SEMI-AUTOMATIC OPEN SOURCE GEOPROCESSING FOR CHANGE-DETECTION IN FEDERAL GEODATA

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ABSTRACT

This project addresses the vast complexity of keeping federal geodata up to date according to the official regulations. Cooperating with the Hessian state agency for land management and geoinformation (Hessisches Landesamt für Bodenmanagement und Geoinformation - HLBG) concepts and solutions have been developed in a two-year project. It is supposed to enhance the efficiency of the geodata update processes within state agencies.

With the help of the concept of change detection datasets are supposed to be updated. The aim of the project is to provide a thematic layer of change indicators for the staff dealing with updating datasets. To assess the feasibility of this approach in a federal agency surrounding two exemplary datasets were defined. The long-term goal is to use semi-automatic change detection processes for increasing numbers of datasets within the agency.

Lake boundaries as well as relevant (meaning: above a Δz-threshold defined by the agency) elevation changes were processed. Light detection and ranging DEM (Lidar) is supposed to be kept up to date without subsequent flights. This paper describes the process of updating the lake boundaries.

According to the needs of the state agency processing rule sets (e.g. accuracy tolerances or minimum area size) were developed. The rule sets were then implemented using the Python programming language to create geoprocessing scripts as post-processing algorithms for raster database queries, which can tackle the data amount for Hesse with its ~21,000 km².

This paper presents the methods which are being used to detect objects and derive features to be used in the process of change detection. Due to the high topicality of the oriented aerial images their derivatives (photogrammetric point clouds, orthophotos) serve as the core element for the detection of change features in the more recent epoch.

INTRODUCTION

Change detection is an inherent part of the day-to-day business in a state agency which is responsible for the whole federal geo-database. Our environment is a very dynamic entity which will never stop changing. Changes occur either due to environmental influences (e.g. erosion or landslides) or man-made changes (e.g. construction sites). Therefore, the update process of a geo-database is a continuous workflow. The update cycle standards were defined by the 'Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany' (AdV) in an additional document (1) to their GeoInfoDok (2) which describes the modelling of geoinformation for the state agencies.

Until now, the change-detection process, in order to keep the data up to date, has been done by a manual comparison of aerial imagery and vector data in a GIS. This process is very time consuming and requires a lot of resources.

This work addresses the issue of developing a more efficient update process. In recent years, a lot of methods and algorithms for image classification and change detection were developed (3,4). Even complex hierarchies (e.g., 5) could be handled with Object Based Image Analysis (OBIA).

DOI: 10.12760/02-2014-1-16

However, fully automated analyses would not deliver the desired results, as the thematic data is very complex and demands human interpretation (especially datasets defining land use not land cover). As a consequence, the proposed methodology works in two steps.

After an automated image analysis possible changes are marked in a vector layer (see subchapter 'Object Extraction'). Those possible changes have to be evaluated manually by a GIS operator. Keeping in mind that the federal state of Hesse has an area of ~21,000 km², a 'change-indicator' layer used in a GIS, significantly decreases the time consumption as compared to a manual check of a statewide data basis. The 'change-indicator' vector layer contains polygons describing areas which have – according to the automatic process – changed between the two epochs. The role of the GIS operator switches therefore from manual change detection to assessing the relevance and validity of the automatically detected 'change-indicators'.

The change detection process is implemented as an automated script in a virtual environment based on a Linux distribution. As a result, thematic datasets (raster/vector) are produced as the 'change-indicator' layer.

Detecting water from imagery is a classic task in remote sensing (6,7,8). Therefore, this paper describes the process of updating the lake boundaries (called 'inland water' below).

METHODS

Changes in the above-described use case 'inland water' were detected using the following described data sources and methodologies.

Data

The whole approach is based on the input data described in Table 1. The ortho-imagery is produced by a contractor for the federal agency. Therefore, atmospheric and radiometric corrections have already been applied so that no further corrections were necessary.

Table 1: Geodata used in the project

Data Product	Resolution / Scale	Data Type
Digital Orthophoto (RGBI) (august 2012)	20 cm (resampled to 1 m)	raster
Topographic Land Use Data - standing water - *sport leisure and recreation area* - *flowing water* - *industrial and commercial area* - *residential area* - *combined use area* - *area with special functional characteristic*	1:10,000 – 1:25,000	vector

The test subset is a region situated in the southwest of Frankfurt am Main near the city of Rüsselsheim. It covers the area of one map sheet of the TK25 map (topographic map to a scale of 1:25,000). Therefore, the test-area extent is ~130 km².

The land use data printed in italics is used to enhance the result of the whole classification process by excluding those areas for being unable to contain 'inland water' whereas the dataset 'standing water' is the one being assessed in the process as it contains the lakes.

