Acquisition and Updating of ATKIS using Satellite Remote Sensing Imagery

Christian Heipke, Sabine Beutner, Bernd-Michael Straub, Helge Wegmann, Christian Wiedemann*
Institute for Photogrammetry and Engineering Surveys, University of Hanover
***Chair for Photogrammetry and Remote Sensing, Technische Universität München**
heipke@ipi.uni-hannover.de, straub@ipi.uni-hannover.de, beutner@ ipi.uni-hannover.de, wegmann@ipi.uni-hannover.de, wied@photo.verm.tu-muenchen.de

ABSTRACT

Remote sensing is one of the workhorses of topographic and thematic mapping of large areas of the Earth surface and is a prime data source for the acquisition and updating of topographic geo-data at small scales. Satellite imagery of a sub-meter ground resolution in the panchromatic channel, which has been announced for some time and will most probably be available in the near future, has the potential to be also useful in medium scale applications. Along with the better resolution a change of automatic image exploitation techniques from purely pixel-based multi-spectral classification to model-based image analysis, and an increasing integration with GIS (Geographic Information System) can be observed.

INTRODUCTION

In this paper we present recent work about the use of remote sensing imagery for the acquisition and update of the basis DLM (Digital Landscape Model) of the German ATKIS, the Authoritative Topographic-Cartographic Information System. ATKIS is a joint undertaking of the Working Committee of the Survey Administrations of the States of the Federal Republic of Germany (AdV). The basis DLM contains objects and related attributes traditionally represented in a map of scale 1:25 000, and at a geometric accuracy of about 3[m]. In ATKIS the surface of the earth is modelled with help of geometrical as well as thematic data. The Survey Administration of the states have the task to keep the database up to date [1].

In this context the use of space line scanners like MOMS-02 and IRS-1C/D for updating ATKIS offer the advantages of large covered area, multi-spectral data, and digital and therefore potentially fast and automatic data flow. The imagery used in the investigations comes from the German MOMS-02 camera mounted on the Russian space station MIR and the Indian Remote Sensing Satellite IRS-1C. Both, panchromatic and multi-spectral images were used. The following questions were approached:

- What is the information content of the remote sensing imagery in view of the ATKIS basis DLM object catalogue?
- Can basis DLM objects be automatically extracted from such images?
- Can data fusion, i.e. the integration of existing GIS data and the imagery be helpful in automatic image interpretation?

While the emphasise of the presented work lies in the investigation of the thematic information contained in the images, issues in connection with the geometric accuracy are out of the scope of this paper.

The work was carried out in three phases. First, we investigated the information content by visual inspection using panchromatic monoscopic imagery. The emphasise was on the detection and delineation of linear features (roads, railway lines, rivers etc.). In the next phase the task was to automatically extract road data from the imagery. In this phase only the road geometry and topology was of concern, road attributes were not searched for. In contrast to the first phase, the complete multispectral information was used. Finally, the remote sensing images were used in combination with GIS data for automatically updating and deriving additional information not contained in the GIS data. In the following chapters these three phases are described in more detail.

VISUAL INVESTIGATION OF THE INFORMATION CONTENT OF THE REMOTE SENSING IMAGERY

In a project with the State Survey of Lower Saxony ("Landesvermessung + Geobasisinformation Niedersachsen, LGN") we are evaluating the suitability of a manual updating of ATKIS basis DLM with IRS-1C image data. Updating of a GIS database such as the ATKIS basis DLM can be divided into the tasks of change detection, geometrical and semantic description of the changes, and their integration into the database.

Based on the experiences gained during the MOMS-02/D2-Mission, in which the cartographic potential of MOMS-02 image data was examined [4], it was decided to concentrate on a number of important topographic line objects only, and to investigate only the geometric data acquisition. The determination of feature attributes was out of scope of this study.

Two representative test areas, one in a rural area and one in the city of Hanover, were defined for this test. In the first area updating was carried out using the given DLM data superimposed onto the imagery, in the second area data capture was performed in isolation (i.e. without use of the DLM data).

