Case study on operational object-oriented image analysis for Land Cover classification in security and emergency application

A case example for ESA-EUSC-JRC Image Information Mining workshop 2009

Brodsky, L., Kolomaznik, J., Bartalos, T.
GISAT, Prague, Czech Republic

Abstract

The aim of this work is to demonstrate current status of the operational object-oriented Land Cover / Land Use classification and specific feature extraction. The focus is put on the automation of the processing chain, while keeping standard level of product quality common to the operational EU activities in the field of security and emergency. The so-called product “standards” are non-formal product specifications common to GMES Services as for instance applied in RESPOND project (Supporting Humanitarian Relief, Disaster Reduction & Reconstruction) supported by ESA.

Semi-automated Object-Oriented Image Analysis is applied by means of developed fuzzy rule set to the case study very high resolution satellite image (Reference Data Set). Results are presented as a data set as well as map sheet ready to print for the end user. The Land Cover database with specific extracted features is validated by visual interpretation.

The classification nomenclature is defined according to a visual inspection of the image, the general guidelines sent together with the image and experiences from other security and emergency products. The results of the work prove operational use of the object-oriented image analysis but also identified some weaker points in the processing chain. Improvements are expected in for instance detection of linear features or object shape generalization algorithms.

Introduction

GEOBIA (GEO-Object-Based Image Analysis) principals are dynamically evolving methods and tools in the last 10 years being applied widely to the Earth Observation images for various purposes. The increasing number of scientific papers (e.g. Definiens compilation at earth.definiens.com) documents well the progress and limits in the application.

The developed methods and tools are applied in a way that replicate human interpretation of RS images in automated / semi-automated ways that result in increased repeatability and production, while reducing subjectivity, labour and time costs.

The security and emergency applications based on the Earth Observation image analysis is one very specific field of Remote Sensing. The user requirements might vary application to application but one of the mutual features is time response. Quick product delivery to the user is an essential requirement. This leads to the use of fully automated or semi-automated image analysis. The product quality and content is not less important. The user requirements and product definitions are decisive for the selection of appropriate image analysis and development of the processing chain. Combination of high time response, product content and high quality of the provided information leads to the need of flexible, robust, fully automated or semi-automated image processing tools (or Image Information Mining tools) applicable to various image data inputs and various information / features to be extracted.

Some of the required features to be extracted are rather a challenge for automated approaches. Frequency occurrence of such features is important information for trade-off

between development of fully automated procedure and visual interpretation with object labelling.
The objective of this case study paper is to demonstrate the operational semi-automated object-oriented Land Cover / Land Use classification and specific feature extraction.

Material and methods

The data provided for this case study consists of multi-spectral very high resolution Quick-Bird image together with panchromatic channel (Reference Data Set). Pan-sharpened image was also included but only with the first three (RGB) channels. In addition, the Global Aster DEM was utilized as an ancillary data source (for terrain topography, contour and stream network generation).
As there was not strict definition of the case study product including classification nomenclature, the selection of classes was done by a visual inspection of the image, the general guidelines sent together with the images and experiences from other security and emergency products.

<u>The selected classification nomenclature:</u>

1. **Artificial (non military areas)**
    a. Built up areas (building blocks)
        i. Damaged
        ii. Not damaged
    b. Urban green
        i. Gardens (backyards with mixed vegetation)
        ii. Grassland and commons (sparsely vegetated areas, cemeteries)
        iii. Parks (with high vegetation)
    c. Roads
        i. Bitumen roads
        ii. Consolidated / dirt roads
        iii. Path / trail
    d. Airport
    e. Construction sites
    f. Mines
    g. Dump sites
    h. Pipelines
2. **Military objects**
    a. Military areas
    b. Trenches
3. **Agricultural areas**
    a. Large and small fields, grassland fields
    b. Small vegetation landscape units (between fields)
4. **Bare soil areas** (not cultivated fields)
5. **Forest**
    a. Evergreen forest
    b. Deciduous forest
    c. Transitional woodland
6. **Water**
    a. River
    b. Lake

c. Canal

7. **Flooded area**

The processing chain consisted of these main steps:

a/ image pre-processing
b/ image segmentation
c/ basic land cover classes detection
d/ segmentation – main land cover classes detection
e/ specific features extraction
f/ post-classification generalization
g/ GIS pos-classification analysis and feature detection
h/ visual inspection

The pre-processing image steps consisted of new pan-sharpening (Zhang and Yun. 2002) that includes NIR channel in the resulting image (figure 1). Next, texture analysis was performed. Mainly first order texture indices at pixel level were derived for detection of artificial classes (figure 2).

