THE OBJECT-BASED APPROACH FOR URBAN LAND USE CLASSIFICATION USING HIGH RESOLUTION SATELLITE IMAGERY (A CASE STUDY ZANJAN CITY)

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Abstract: Urban land use maps is one of most important data for urban planner in the planning process that its production by using traditional methods need to high cost and times. Currently, urban land-use mapping is still largely based on visual interpretation using aerial photographs or satellite images, owing to the complexity of urban patterns and the lack of tools for automatic solutions. Instead, object-oriented methods can be image segmentation based on the spectral characteristics, form, texture, and relationships between phenomena that result in a hierarchy of classes in the classification of land use; especially urban land use. In this study segmentation and hierarchical classification approach based on spatial frequency characteristics applied to Quick-Bird multispectral satellite data for urban main land use classification in northern part of Zanjan city. The results shows that residential, green space, main building such as commercial and sports area and water body has been classified more than 81% overall accuracy.

1.Introduction:

Land-cover and land-use information is essential for urban planning and management. The terms 'land cover' and 'land use' are often confused. Land use can be defined as the use of land by humans, usually with an emphasis on the functional role of land in economic activities. Land use is an abstraction not always directly observable under even the closest inspection. In contrast, land cover designates the visible evidence of land use or aspects of it such as roads, buildings, parking lots, forest, rivers. Whereas land use is abstract, land cover is concrete and therefore is subject to direct observation. Another distinction is that land cover lacks the emphasis on the economic function that is essential to the concept of land use (Campbell, 1996).

Urban areas as centers of economic and social development are an important objective in the application of remote sensing technology. Common problems in detailed and accurate urban area remote sensing results from the spatial and spectral heterogeneity of the urban environment typically consisting of built up structures (buildings, transportation areas), various vegetation covers (e.g. parks, gardens, agricultural areas), bare soil zones and water bodies. In order to accurately characterize this complex spatial environment, specific spatial and spectral sensor characteristics and improved image analysis techniques are required. New data resources and innovative concepts in image analysis have the potential for improving the mapping and analysis of spatial urban land use and land cover. Data from new high-spatial resolution satellite sensors IKONOS and QUICKBIRD are available. These data have significant potential for detailed digital imaging of the urban environment (Herold and et al, 2003).

Urban land-use in an urban planning context refers to certain functions with related social-economic characteristics. For instance, a residential area consists of a number of physical features such as residential buildings, parking spaces, footpaths, green space, and maybe canals. Quite often, these features are targets of land-cover classification. Physical features in general have certain associations with spectral features, so they can be identified by using multi-spectral information from remote sensing images. However, land use cannot be determined directly from land-cover information (Barr and Barnsley, 1997; Zhan et al., 2002). This is because land use is an abstract concept – an amalgam of economic, social and cultural factors – one that is defined in terms of function rather than physical form. Urban land use might be distinguishable in terms of the morphological properties of, and the spatial relations between, their component land-cover parcels (regions) (Barnsley and Barr, 1997). It is possible, for example, that different sample areas of the same nominal land use might exhibit somewhat different morphological properties and/or spatial relations in terms of their component land-cover regions. If the within-class variation (i.e. within a single land use) is greater than the between-class (i.e. between different land uses), then it will not be possible to identify and to distinguish urban land use consistently on the basis of these structural measures (Barnsley and Barr, 1997). Besides the morphological properties and the spatial relations in terms of their component land-cover regions, a number of other indicators are needed in order to identify land use, such as proportion of areas covered by different types of land cover, building density, floor area ratio, or evidence derived from other sources. In addition, correct delineation of the spatial extent of a land-use unit is a crucial factor, and many land-use-related measurements (such as building density) may be influenced by delineating different land-use units, possibly leading to incorrect identification. Therefore, in this research an intermediate stage is proposed for finding spatial units where certain functions are held spatially. This inters mediate stage between land-cover classification and land-use classification reflects what is happening in the human vision system. The indicators, as mentioned above, are supposed to be extracted from laser data or multi-spectral images. M any features essential for land -use classification are per-object based. They are difficult or impossible to extracted by per-pixel approaches. Therefore, the object-based approach is needed.

