (GIS) have not only changed dramatically the number of digital map users over the last years but also their demands. Large scale topographical maps are needed as an important basis for numerous GIS applications. These users demand data sets that are updated frequently in all three dimensions. This leads to a necessity for data sources and processing/analysing systems that can cope with these demands and emphasises the necessity of integrating remote sensing and GIS.

Automated updating with high resolution data faces two problems: First the difficulty of classifying high resolution data where each pixel is related not to the character of object or area as a whole, but to components of it. Simple pixel-based analyses may be invalid for certain environments and tasks. In some case the classes that are required to be mapped may disappear altogether, for instance, suburban becomes buildings and vegetation. (Smith & Hoffmann 2000). Second, the complexity of urban areas to be mapped.

It was found that using just multispectral information for classification does not lead to precise and consequent interpretation results of urban land use (Gong & Howarth, 1990; Fung & Chan, 1994; Johnsson, 1994; Barnsley & Barr, 1996; Zhang, 1998, Gao & Skillcorn, 1998), because the differentiation between urban object classes is done not only with the help of spectral information, but also with spatial information of the image data. The same colours in a data set might show different objects (e.g. in some areas roofs and streets are built of very similar materials), the expressiveness is ambiguous. Only the combination with spatial information leads to unambiguous identification (Strathmann 1988). Investigations also showed, that spectral classification of higher resolution data (TM and SPOT data sets in comparison with MSS data) does not automatically lead to higher classification accuracy (Johnsson 1994, Gong & Howart 1992, Toll 1984), because higher spatial resolution mostly widens the variance of classes, thus leading to misinterpretation (no unambiguous differentiation between classes, overlap and mixing). Finer spatial resolutions actually reduced classification accuracy for certain land cover types. The coarse spatial resolution of the Landsat MSS smoothed out spatial complexity within heterogeneous land cover types, such as urban. It was found that although finer spatial resolutions reduced the proportions of mixed pixels, the number of detectable classes increased and became less separable spectrally (Markham and Townshend, 1981, Bruniquel-Pinel & Gastellu-Etchegorry 1998). In order to enhance spectral classification results, some authors tried to integrate spatial information. The difficulty of extracting meaningful texture information is emphasised, in most cases the accuracy of classification or segmentation could not be enhanced (Ryherd & Woodcook 1996; Gong & Howarth 1990).

To solve the complex problem of classifying high resolution data of urban areas, the interpretation of multiple data sources was proposed (Haala 1999). The author used a combination of aerial photographs and elevation data acquired by a laser scanner. Classification was done pixel-wise with training areas using an additional channel concept. The integration of digital elevation data showed promising results.

The approach described in this paper has the advantage of using one homogeneous data set. HRSC-A data provides a digital surface model and panchromatic and multispectral information, processed from the same data base. This avoids problems of co-registration of different data sets acquired with different sensors and at different times. The paper highlights some of the results of a pilot study aimed at the interpretation of high resolution data sets of the latest digital camera technology (HRSC-A) to increase productivity and efficiency of digital topographical database updating. New object-oriented approaches allow interpretation of these high resolution data sets. An approach for automated house detection and updating of vector data sets will be discussed, using multiresolution segmentation and a knowledge-based classification technique. The integration of high resolution elevation data leads to much better interpretation results, significant further automation of updating can be achieved. In the pilot study the approach and concepts have been tested for updating of the Dutch 1:10.000 Top10Vector database.