Figure 1.: Pan-sharpened image including NIR channel

Beside that, visual interpretation was employed to derive the road network in the pre-processing stage. This step was done by manual editing as this component of the land cover has high importance in the product and current evaluated methods does not give sufficient quality. Several approaches of automatic or semi-automatic were tested but did not provide reasonable result. The tested approaches included: semi-automatic so-called intelligent digitizer, feature object tool (FOX) implemented in COTS software and also fuzzy snake methodology. Improvement of methods and tools for linear feature extraction is needed. Next, main land cover classes were classified by means of contextual as well as spectro-textural classification rule ware. Semantic grouping is an important feature of the applied procedure.

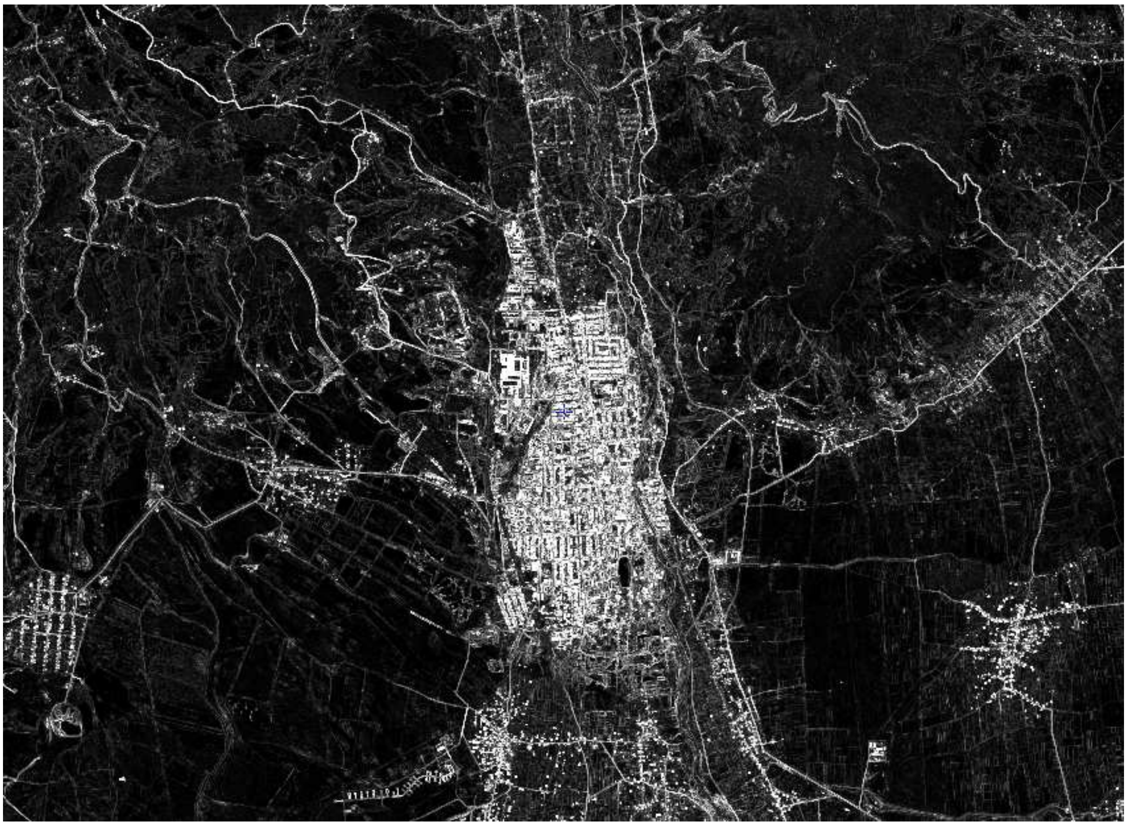

Figure 2.: Example of texture analysis (standard deviation)

Next steps (b/ to f/) were done solely in the Definiens Developer environment (version 7). Image pre-segmatation in the whole process included several main segmentation procedure including simply chessboard segmentation as well as multi-resolutional segmentation (Region Growing Algorithm). Basic land cover classes were detected by means of spectral and textural features computed at pixel or object level. Fuzzy rule set with sequential approach was used.
Specific features extraction, as for example destroyed buildings or linear vegetation landscape units were done after the main land cover classes were fully classified as background layer. Segmentation at lower spatial layer was necessary. Fuzzy rule set with spectral, textural and contextual approach was applied.