Many computer-aided classification methods have been developed since the early stages of remote sensing application in 1970s (Curran, 1985; Schowengerdt, 1997; Richards and Jia, 1999; Mather, 1999; Tso and Mather, 2001; Campbell, 2002). Most existing approaches are pixel-based, using multi-spectral data alone, and aim at land-cover mapping, since the spectral information contained in remote sensing images consists of electromagnetic reflections of the physical properties of terrain features. Many existing classifiers fail to produce high-accuracy results because of the existence of mixed pixels caused by the limited spatial resolution of sensors. Therefore high spatial resolution images will be tested in this research to find out if such data can be used for producing better land-cover maps. Please note that in this dissertation high spatial resolution or high resolution refers to images with a spatial resolution from 0.5 m to 4 m produced by sensors such as IKONOS, QuickBird, TopoSys(Zhan,2003).

Object-oriented analysis (OOA) is a method of analysis that examines requirements from the perspective of the classes and objects found in the vocabulary of the problem domain (Booch, 1993). Many principles and techniques for managing complexity have been collected in the OOA, such as abstraction, encapsulation, inheritance, association. (Coad and Yourdon, 1990). The OOA approach is applied in object-based spatial data modeling in the planning and management domain in order to support object-based image analysis toward land-cover and land-use classification in urban areas. Considering the implementation of the OO models in a raster environment, these objects are formulated based on the raster representation. In the following sections, a layered sequence is followed for the OOA – from Subject layer, Class-&-Object layer, Structure layer, Attribute layer to Service layer (Coad and Yourdon, 1990). Object-based conceptual analysis in the planning context follows the same line as OOA and is presented toward urban land-cover and land-use classification as a subject layer. A brief introduction of the OO approach and tools will follow. In the coming sections, conceptual modeling is elaborated by using an adapted syntax based on the notions from both UML (United modeling Language) and OMT-G (Object Modeling Technique for Geo graphic Application), and on the notion presented by Molenaar (1998), corresponding to Class-&-Object layer, Structure layer, Attribute layer and Service layer. A number of diagrams are produced concerned with class, structure, attribute and operation. Please note that the conceptual modeling presented in this chapter focuses on the problem domain of urban land-cover and land-use classification based on high-resolution data and does not aim at a general model for GIS in urban planning and management. Therefore, structures, attributes and operations, such as ownership, address and building materials of a building, which rely on additional data rather than remote sensing data, are not considered in this modeling.

This paper presents an example of object-oriented mapping and analysis of Quick-Bird data in the Northern party (Shahrak Karmandan) of Zanjan city in northwest part of Iran. The dataset consists of one frame image captured from Quick-Bird images in September 2008. In this study we will describe the preprocessing of the data including the radiometric correction of atmospheric effects and derivation of reflectance values using field spectra. For image segmentation and classification we used the eCognition Developer 8.7 software system that provides state-of-the-art techniques of digital object-oriented image analysis. The derived land cover map was further analyzed with spatial metrics to derive an additional level of information related to urban land use and socioeconomic information. This study documents the potentials of the combined application of high spatial resolution space-borne Quick-Bird spatial metrics to allow a detailed and accurate mapping and analysis of urban land cover and land use.

2.Case Study Area

The Study area is located between 36° 41' 20" to 36° 41' 58" N and 48° 29' 34" to 48° 30' 57" E. This area include 192.0 hectares area and located in northern part of Zanjan city and famous to Shahrak-Karmadan and Azadegan township. The case study is shown in Figure 1.

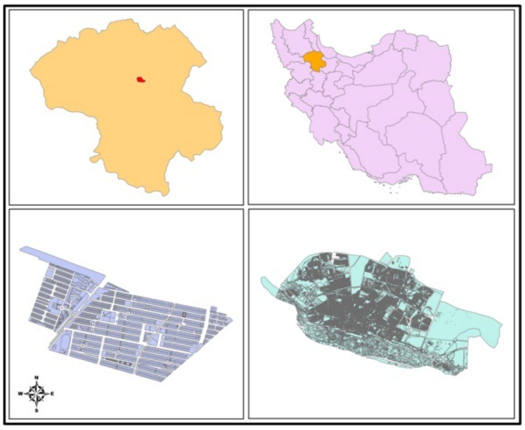

Figure1: Case study location map

3. Material and Methods

- **Materials**

The data used in this paper can be categorized in three types Quick-Bird multispectral images (0.6 m spatial resolution) acquired in September 2008 covering the Shahrak-Karmandan area in northern part of Zanjan city (Figure 2), Thematic land use map in 1:2000 that captured form Zanjan city master plan for accuracy assessment and results check and DSM data(0.5 m spatial resolution) that processed by 1:2000 3d topographic map form Zanjan city.

