Comparison of Different Image Classification Methods in Urban Environment

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Abstract – Urban growth, land cover and land use data play an important role in ecological and environmental research. In several studies remote sensing data are used as a source data, but the results are not quite satisfying for detailed land cover detection in urban areas. This study has been carried out to find an appropriate method to classify the high resolution remote sensing data (WorldView2). In our work beside traditional pixel-based method (NDVI analysis, supervised classification) we used the segment-based classification to compare the object-oriented with pixel-based classification approach. The results of land cover classifications derived from remotely sensed data are compared by accuracy assessment. An appropriate methodology for urban land mapping using high resolution remotely sensed data is presented and evaluated in the city of Székesfehérvár.

Keywords: satellite images / image classification / urban area / WorldView

1. INTRODUCTION

A research project No. TÁMOP-4.2.1/B-09/1/KONV-2010-0006 aims the production of different thematic maps to characterize the urban ecological environment. At three Hungarian cities (Sopron, Székesfehérvár, Szombathely) the environmental conditions have been examined inside the urban area. The data from remote-imaging satellites has been used as the data source. Land cover mapping is one of the most important and typical applications of remote sensing data. Land cover corresponds to the physical condition of the ground surface. The number of remote sensing platforms increased during the last decades and produced more and more detailed geographical data. Sensors can provide accurate and timely information on urban land cover, its location and spatial configuration, as well as growth rates. Land cover mapping from remotely sensed data is based on image classification. With a finer spatial resolution, the number of detectable sub-class elements increases as well. The resulting increase in the within-class spectral variance may make separation of spectrally mixed land cover types more difficult. Due to the spectral heterogeneity of urban surface types and the spatial complexity of urban scenes, very high resolution image classification of urban areas often results in land-cover maps low thematic accuracy (LU at al. 2010). Number of studies focused on the issues of spectral properties of urban materials and their representation and mapping from remote sensing data. The results indicate highly complex and diverse spectral properties of urban land cover types. The spectral separability of urban land cover types is strongly dependent on spectral sensor characteristics (HEROLD et al. http://www.geogr.unijena.de/~c5hema/pub/istanb_herold_gardn_hadl_roberts.pdf). Several research results have shown that traditional, pixel-based classification methods are not
suitable for very high resolution images (WANG 2004). The recent proliferation of tools for image processing, analysis and modeling has opened up avenues for significant progress toward observation of urban environment. The development of classification methodologies for analysis of high resolution satellite imagery plays a relevant role on studies related with mapping of urban environments (ZHOU 2008). Several research studies have been carried out to find an appropriate method to classify the high resolution remote sensing data (ZHANG 1999, FEKETE at al. 2008).

The aim of this paper is to describe and compare of different classification methods applied for land cover mapping in urban area.

2. STUDY AREA

Székesfehérvár is situated in central Hungary. With a total area of 170.9 sq km it is the second largest settlements in the Transdanubian region. It is the county seat, the cultural and economic centre of Fejér County. According to the historical documents the place has been inhabited since the 5th century BC, but Székesfehérvár was first mentioned in 1009, as Alba Civitas. As early as the Middle Ages the town was an important traffic junction. A town rights to the settlement was granted by Saint Stephan and it was the royal seat for hundreds of years. In the 13th–15th centuries the town prospered, several palaces were built. During the next period of history (Ottomans occupation) the city was destroyed. The city began to prosper again only in the 18th century, several new buildings were erected. After the war for independence (19th century) Székesfehérvár lost its importance and became a mainly agricultural city. New prosperity arrived between the two world wars, when some factories were opened. After World War II the city was subject to industrialization. By the 1970s Székesfehérvár had swelled to more than 100 000 inhabitants (in 1945 it had only about 35 000.) The city and its surroundings were the most dynamically growing regions of Hungary in the 1990's. It is inhabited by 101 973 people (KSH; 2010), the density of population is 594-person/sq km and ranks among the middle-sized cities of the country. The Figure 1 shows the study area in the 19th century and at present.

Figure 1. Székesfehérvár in the 19th century and at present. Source: The 2d military survey 1819-1869, WorldView2 2011
3. OVERVIEW OF DATA

Remote Sensing data
The study used the following remote sensing data:

- WorldView2 satellite image (2011)
- LANDSAT TM (1986, 2006)
- Airborne photographs (2008, 2009)

WorldView-2 developed by DigitalGlobe, USA, in 2009, is the first high resolution multispectral commercial satellite having eight spectral sensors from the visible to near-infrared range. Spatial resolution of the Pan is 0.5 m and MS sensors is 2.0 m. WorldView-2 image was acquired on July 11, 2011. LANDSAT satellites have been a major component of NASA’s Earth observation program. Images are available since 1972 from six satellites. The Thematic Mapper sensor supplies high resolution visible and infrared images with spatial resolution of 30 m.