Post-classification step consisted of size and shape generalization. Size generalization is simply applied by analysis of object area and its contextual features. Shape generalization was processed by means of mathematical morphology technique.

GIS post-classification analysis and feature detection was applied to detect specific features by means of DEM and land cover classes. At first, attempt to extract road network was performed. The approach comes up more or less from so called fuzzy snake methodology. The extraction was based on approach utilizing both optical and textural bands as an input into unsupervised ISOCLUSTER classification. The textural band selected included standard deviation, mean and kurtosis, all both for blue and green band. As an inverse classification mask was used a layer of buildings classified previously in Definiens. Subsequently, the clusters corresponding to the road surfaces were manually selected on top of the imagery and served as an input into automatic vectorization realized in ESRI ArcScan toolbox. Prior to the automatic extraction of vectors clean-up of input raster had to be carried out and proper vectorization parameters had to be set up. The roads extracted must be viewed as semi-product which requires further manual editing to remove spackles and false road lines, connect dangling lines and complete missing segments. On the other hand, they may serve as a valuable baseline for further vectorization since they copy the feature shapes reliably and contain information on width of the road, which is derived during the process by ArcScan.

Low resolution Global ASTER DEM (30m GSD) was used as a source for terrain analysis. As a result, topographic contours with 20m spacing and stream network were derived automatically using standard functionality in ArcGIS. It was necessary to employ further manual post-processing of obtained features and in case of contours also line smoothing to ensure proper placement and acceptable cartographic look-and-feel representation.

Quick and simple method of detection of stream crossings is based on GIS intersection of road network and stream network feature classes. Manually extracted road network was employed in this step to improve the confidence of the result. By this mean locations of bridges / fords were detected. Distinction between classes in the output layer and clean-up (addition or removal of false points) was done by interpretation for each resulting point.

Results and Discussion

The result of the Land Cover / Land Use classification and specific feature extraction is presented as a vector data set (figure 4) and map product ready to be printed for the end user.

Rule based object-oriented classification approach applied to the very high resolution image proved to be effective way of Land Cover / Land Use classification and feature extraction. Definiens Cognition Network Technology enabled rapid classification knowledge-base development with some level of transferability to other cases. One of the main distinctions of this approach is that it emulates human cognitive processes, familiar to interpreters who extract information from the image.

The importance of scale object-based mapping is enhanced in case of very high resolution imagery. These images consist of large scale as well as small scale variations that have to be tackled at the same time.

The difficulties identified in the classification processing chain are described as follows: the extraction of road network by automated approach is rather problematic, especially in case of landscape that consist of fuzzy changes of the road types an unclear borders. The other linear features as for instance trenches can be identified but since these objects are mostly spectrally heterogeneous the shape of resulting object may be difficult to detect besides the fact that some parts of the class may be spatially disconnected. Most of these features were extracted in semi-automated way. First, potential objects were classified based on fuzzy rules including shape characteristics. Afterwards improper objects were unclassified by visual inspection on the segments level. This approach assures maintaining of segments' shapes as outputted during segmentation. Other classes like airport, commercial areas, parks, etc. appear in the image in a limited number of examples. These may be identified by automation approach but it is a question how effective it is to develop dedicated rule-ware if they are identified in the whole scene only as one or two examples.

An experiment in semi-automated road extraction was done (figure 3) as described above. Drawback of this approach lies in utilization of built-up mask. While it may radically increase the accuracy of the obtained road network inside urban areas, on the other hand the manually extracted roads had been made use for its generation considerably increasing its reliability here. Therefore, extraction process should be perceived as truly (semi-)automatic only outside of built-up areas. Nevertheless, it must be mentioned that if the reliable mask of buildings could be obtained without prior road delineation the method is quite promising then.