The first test region lies in Lower Saxony near the city of Göttingen. Panchromatic image data of IRS-1C was used for the investigation of the information content in this area. The results of the relatively large test area (two sheets of the German topographic map 1:25000, corresponding to a size of about 245 [km²]) were compared to existing and up-to-date ATKIS data [3]. As expected, contrast had a major influence on the

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interpretation possibilities. In an area with poor contrast, for example densely built up areas, only approximately 50% of the linear ATKIS objects could be identified while in open terrain the rate was larger than 75%.

Two stereoscopic IRS-1C panchromatic images of the city of Hanover - more precisely the EXPO terrain - were used in the second test. Again, densely built up areas and open terrain were investigated. The images were recorded in December 1996 at a low sun angle, and in some parts they showed a thin snow cover. They constitute the only stereoscopic data set available for this study. Partly due to the unfavourable conditions during data acquisition, only about 55% of the linear ATKIS objects in the open terrain and even less in the built up areas could be identified from the image data in monoscopic mode. Stereoscopic data capture is still in progress at the time of working and is expected to increase the given numbers to some extent.

As for the investigated updating procedures it was observed that the updating task with superimposed GIS data (Göttingen) was somewhat easier than data acquisition in isolation (EXPO), because the context given by the GIS data was often helpful for identifying and delineating objects which otherwise would have been undetectable.

AUTOMATIC EXTRACTION OF ROADS

In this section an approach is presented for the automatic extraction and evaluation of road networks from MOMS-2P imagery [6, 8]. Due to the limited ground resolution of traditional satellite images a road model purely based on local characteristics is rather weak. Therefore, a significant number of false alarms are to be expected. For this reason, the road network is also considered, and regional, and global properties are incorporated into the object space model:

Locally, radiometric properties play the major role. The road is modeled as a line. It can have a higher or lower reflectance than the surroundings.

Geometry is explicitly introduced on the regional level. Regional characteristics incorporate the assumption that roads are composed of long, straight, and horizontal segments. Globally, roads are described in terms of topology: the road segments form a network, in which all segments are topologically linked to each other.

It should be noted that the appearance of roads in the various channels of the multi-spectral images may deviate from the object space model, e.g., due to different contrast of the images, occlusions, shadows, or aliasing effects. Also, roads in different parts of the world exhibit different characteristics. The notion of straightness, for example, is more pronounced in a road in Australia than in Central Europe.

The extraction strategy is derived from the model and is composed of different steps. After line extraction according to [5] postprocessing of the lines is performed with three different tasks in mind: (1) Increase the probability that lines either completely correspond to roads or to linear structures not being roads. (2) Fuse lines extracted from different images. (3) Prepare lines for the generation of junctions. Then a weighted graph is constructed from the lines and the gaps between them. The weights are derived from local (radiometric) and regional (geometric) criteria. Road network generation is carried out by calculation of „best paths“ between various pairs of points which are assumed to lie on the road network with high probability. In this way, global topological information is introduced into the extraction process.

The evaluation of the extraction results is carried out by comparison to manually derived reference networks [7]. In open rural areas depending on the complexity of the landscape about 60%-80% of the existing roads could be detected, and about 95% of the extracted structures were indeed roads (see [6] for details).

USE OF GIS DATA TO SUPPORT AUTOMATIC IMAGE INTERPRETATION

This chapter describes a procedure for the automatic extraction of vegetation areas from satellite imagery for updating possibly outdated DLM objects. An existing DLM – the ATKIS basis DLM – is used to support automatic object extraction from the imagery. The procedure is subdivided in two major tasks, the extraction of the thematic information from multi-spectral imagery and the extraction of the refined object boundaries from panchromatic imagery of higher resolution.