Object Extraction

The object extraction is a classic application of OBIA. The OBIA emerged when the spatial resolutions of imagery increased and contextual information had to be taken into account to identify objects (4). Through combination of spectrally similar pixels (based on user-defined threshold parameters) larger vector objects (segments) are being created (image segmentation (9)) in order to reduce complexity of the scene. Those segments enable polygon attribute derivatives (e.g. area, perimeter, centroid [...]) to be utilized, which can then be used in the further process.

Within this approach, the connected component algorithm, implemented in the OTB library, was used to extract the object geometries. The results are created within a classification-based change detection, implemented as a check against the federal data.

The proposed change detection algorithm for ‘inland water’ consists of the following four steps:

1. Detection of water bodies (lake/pond)

   The digital ortho-imagery provides four channels. The bands in the green and near infrared are used to estimate the Normalized Difference Water Index (*NDWI*) (10):

$$NDWI = \frac{GREEN - NIR}{GREEN + NIR}$$

   The *NDWI* has a range of [-1,1]. Due to the fraction in this index it is not sensitive to the pixels’ intensity.

   A threshold on the *NDWI* and the Digital Number (DN) in the infrared channel is used to mask out all areas which are supposedly not water. This process of elimination leaves then only the pixels which are possibly water. Vector-based segments are then produced based on those remaining pixels.

2. Deriving the raster-based difference dataset

   The remaining image segments are classified as ‘inland water’ and compared to the federal data set of the Official Topographic Cartographic Information System (ATKIS).

3. Application of minimal size threshold

   Due to the data modelling guidelines in federal topographic data sets, a minimum size of the image object’s area (segment size) is used to reject small objects in the further processing (e.g. minimum lake area threshold of 1,000 m²).

4. Application of accuracy thresholds

   The agencies data models imply certain thresholds which define changes as relevant. For example, all changes of coastlines are rejected, where the new coastline is within a 7.5 m buffer of the coastline in the reference dataset. The relevance in this case is defined as a coastline change of more than 7.5 m. The threshold of relevance for the size of the changed ‘inland water’ is 1,000 m². The change of a lake is relevant when the coastline changes by more than 7.5 m and the remaining changed area is >1,000 m².

   This leads to the smaller ‘change-indicator’ in the figures below as compared to the corresponding federal dataset (7.5 m buffer).

The crucial information within this step is the definition of relevance and its implementation within the change dataset. Depending on the task or possibly changing regulations in the future, those thresholds defining the relevance can be adjusted by the agency.

RESULTS

Figure 1 shows the result of a change detection operation. The left subfigure shows the case of a silt up quarry pond. Active quarry ponds are by nature dynamic bodies of water whose shape can change extensively within a short period of time. Therefore, those types of bodies of water are the most frequently addressed ones in this process. The right subfigure shows the opposite case. Here, a new quarry pond that has recently been created is not at all contained within the data.