Figure2: Quick-Bird image from case study area

- **Methods**

The first step in object-oriented analysis with eCognition is a segmentation of the image. This process extracts meaningful image objects (e.g. streets, houses, vegetation patches) based on their spectral and textural characteristics. In eCognition the segmentation is a semi-automated process where the user can define specific parameters that influence size and shape of the resulting image segments. The resulting objects are attributed not only with spectral statistics but also with shape and context information, relation to neighboring objects and texture parameters. Given a spatial resolution of 0.6 m typical individual land cover objects (built up structures) are represented by several pixels. The segmentation was performed by equally weighting of all 3 bands, using the following parameters: Scale 30, Color 0.5/Shape 0.2; Smoothness

0.4/Compactness 0.5. The results of the image segmentation are shown in Figure 3.

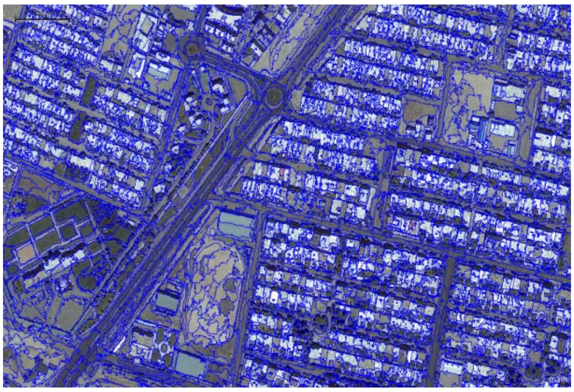

Figure 3. eCognition segmentation result in case study area

The image classification in this study is based on user-defined a nearest neighbor algorithm, which performs class assignment based on minimum distance measures. The classification process can include a variety of different information, ranging from spectral mean values for each object, to measures of texture, con text and shape. The goal of classification was to provide a detailed and accurate land cover product that forms the basis of further analysis of urban structures and refinement of the thematic map towards representing land use and socioeconomic information for specific applications. In this paper nearest neighbor feature space included layer value main (Brightness, layer and max diff) and Geometry (Shape and Based on polygons) has been selected as features for image classification.

The classification in eCognition was implemented as hierarchical system with Level I classes: In this paper we define 10 classes for image classification. The selected class included agricultural lands, Building1 (included residential area), Builning2 (Main building included sports and administrative and big size building), Dense tree, New planting trees, Open space, Road (Asphalted and main networks), Road2 (footprints and minor network), Shadow.
The results of the land use classification are shown in Figure 4.

According to classification image residential area has been classified in two classes building 1 that included residential land use and building 2 included major building such as apartments and sports and administrative land use. The results shown that this land uses included totally 42.84 hectares. Due to spectral variability of green space and trees, these land uses has been classified in high accuracy in comparing with other land uses in case study area. Table 1 are shown land use classification results in case study area. According to this results roads and main networks with 56.47 hectare in included maximum area in comparing with other land uses and agricultural land with 3 hectares is included minim area in case study area.