2 DISADVANTAGES OF AERIAL PHOTOGRAPHS

Up to now only aerial photographs offered a sufficient resolution for mapping in large scales (> 1:10,000). Investigations of the University of Hannover showed, that satellite data could be used for scales up to 1:25,000 (IRS 1 C, resolution of 6 m) (Konecny 1999). Automated interpretation of aerial photographs is very difficult and uncertain due to some of their properties:

- Problem of **relief displacement** – tops of objects appear to lean away' from the principal point of the photograph, both their tops and their sides are visible from the position of lens (Figure 1). This difference in apparent location is due to the height (relief) of the object and forms an important source of positional error in vertical aerial photographs. The direction of relief displacement is always radial from the nadir, it reaches a maximum at the corners of the photograph (Campbell 1996).
- **Mosaicking** of photos is difficult due to the different geometry of adjacent photos
- **Different base** for orthoimaging: the used digital elevation model cannot model objects above the ground level
- **Spectral classification** is not possible because of different grey values of the same objects. Due to physical reasons there is a decline of brightness from the center of the image towards the corner of the photograph, depending on their position on the image same features do not have the same spectral properties (Hildebrandt 1996)
- **Radiometric resolution** often is poor (6 bit of photos versus 8-10 bit of digital camera)
- Aerial photos have **different scales** Tilt is caused by displacement of the focal plane from a truly horizontal position by aircraft position. Image areas on the upper side of the tilt are depicted at scales smaller than the nominal scale. Areas on the lower side of the tilt are depicted at scales larger than the nominal scale (Sabins 1996).

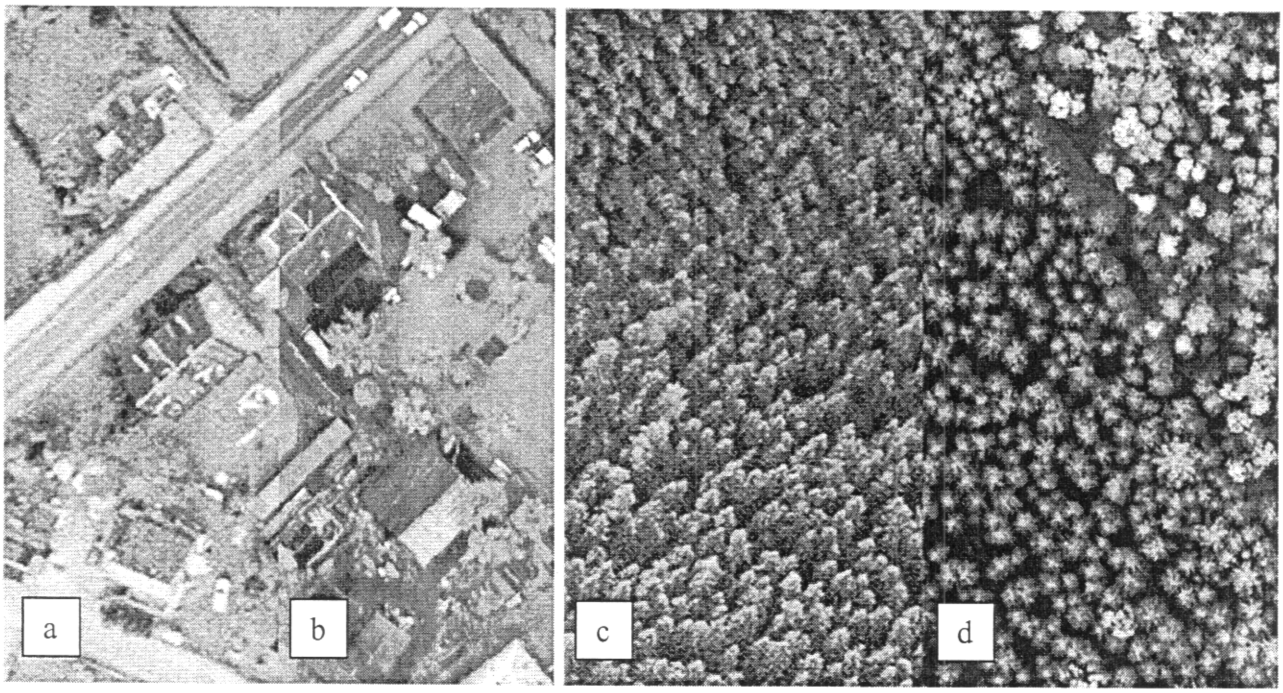

Figure 1: Comparison of aerial photographs and digital camera data (HRSC-A): Village at Tharandter forest (left hand images), Tharandter Forest (right), a) c) aerial photo, Nadir, 40 cm, flight altitude 2500 m, acquisition date: October 23th 1998, b) d) HRSC-A, Nadir, 25 cm, flight altitude 3000 m, acquisition date: October 21th 1998