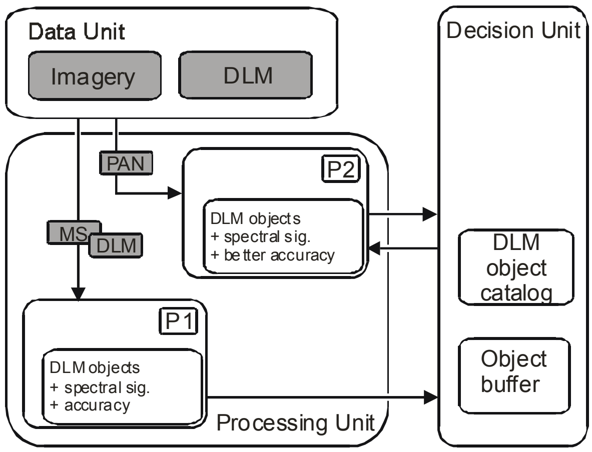

Fig. 1: Data and data flow for object extraction

Fig.1, gives an overview of the used data and the data flow for updating of an existing DLM. The approach encloses three major parts for extracting objects from imagery with different geometric and radiometric resolutions: (1) a data unit with images and existing DLM objects, (2) a processing unit with processes for automatic feature extraction from the images and (3) a decision unit containing the definitions of the DLM objects and an object buffer. The object buffer is used to temporarily store objects which have additional attributes in comparison to the ATKIS basis DLM objects. Two different processes – labelled with P1 and P2 in Fig.1 - were used to extract vegetation objects from multi-spectral and panchromatic imagery from IRS-1C.

The first process P1 carries out a supervised multi-spectral classification followed by an intersection of the results with the DLM vegetation objects. The input for P1 were the multi-spectral image and all vegetation DLM objects from the data unit. The vegetation objects were used to split the image into two different regions depending on the ATKIS feature classes *arable land* and *grassland* as one region and *wood* as the other region. The result of cluster analysis in these subsets are several spectral signatures - according to the appearance of the objects in the real world in the imagery - with a known relation to the ATKIS feature classes. These spectral signatures were used to classify all non-sealed areas in the original image. Afterwards the result is vectorized and intersected with the ATKIS data. All lines in the vectorized image which have a corresponding line in the DLM were replaced by the ATKIS lines because the geometric accuracy of ATKIS is better. Many of the original ATKIS basis DLM objects are split into several new DLM objects with different spectral signatures. These new objects have two additional attributes, the *spectral signature* – calculated in the classification process - and the *geometric accuracy* – depending on the ground resolution of the imagery and image processing. The new objects were temporally stored in the object buffer of the decision unit.

P2 extracts refined object boundaries from the panchromatic imagery and the DLM objects in the temporary object buffer. The boundaries of these DLM objects were extracted with a higher accuracy, because the panchromatic image has a higher geometric resolution than the multi-spectral image. The boundaries of the temporary DLM objects – calculated in P1 - are used as approximations for extracting the position and direction of edges in the panchromatic image. Afterwards the extracted edges are transformed to the vector format. Finally, the boundaries of the DLM objects extracted from the multi-spectral images and not contained in the ATKIS basis DLM were overwritten by the lines extracted from the panchromatic image and sent back to the decision unit for updating the DLM.

The prior-information contained in the DLM was applied in two different ways, (1) calculating the appearance of vegetation in the satellite imagery and (2) adjusting the borderlines of the extracted vegetation objects. In the described study the integration of ATKIS data into automatic image interpretation was useful to focus the object extraction on parts of the scene with the intention to reduce the ambiguity inherent in the results of local image processing. First applications of the presented procedure confirm its efficiency, details are given in [2].

CONCLUSIONS

In summary, the investigated remote sensing imagery was adequate in extracting some of the basis DLM objects for ATKIS, but a higher resolution seems indispensable for a more detailed and complete data capture across different object classes. While automation was shown to yield good results in some cases, automatic procedures in general were found to need an even higher resolution than a human operator. To this end the upcoming high resolution satellite images carry a lot of hope. In any case, they will prove to be a rich source of information for the acquisition and update of geo-data for less demanding GIS than ATKIS. In order to fully exploit the information content of the imagery data fusion concepts combining image and GIS data are strongly recommended.

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