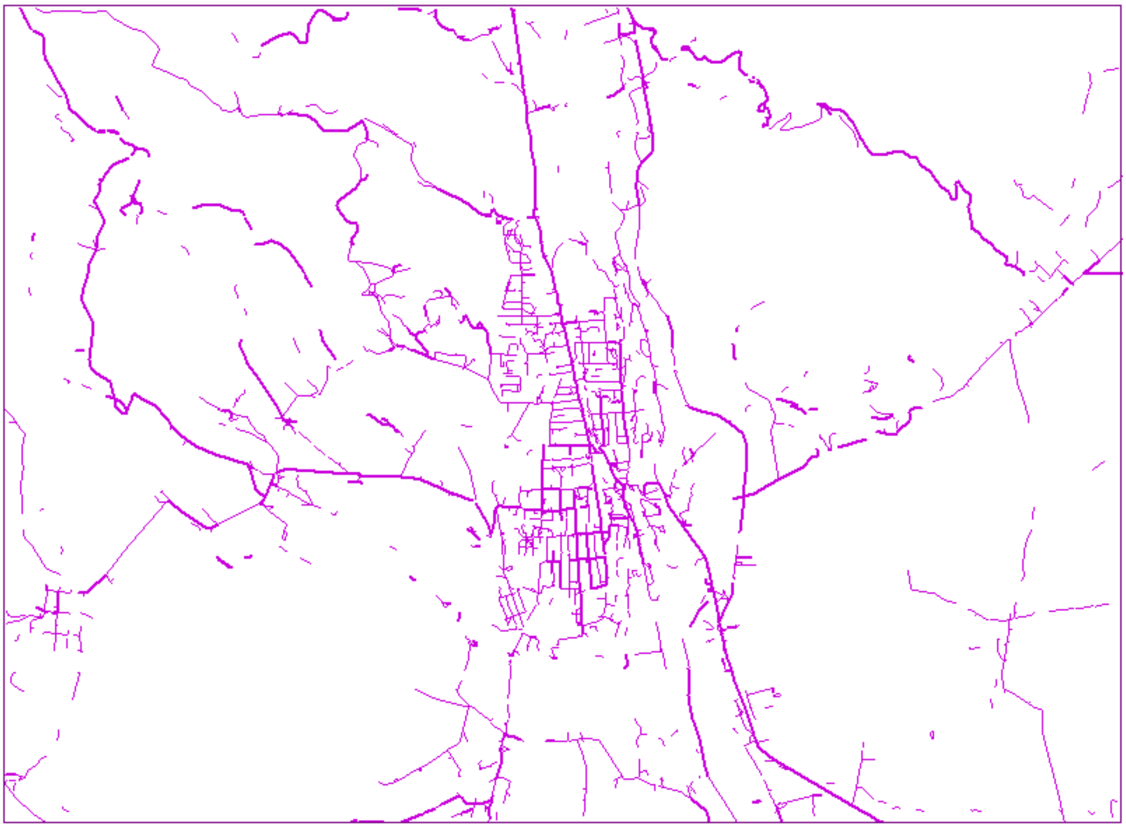

Figure 3.: Road network derived from the image derivatives by semi-automated manner

The second problematic topic of the object oriented image classification is performance in case of large very high resolution scenes. Performance of segmentation algorithm is a crucial point of the processing chain. Various segmentation algorithms exist with different computational complexity and demand. It is necessary to combine them in a purposive manner. Grid processing environment distributing the computation demand to different nodes may help, however other issues have to be tackled then.

Another issue for the discussion on potential improvements is the shape generalisation methods. Existing methods implement mathematical morphology algorithms (closing and opening) with possibility to define the structural element enabling great improvement of shape appearance of the final land cover objects, but has its limitations. Problematic might be linear features as roads or rivers that may be disconnected by the morphology approach. Other problematic classes are objects with complex shapes as for instance urban areas.