3 CURRENT TOP10VECTOR REVISION PROCESS

The Dutch Topographic Service (TDN) produces maps and databases at scales ranging from 1:10,000 to 1:500,000. One of their products is TOP10vector, a digital topographic database in vector format, which can be used in the scale-range 1:5,000 to 1:25,000. TOP10vector is based on black-and-white aerial photography at scale 1:18,000 combined with reconnaissance survey in the terrain. The production flow for TOP10vector is described in detail by Asperen, 1996.

The process starts with detection of changes in the aerial photograph enlarged to scale 1:10,000 compared to a transparent film of the TOP10vector data set. New topography is annotated on the photograph. Mapped features that no longer exist are marked on the transparent film. This is done partly at the office and partly in the terrain. After field survey the enlarged aerial photographs with the new annotated topography are scanned. Parallel when to these activities, photogrammetric processing, i.e. aerial triangulation and block adjustment is applied on the original aerial photographs in order to provide parameters for geometric rectification of the scanned aerial photograph. Combining these transformation parameters with a height model, the scanned aerial photograph is transformed into a digital orthophoto. By means of heads-up digitization of the changes annotated on the orthophoto the TOP10vector data set is updated. Codes expressing topographic theme, topological and spatial relationships are attached to the digitized points, lines and centroïdes. When digitizing is finished, software is applied to build the areas as closed polygons. Finally, some automatic checks are done and a check plot is inspected visually.

4 THE HIGH RESOLUTION STEREO CAMERA – AIRBORNE (HRSC-A)

The *High Resolution Stereo Camera - Airborne* (HRSC-A) digital photogrammetric camera and its processing software provides the geoinformation industry for the first time with an entirely digital and fully automatic process to produce highly accurate digital image data. The multiple line pushbroom instrument was originally developed for planetary exploration (Neukum et al., 1995, 1999). The multispectral, multi-line (9) and multi-stereo system provides digital ortho-images and digital surface models with an accuracy of 10-20 cm. The pixel resolution is 15 cm (at 3000 meter) (Wewel & Brandt 1998). The camera combines high resolution, photogrammetric accuracy, all-digital acquisition, and both multispectral and elevation information. Nine superimposed image tracks are acquired simultaneously (along-track) by nine CCD line sensors mounted in parallel on the instrument focal plane. Five of these are panchromatic sensors arranged at specific viewing angles and provide the multiple stereo capabilities of the instrument. Four of the nine CCD lines are covered with different filters for the acquisition of multispectral images. According to its development for space missions, the camera has small dimensions, low mass, low power consumption and a robust design. HRSC-A is extremely sensitive to variations in light density, allowing aerial mapping to continue under a wide range of weather conditions (Renouard & Lehmann 1999).

A slightly modified version of the instrument has been adapted for operation in terrestrial airborne remote sensing. During image acquisition, data rates of 10 MByte/s provided by four parallel signal chains can be stored on a high-speed tape recorder. The camera is mounted on a stabilised platform (ZEISS T-AS) in order to damp mechanical vibrations and to enforce near-nadir viewing. Position and orientation during flight navigation are measured continuously by means of differential GPS and INS. A completely automated procedural software system has been built up for airborne application. It makes use of a set of systematically pre-processed image, orientation and calibration data (Wewel & Scholten 1999).

Since the first airborne experiments (May 1997), the HRSC-A system has been used for a variety of different applications. Simultaneous high resolution multispectral orthoimages and DEM data have been acquired for applications as different as volcano monitoring, mapping of urban areas (Hoffmann & Lehmann 2000), for applications in the fields of forestry and agriculture, mapping of flood hazards, of open coal mines and of coastal zones. The potential of the HRSC-A system for photogrammetric surveys in urban areas has been shown in its operational use at several european cities (Renouard & Lehmann 1999). Specifically, the availability of five stereo observation angles is beneficial for the measurement of man-made objects typically including steep surface discontinuities (Neukum 1999).

