An Assessment of the Effectiveness of Segmentation Methods on Classification Performance

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Abstract

Object-based classification approaches have been recently employed successfully in many research studies. These approaches aim to create segments on the image considering spectral similarity of the neighboring pixels, which is known as image segmentation. Segmentation methods use spectral information as well as textural and semantic information of the pixels. It is a fact that parameter setting of segmentation methods is of considerable importance in producing accurate classification results. Therefore, determining optimum values for the parameters is regarded as a critical stage in segmentation processes. In this study, effectiveness and applicability of the segmentation approach was analyzed utilizing a high resolution Quickbird satellite image. Multi-resolution segmentation technique, which has been reported to be a robust method, was employed with its optimal parameters for scale, shape and compactness that were defined after an extensive trail process on the data set. Resulting image object was then used in supervised classification using the nearest neighbor algorithm with fuzzy membership functions. Classification performances produced for different parameter settings were thoroughly analyzed and it was found that parameter setting in segmentation applications produced highly varied classification accuracies. It was also observed that segmentation algorithms could help to improve spectral discrimination, particularly for spectrally similar classes.

Keywords: Segmentation, object-based classification, nearest neighbor, accuracy assessment.

1. Introduction

Classification of the remotely sensed images is a common practice to obtain information about the Earth's surface. Classification can be defined as the assignment of each pixel on the original image to a feature class, depending on the spectral reflectance values of the objects (Kavzoglu and Colkesen, 2009). There are many methods (e.g. maximum likehood, decision tree, support vector machines) available in the literature to classify remotely sensed imagery. In recent years, object based image analysis (OBIA) has been widely used in remote sensing applications. OBIA is a sub-discipline of GIScience devoted to partitioning satellite imagery into meaningful image-objects, and assessing their characteristics through spatial, spectral and temporal scale (Hay and Castilla, 2006). The new concept's basic principle is to make use of important information (shape, texture and contextual information) that is present only in meaningful image objects and their mutual relationships (Darwish *et al.*, 2003).The approach has been recently applied in many applications, including detecting forest landscape, building extraction, change detection, determining shadows.

OBIA is a classification process creating image objects grouped by contiguous and homogeneous pixels whose textural and geometric features are considered. The process takes into account limited but highly representative number of pixels instead of all pixels in the image. Segmentation considers geometric and textural relationships to establish relationship between image objects and real world objects. The use of segmentation images in classification process affects the quality of classification and correctness of the resulting thematic maps. Setting of segmentation parameter is an important step that is usually performed with exhaustive trials searching optimal combination for the parameters. Several studies were reported on this particular issue (e.g. Bo and Han, 2010; Feitosa *et al.*, 2006; Addink *et al.*, 2007; Darwish *et al.*, 2003).

The aim of this research is to investigate the effect of parameter setting of segmentation in extracting land use/cover classes from a multispectral image. Different segmentation parameters were used on process and classification results were obtained using overall accuracies for each parameter.

2. Study area and Data Sources

The study area chosen for this research is located in Trabzon province of Turkey (Figure 1). The area includes urban regions as buildings, undeveloped regions as grassland, bare soil, road, sea (open water) and forest. Quickbird pan-sharpened satellite imagery acquired on 05 May 2008 was utilized in this study. The dataset has 0.6 m spatial resolution with 4 channels and 16 bit radiometric resolution. 1451 x1421 portion of the Quickbird image covering the study area was extracted and used in subsequent analyses. eCognition Developer (v8.7), a widely-used object based image processing software, was used to apply segmentation and classification methods considered in this study.

Figure 1: Location of the study area, Trabzon, Turkey.

3. Methodology

There are two fundamental procedures on object based image analysis, which are segmentation and classification process. Segmentation process is the first step in this analysis. This process allows merging homogenous and contiguous pixels on the imagery using spectral properties of the pixels. Multi-resolution segmentation is the most popular algorithm for object based image analysis, also known as region merging technique. It was used here to produce image object primitives for a further classification process.

Scale parameter and homogeneity criterion are used to create image objects in multi-resolution segmentation. Homogeneity criterion is defined as a combination of spectral homogeneity (i.e. color criterion) and shape homogeneity (i.e. sum of the smoothness and compactness parameter). Shape and compactness parameters are set by the analyst prior to segmentation process. Fundamental theory and formulation of these parameters can be found in Baatz and Schäpe (2000) and Benz *et al.* (2004).