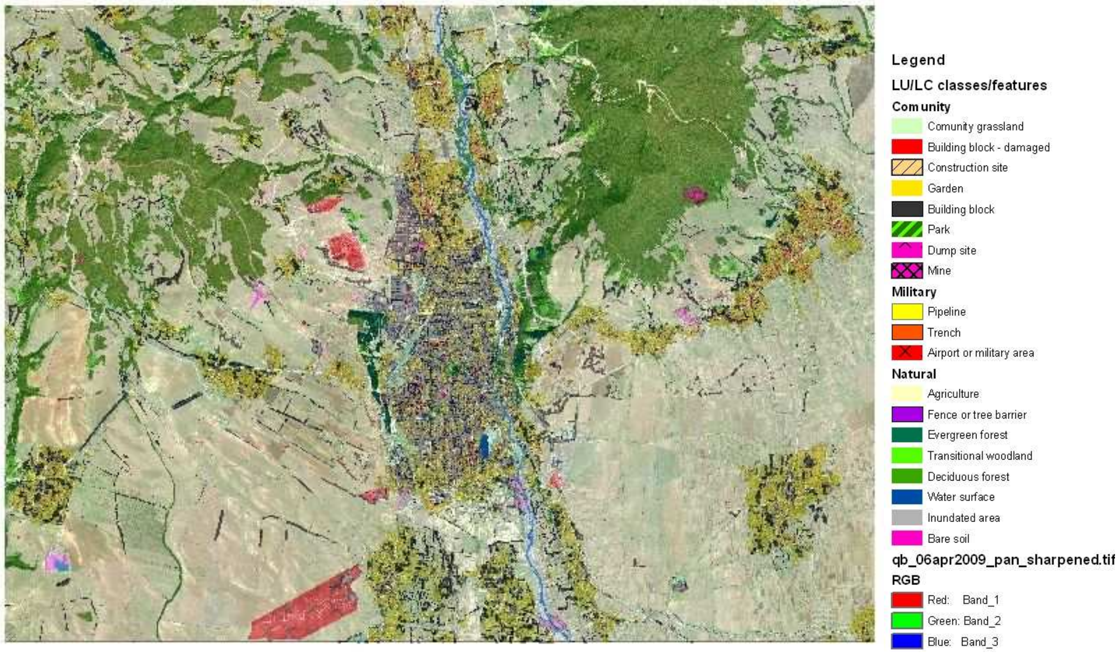

Figure 4.: Classification result of the Land Cover and Land Use database

Also terrain analysis and processing methods deserve brief discussion. Low resolution DEM is due to its resolution limited in both horizontal and vertical accuracy. As a result, this limitation transfers also on derived products. If the automatically obtained stream network is overlaid with the VHR imagery, various shifts are visible. Besides that, delineation of automatically obtained streamlines seem to be even less confident in flat areas, where the streams have been conducted from original channels into artificial ones, e.g. due to irrigation purposes. Streamlines may be corrected quite quickly manually utilizing the automatic output as a guiding skeleton. In case of wider flows such as rivers, which polygon outlines may be detected by means of classification, the correct location of flow axis is obtainable in GIS as a polygon centreline.
The problematic is enhancement of DEM, derived TIN or contours using updated stream network. If we wanted to update also thalwegs in DEM in sense of positional shift and elevation correction copying the longitudinal profile of updated streamlines, each stream would have to be segmented into minimal pieces holding the elevation information. This requires further processing including manual steps. Additional topographic source that might be utilized for creation of accurate terrain representation are topographic maps. In the Caucasus area the most reliable source is former Soviet Union topographic maps in scale 1:50,000 from 1970' and 1980', which among others contain comprehensive elevation information including height points and contour lines. Disadvantage of solution that utilizes scanned topo maps is limited capability of processing automation. On the other hand it is balanced by possibility of radical improvement of terrain representation.
Since the bridges feature class was obtained as an intersection of road and stream network, both results of manual editing, they are not coincident with stream and roads demonstration outputs, which are fully automatic products. Apart from fully automated dataset outputs (before mentioned streams and

roads), the output zip file contains also LU/LC classes, contours and bridges which undergone further manual interpretation an editing as described in this document.

References

Anonymous: project RESPOND (Supporting Humanitarian Relief, Disaster Reduction & Reconstruction), http://www.respond-int.org/

Anonymous: Definiens scientific paper resources compilation http://earth.definiens.com/learn/resource-center/show-more?type=Scientific%20Paper

R.M. Haralick. (May 1979). Statistical and structural approaches to texture. Proceedings of the IEEE. Vol. 67, No. 5. pp. 786-804.

Zhang, Yun. (2002). Problems in the fusion of commercial high-resolution satellite as well as Landsat 7 images and initial solutions. In ISPRS, Vol. 34, Part 4, "GeoSpatial Theory, Processing and Applications", Ottawa

Zhang, Yun. (June 24-28, 2002). A new automatic approach for effectively fusing Landsat 7 as well as IKONOS images. IEEE/IGARSS'02, Toronto, Canada.