5 NEW METHODS

During the last decade GIS has proven to be an indispensable tool. However, GIS is dependent on accurate and up-to-date data sets. There is a strong demand for a quick, cost-efficiently, reliable and automated updating. Remote sensing data is an important data source for the updating of GIS databases. Some methodical obstacles are preventing extensive automatic processing: The problem of extracting information directly from remotely sensed data is not solved yet. There are no systematic methods for image fusion or data fusion for different applications in an operational way (combining existing data sets with GIS database, e.g. cadastral or landscape model data).

For this research a beta version of the software package eCognition was used (the software will be introduced to the market this year). The software for object-oriented and multi-scale image analysis was developed by Delphi2 Creative Technologies, Munich. The procedure is based on the so called 'Fractal Net Evolution' approach which is a method to describe complex semantics within largely self constructing and dynamic networks. Basic part is a new patented technique for object segmentation. It extracts image object-primitives in arbitrary resolution into fine or coarse structures. Important semantic information necessary to interpret an image is mostly not represented in single pixels but in meaningful image objects and their mutual relations. Beyond the pure spectral information, image-objects are characterised by a number of additional features such as texture and form which can hardly be exploited using pixel-based approaches. This technique has been adapted to find image objects in textured data, such as SAR images, high-resolution satellite imagery, airborne data or medical images (Baatz & Schäpe 1999). The algorithms used for segmentation are not published yet. The classification strategy consists of three main points: **Object orientation, representation** of the image information in different scales simultaneously and **description, processing and analysis** of image information by means of semantic networks.

The procedure contains two basic domains. The strategy is to build up a hierarchical network of image objects which allows to represent the image information content at different resolutions (scales) simultaneously. Each image contains different semantic levels in the same time. By operating on the relations between networked objects, it is possible to classify local object context information. In a second step the image objects will be classified by means of fuzzy logic, either on features of objects and/or on relations between networked objects operating on the semantic network. The programme works on an arbitrary number of channels and allows the treatment of arbitrary data types simultaneously, e.g. different resolution, GIS-layer, elevation etc. It can also be used to extract and export image objects for GIS applications in vectorised form (Baatz & Schäpe 1999).

6 DETECTING HOUSES: AN APPROACH WITH ECOGNITION

6.1 Available data

The HRSC-A data set of the city Nijmegen was acquired at November 4th 1999 around noon. Flight altitude was 3000 m, pixel size of the nadir image: 15 cm. For this approach the multispectral data and the DSM were used, the data sets were resampled to the original resolution of the DSM of 50 cm. The vector data set of Top Dienste is from 1998, available as e00 file. It was converted from vector to raster format, the resolution of the image data is 50 cm.

6.2 Approach for detection of houses

The approach consists of four parts: Multiresolution segmentation of the image, dividing the image in high and low areas, dividing high areas in buildings and areas other than buildings (vegetation) and finally combining the rasterised vector data set with the classified image extracting areas with new houses. The basic information for interpretation was