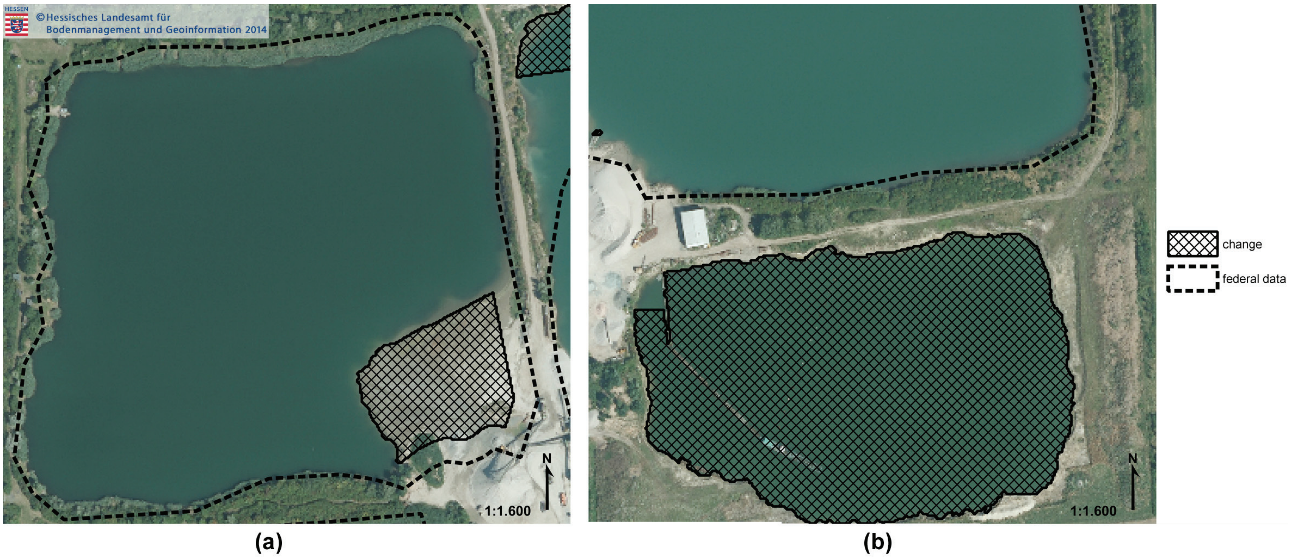

Figure 1: The two different types of changes which can occur. (a) silt up quarry pond; (b) quarry pond, which is not present in the federal database.

The challenge of the process is the need for universality. The parameters of the water detection step have to be very robust, as they should apply to every orthophoto tile which is processed. That is why incorrect detections appear frequently, so-called 'over-detections'. To address the problem of the overmuch detected areas then, exclusion areas (which exclude the existence of a large body of water by data modelling conventions, see Table 1) are being used to eliminate the incorrect detections.

The most frequent problem solved by this approach is the classic situation of large industry buildings the shadows of which are detected as water (11).

The second problematic situation is the case of overshadowed lakes (see Figure 2) in forests or very shallow water with a high amount of vegetation in/on the water. In this case, the geometry in the federal data fits reality. However, a change was detected as the process did not detect water in imagery, but had a reference in the federal data. The resulting delta was detected as a relevant change.

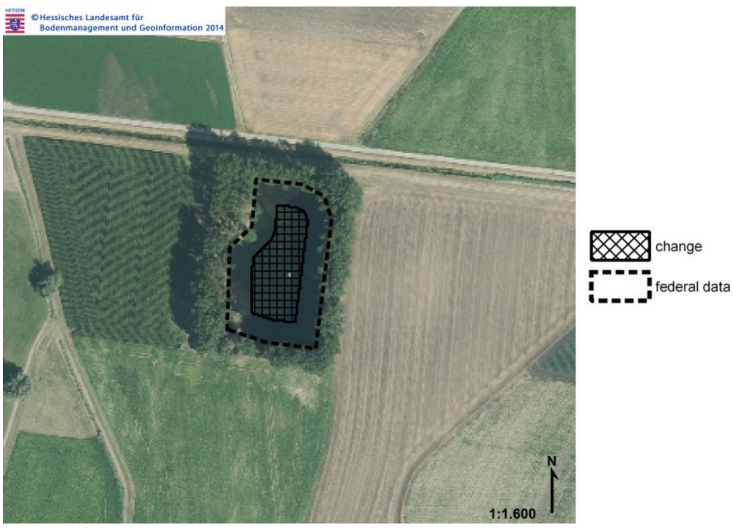

Figure 2: Overshadowed body of water falsely detected as change.

Water detection for overshadowed lakes and lakes with a high share of vegetation in the water (spectral signatures differ a lot from water) is not possible in this process and will therefore lead to misclassifications.

Extrapolation of the processing times for test areas of the first thematic datasets resulted in reasonable processing times (<6 h) for the whole federal state of Hesse. Therefore further studies are supposed to be conducted as the project is extended.

CONCLUSION

The feedback from the two departments within HLBG points out the usability of the delivered output data. Despite of still existing false detections the quality of the output is more than sufficient to act as an indicator of changes. Cartographic engineers could now use the change-indicator map during their data revision.

However, the major challenge remains to tackle the heterogeneity of the imagery data. Thresholds developed for the current data might not be applicable in future, as the sensors or the contractors who deliver the imagery change and therefore the radiometric attributes of the data might differ. The matter of seasonal dependencies of the results could not be addressed yet. The flights are usually performed during the summer months (mostly August). The effect of the variance within that timespan on the thresholds has to be part of future research.

This approach can be transferred to any feature detectable in ortho-imagery (e.g. forest, grassland […]). Due to its variability the processing framework is currently being adapted to be used in an elevation-model change detection approach, which means a very different input data pool.

ACKNOWLEDGEMENTS

We would like to thank the Hessian State Agency for Land Management and Geoinformation (Hessisches Landesamt für Bodenmanagement und Geoinformation – HLBG) who fully funded this project financially and provided all the different sources of geodata which were used during the project. We would like to express our special thanks to Gerd Köhler, Carsten Dorn, Christian Rzeznik (Department of Photogrammetry and 3D Geodata) as well as to Heike Bender (Department of Topography) for substantial support.

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