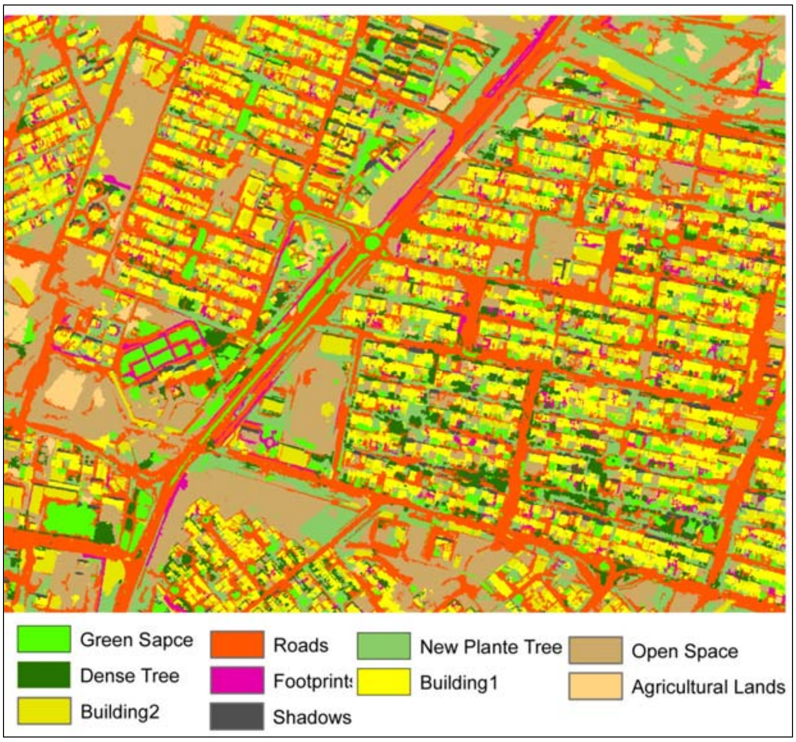

Figure 4: Land use map of case study area extracted from the multispectral Quick-Bird image

Table 1: Land use Classification Results in case study area

Land use	Area(Hectares)	Percent
Green Space	11.80	6.15
Dense Trees	9.91	5.16
New Plant Trees	25.85	13.46
Building1	28.89	15.05
Building2	13.93	7.26
Roads	56.47	29.41
Footprints	4.91	2.56
Agricultural Lands	3.22	1.68
Shadows	3.36	1.75
Total	192.00	100.00

An accuracy assessment was performed applying the field mapping results and considering one image object as one reference point. The error matrix is shown in Table 2. It indicates a very accurate (0.9) classification for green space, dense trees, Building1, footprints bodies and Agricultural Lands. Also it indicated that roads due to similar spectral with other objects such as open space and shadows have low accurate (0.6) in comparing with other land uses.

This result generally reaffirms the aforementioned problem that spatial and contextual measurements are applied as global variables and cause classification uncertainties due to the heterogeneity of the urban built up structure. However, the overall classification results (overall accuracy 81 %) can be considered good and are encouraging for further application of this mapping product.

Table 2: Error matrix for the classification results derived from Quick-Bird data with eCognition

Land use	Green Space	Dense Trees	New Plant Trees	Building1	Building2	Roads	Footprints	Open Space	Agricultural Lands	Shadows	Total	Error C
Green Space	22394	1167	0	177	9	107	238	9	0	0	24101	0.071
Dense Trees	8	7651	0	49	20	217	111	0	0	0	8056	0.050
New Plant Trees	0	66	9302	771	418	170	118	7	1376	27	12255	0.241
Building1	0	0	0	13671	8	58	0	10	0	19	13766	0.007
Building2	0	0	34	788	13659	4	0	15	4494	2	18996	0.281
Roads	581	3241	2277	405	193	16851	1441	832	1992	328	28141	0.401
Footprints	0	0	0	345	0	4	4077	0	0	0	4426	0.079
Open Space	0	361	980	699	874	192	1331	39722	8968	0	53127	0.252
Agricultural Lands	0	0	0	0	130	0	0	0	28166	0	28296	0.005
Shadows	0	546	0	0	3	0	0	0	0	1685	2234	0.246
Total	22983	13032	12593	16905	15314	17603	7316	40595	44996	2061		
Error O	0.026	0.413	0.261	0.1913 0	0.108	0.043	0.443	0.022	0.3740 0	0.182		Overall
Procedure	0.9	0.9	0.7	0.9	0.6	0.5	0.9	0.6	0.9	0.7		
User	0.9	0.6	0.7	0.7	0.8	0.9	0.6	0.9	0.6	0.8		0.818