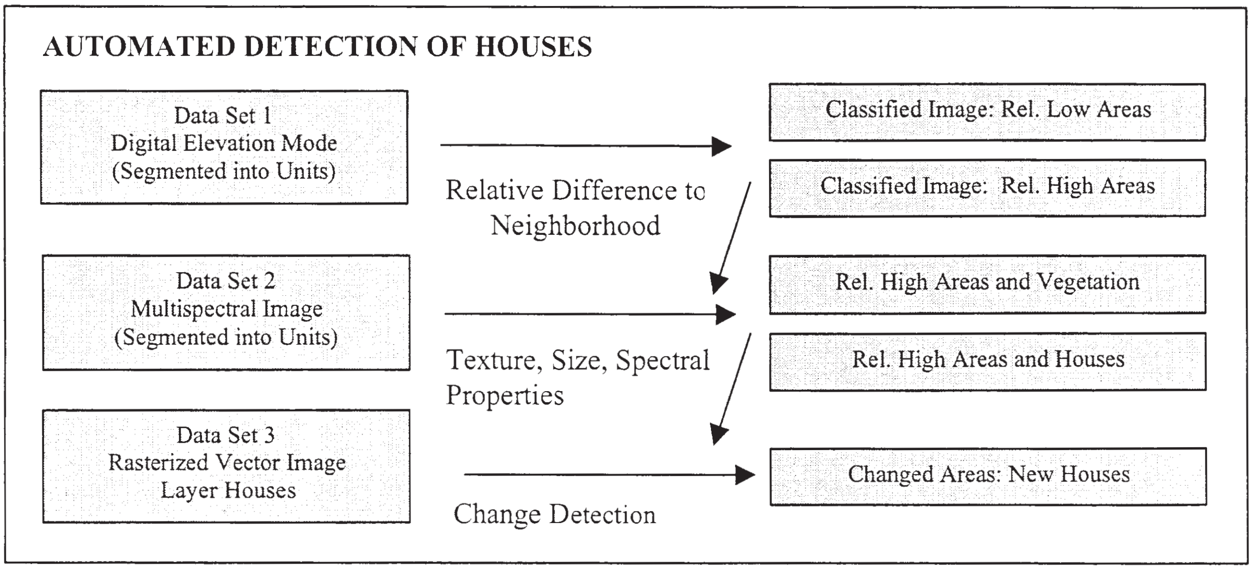

Figure 2: Strategy for automated detection of houses

supplied by the Digital Surface Model. For this approach three properties of houses were used: They are higher than the surrounding areas, they have a minimal and maximal size, and they generally have a homogeneous texture (compared with vegetation) (Figure 2).

6.2.1 Multiresolution Segmentation and hierarchical network of image objects

A basic part of the procedure is an object segmentation which is able to find image objects in any chosen resolution (fine or coarse structures). The algorithm is based on the assumption that image objects are characterised by colour and spatial continuity. The hierarchical structure represents the information of the image data in different resolutions simultaneously. Each object 'knows' its context, its neighbourhood and its sub-objects. Thus, it is possible to define relations between objects, e.g. 'relative border length to other classes' and use this additional context information for classification (Baatz & Schäpe 1999).

The size of image objects is defined using the "object scale parameter" that determines the object resolution, for segmentation all or single bands can be used. In order to reduce processing time, in first tries only the DSM was used for segmentation. The geometry of houses was unsatisfying then. Thus a combination of DSM and nadir image was used, showing much better results (Figure 3).

Figure 3: Result of segmentation: original nadir data set (left, resolution: 50 cm), and segmented image (right).

6.2.2 Definition of classes, Classification of Image Objects

6.2.2.1 Dividing the image in high and low areas

ECognition allows a knowledge-based classification, using a set of rules, including spectral and textural information, form, neighbourhoods, logical expressions and many more. Classification is done based on fuzzy logic. The advantage of fuzzy-logic is the possibility to integrate most different kinds of features and to connect them by means of (fuzzy-) logical operators. Thus complex class descriptions are possible. Compared to neural networks the advantage is a transparent and adaptable set of classification rules. Each single step of classification can be retraced for each image object in detail. The classificators used for the class descriptions are nearest neighbour or membership functions (Baatz & Schäpe 1999).

The data set was first divided in relatively high and relatively low areas. High objects are brighter than the surrounding (lower) areas in the DSM. This fact was used for interpretation. The DSM was classified, using the expression "mean difference to darker neighbours". A second parameter defined a minimal value of DSM.