Other data sources used for investigation
- Field reference data (GPS)
- Vector data from Cadastral maps
- Attribute data gained from the municipalities
- Other statistical data

Ground reference data were acquired to characterize the spectral properties of urban surfaces and to develop a basis for the validation of the image classification. The selection of test sites were done by low altitude photographic flights and field mapping using field reference data, vector data from Cadastral maps and building dataset of the study area as a base.

4. METHODOLOGY AND RESULTS

The land cover maps were created using supervised classification techniques in IDRISI TAIGA. In the pixel-based analysis the maximum likelihood method was applied to identify and classify pixels. It was performed on multi-channel data (visible and near infrared) and this process assigns to each pixel in an image a particular class based on statistical characteristics of the pixel values. The pixel based-classification, segmentation and NDVI analysis were done to map the land cover. The final result of the analysis consists of maps and statistical data.

Defining the categories the next main view-points were considered: to give names to categories by simply using accepted terminology and to use remote sensing as the primary data source. According to the ground truth, five main classes were distinguished in this test: building area (2 classes: tiled and flat roof), road and associated area (3 sub-classes: road, parking place, other man made area), vegetation (3 sub-classes: trees, bush, grass) and water.

4.1. Pixel-based classification

In supervised classification, the spectral features of some areas of known land cover types are extracted from the image. Every pixel of the image is then classified belonging to one of the classes depending on how close its spectral features are to the spectral features of the training areas. The mathematical methods we used in classification was the Maximum Likelihood Classifier (pixel can be classified by calculating for each class with its probability values). The Figure 2 shows the results. The Table 1 includes statistical data of the classification.
4.2. Segment-based classification

Segmentation of images is one of the main tasks that have to be solved in the object-based classification. Segmentation is a process by which pixels are grouped into segments according to their spectral similarity. Segmentation employs a watershed delineation approach to partition input imagery based on their variance. A derived variance image is treated as a surface image allocating pixels to particular segments based on variance similarity. Segment-based classification is an approach that classifies an image based on these image segments. Before carrying out the segment-based classification, the classes (training area) were assigned on the image segments. The result of classification is shown in Figure 3. The Table 1 includes statistical data of the classification.
Table 1. The results of classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Pixel-based classification area (ha)</th>
<th>Segment-based classification area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building_flat roof</td>
<td>897.2</td>
<td>832.1</td>
</tr>
<tr>
<td>Building_tile roof</td>
<td>328.6</td>
<td>321.6</td>
</tr>
<tr>
<td>Road and associated area</td>
<td>308.7</td>
<td>343.4</td>
</tr>
<tr>
<td>Vegetation</td>
<td>2687.4</td>
<td>2724.5</td>
</tr>
<tr>
<td>Water</td>
<td>21.6</td>
<td>22.1</td>
</tr>
</tbody>
</table>

A supervised classification is based on the single value of pixel and does not utilize the spatial information within an object. Because of the complexity of surface features and the limitation of spectral information, the results of traditional classification methods can be mistaken, even it can give a confused classification.

5. ACCURACY ASSESSMENT

The results of the land cover classifications derived from remotely sensed data are compared by an accuracy assessment. An accuracy assessment of the classification results was performed using reference data. The reference samples are ground truth data coming from the vector data from the cadastral map and the field reference. The error matrices have been generated. The assessment indicates the producer’s and consumer’s accuracy and overall accuracy in Table 2.

Table 2. Accuracy assessment results from the pixel-based and the segments based classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Pixel-based classification</th>
<th>Object-oriented classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Producer’s accuracy %</td>
<td>User’s accuracy %</td>
</tr>
<tr>
<td>Building_flat roof</td>
<td>81.2</td>
<td>76.1</td>
</tr>
<tr>
<td>Building_tile roof</td>
<td>53.9</td>
<td>32.5</td>
</tr>
<tr>
<td>Road and associated area</td>
<td>20.8</td>
<td>78.0</td>
</tr>
<tr>
<td>Vegetation</td>
<td>89.1</td>
<td>47.2</td>
</tr>
<tr>
<td>Water</td>
<td>99.6</td>
<td>100</td>
</tr>
<tr>
<td>Overall accuracy: 64.2</td>
<td>Overall accuracy: 71.5</td>
<td></td>
</tr>
</tbody>
</table>

Analyzing the results of accuracy assessment we can see that the object-oriented classification produced more accurate results, than the other method. Looking the results of categories we have find differences especially in the following categories: building flat roof, road and associated area. As we expected, the roads, parking places are classified as buildings, which are obviously misclassified. The errors of omission and commission are high, and it is caused by the spectral similarity of categories.
6. CONCLUSION

In our paper, we compared pixel-based classification and object-oriented classification approaches using multi-spectral satellite image of Székesfehérvár. The object-based classification of high resolution satellite data was shown to be an effective tool for analyzing land cover in urban area. An urban ecosystems present a wide structural diversity and consequently spectral variability therefore the process of classification needs not only spectral information but other information like context or geometry as well.

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References