4.Spatial Metric Analysis

To further analyze and refine the land cover mapping product, we applied a set of spatial metrics to describe the built up structure in the study area and to explore the ability to represent land use pattern and socioeconomic characteristics. Spatial metrics are a useful tool to quantify structures and pattern in a landscape represented in a thematic map or classified data set. They are commonly used in landscape ecology (landscape metrics, Gustafson 1998). Recently, there has been an increasing interest in applying spatial metrics concept in an urban environment, emphasizing the strong spatial component in between objects of urban structure and related dynamics of change and growth processes (Barnsley and Barr 1997, Bauer and Steinnocher 2000, Alberti and Waddell 2000, Herold et al. 2002a). In this paper we used population density and land use map as spatial metric data for result and accuracy control. Figure 5 and 6 shows an example of applying this concept to a thematic subset of classification result in the case study area.

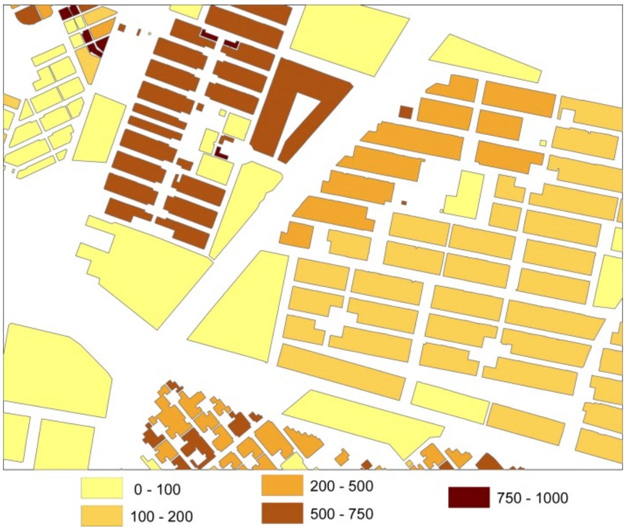

Figure5: Population density in case study area in 2006

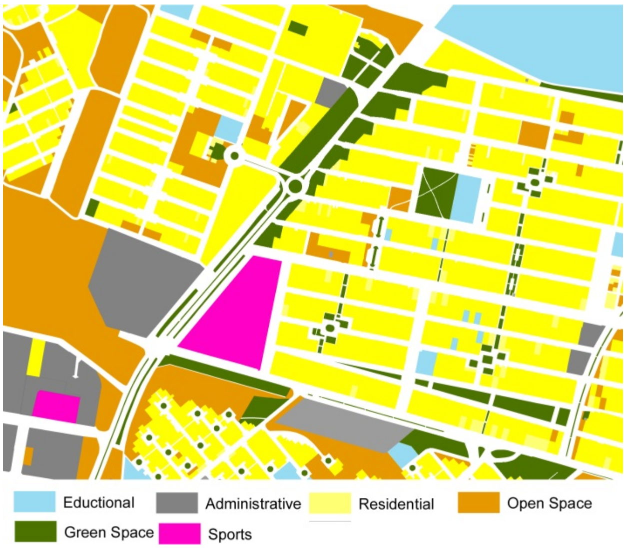

Figure 6: Main land use classes in case study area capture from Zanjan master plan 2007

Although these maps cannot really be compared in quantitative terms due to the different spatial domain upon which they are based (also known as modifiable area unit problem), they clearly show the ability of the approach to represent specific spatial characteristics in urban areas. Given the high spatial resolution of the remote sensing data, it is possible to capture more spatial variability than traditional datasets such as CENSUS (Donnay and Unwin 2001, Liu 2002).

5. Conclusion

This paper explores an object-oriented approach to address and investigate specific problems and challenges in high-resolution mapping and analysis of larger urban areas. The study applied Quick-Bird images acquired in the Shahrak-Karmadnad abd Azadegan township in northern part of Zanjan city. Given the sensor capabilities and the spatial and spectral complexity of the urban environment, image segmentation and object-oriented classification provide a useful approach to map urban land cover with good separation of important categories (e.g. built/non-built up, roads). The overall accuracy achieved was 81 %. The incorporation and further analysis of the land cover product using spatial metrics provide and additional level of information and relate the physical built up structure to urban land use and socioeconomic characteristic

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