6.2.2.2 Dividing between houses and other high objects

In a next classification step the detected high objects were divided in buildings and other high objects (generally vegetation). For this differentiation the different texture properties of vegetation and houses were defined. First tries using only the nadir image showed instable results. For non-urban areas it worked using just the nadir. The complex situation in urban areas required a more detailed information, provided by multispectral data sets. Another possibility to differentiate between vegetation and non-vegetation is using an additional channel with the result of the Normalised Difference Vegetation Index (NDVI).

6.2.2.3 Change Detection: Detecting New Houses

The next step combines the classification result for houses and the vector data set. Input Data was the rasterised Top10Vec and the classified Image (Houses). Both layers were compared in the next classification step, highlighting only the new houses (Figure 4). This result can be exported and implemented into the vector data set.

Figure 4: Nadir image with rasterised vector data set (white) (left) and house detection (white: houses in the vector data set, light grey: low areas, dark: new houses, dark grey: low classification probability (shadows)

7 DISCUSSION OF RESULTS , PROBLEMS AND LIMITATIONS

The combination of high resolution imagery, high resolution elevation information and a new object-oriented approach showed very promising results for automated updating of data sets. All houses of the test area could be found, using the spectral, geometric and textural properties of the image objects. Due to the fact that only few parameters were used, the approach proved to be stable.

The automated determination of image objects is a powerful tool, delivering polygons of units that can be exported as vector layers, no digitising process is required. Another advantage is the classification in different scales, although the segmentation might lead to coarse structures and huge image objects, the high resolution of the original data is still available for interpretation.

The quality of the classification and the proposed approach mainly depends on the quality of the Digital Surface Model. This DSM is the result of a matching process, the resolving data file is a 16 bit file. The resolution of DSM generally is 50 cm in x and y and 10 cm in z, the acquired area can be depicted in more than 32000 steps à 10 cm. This allows modelling of maximal 3200 m of elevation difference, a sufficient range for most parts of the world. The beta version of eCognition requires 8bit-data. The signed 16-bit files of DSM have to be reduced to 256 grey values. This is a limitation for interpretation, especially in areas with big relief differences. Information is reduced and important relief differences are smoothed, thus complicating the interpretation. This information loss has consequences even in relatively flat areas like The Netherlands. The way of reducing the data sets to 8 bit has to be improved. Another limitation is the difficulty to process precise DSMs in urban areas, especially in zones with narrow streets and in shady areas. Using the DSM for object segmentation is like generalising the image, e.g. single houses often are combined to house units, especially if there is only small space between them, fine structures might disappear.

There are limitations detecting low houses due to the low "mean difference to darker neighbours". And it might be difficult to detect high houses that are surrounded by high vegetation. Depending on the accuracy of the segmentation the exact shape of houses was not always depicted. Huge buildings that were segmented in many units were difficult to extract because the parameter "mean difference to darker neighbours" does not detect these areas, additional parameters (relative border to houses e.g., plus high absolute DEM-Value) have to be found.

A serious limitation for an automated updating of the vector data sets is the misfit of vector and image data due to the different geometry (different bases: the vector data set derived from interpretation of aerial photos, geometric properties are different, based on a Digital Surface Model). The house vector data set shows different geometric positions than the found houses in the image data. Only for some parts automated monitoring is possible.

8 CONCLUSION

The combination of the new approach of eCognition (multi-resolution segmentation, hierarchical networks) and the multispectral high resolution data of HRSC-A with its accurate Digital Surface Model shows very promising results and is an important step towards the integration of remote sensing and GIS, showing an operational way for interpretation of high-resolution data.
Detection of single houses was possible using the elevation and spectral information supplied by the sensor. The camera data has important advantages compared with aerial photographs, especially in depicting the real geometric locations of houses. The approach will be tested for huge heterogeneous urban areas in order to develop a stable classification and updating strategy. All steps of image analysis can be recorded as a complete procedure. Thus, the whole strategy for solving a particular problem can be applied to other data of the same type.

An automated updating procedure requires data with the same geometric properties. The future task will be to adjust the data sources (multitemporal vector and image data) using high resolution imagery in order to enable an automated process.

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