In segmentation applications scale parameter is regarded as the most important one as it most considerably affects the classifier performance. In general, higher values for the scale parameter result in larger image objects, smaller values in smaller ones. Since there is no certain rule in scale parameter determination, the selection of optimal parameter values varies depending on image resolution and image scale. These parameters are user-defined and usually determined by trial and error methods.

The selection of the segmentation parameters is a crucial step in object based classification. The success of these approaches is dependent on the quality of the image segmentation (Shackelford and Davis, 2003). A clear definition of homogeneity per object allows comparing different segmentation results and different optimization procedures (Baatz and Schäpe, 2000).

Classification process that is the second step in segmentation usually includes two types of supervised classifiers, namely nearest neighbor classifier and membership function. Membership functions allow defining the relationship between feature values and the degree of membership to a class using fuzzy logic. Nearest neighbor classification uses a set of samples of different classes in an attempt to assign class values to a segmented object. The procedure consists of two major steps: teaching the system by giving it certain image objects as samples and classifying image objects in the image object domain based on their nearest sample neighbors (eCognition, 2011). The software distinguishes two types of nearest neighbor expressions, namely standard nearest neighbor and nearest neighbor. The standard nearest neighbor option automatically selects mean values of objects for all the original bands in the selected image. The nearest neighbor option requires users to identify variables (e.g., shape, texture, and hierarchy) under object features, class-related features, or global features (Myint *et al*., 2011).

3. Results and discussions

In this study, performance of object based-classification was investigated with the different segmentation parameters on a land use and land cover mapping problem. Multi-resolution segmentation algorithm was applied for the creation of segmented images. In order to accomplish the objectives of the study, ten scale settings (5, 10, 20, 35, 50, 70, 100, 150, 200, and 300) and nine shape settings varying from 0.1 to 0.9 were applied to create segments. It should be noted that compactness values were kept constant as 0.5 for all parameter combinations. Segment sizes for these settings are shown in Figure 2 for a selected part of the image to indicate variations in segment sizes for the study area. It can be seen from the figure that increasing the scale parameter results in over generalization behavior, producing few number of segments that do not represent the details in the image. It is also clear from the figure that although there exist four buildings in the image, only one was detected when scale was set to 200 and 300.

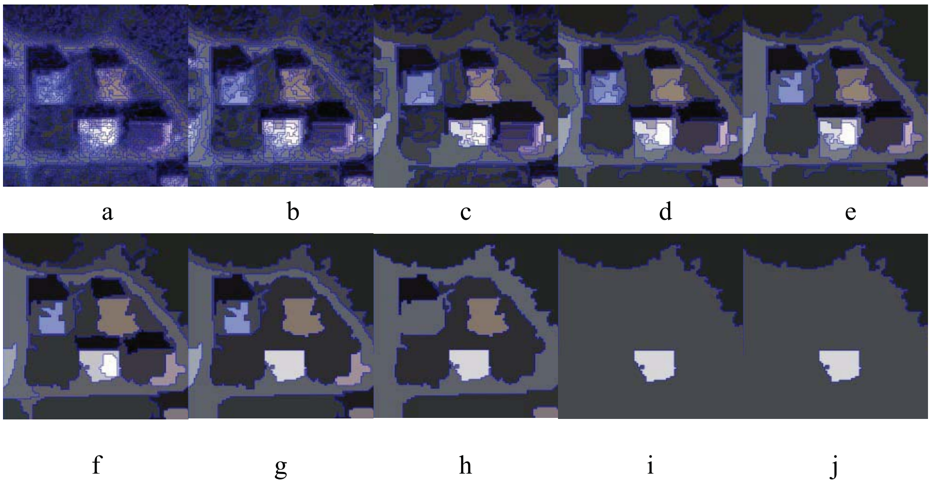

Figure 2: Segment sizes with different scale parameters (a=5, b=10, c=20, d=35, e=50, f=70, g=100, h=150, i=200, j=300).

Segmented images were classified using the nearest neighbor classifier to determine the effects of the segmentation parameters on the classification accuracy. It should be noted that the study area mainly covered seven land use/cover classes, namely, building, water, forest, bare soil, pasture, road and shadow. In order to test the classification performance, a test data set containing 14.000 pixels (i.e. 2.000 pixels for each class) was created using random pixel selection strategy. Variations in the classification performances were analyzed by comparing overall classification accuracies derived from the error matrices based on TTA (Training or Test Areas) mask. The overall accuracies in relation to different parameter setting were given in Table 1. It was observed that higher classification accuracies were calculated by low scale-shape combinations. In addition, it was found that selecting small scale parameters, which are known as fine scale, could be important to create more homogeneous image objects. When the results were analyzed, it was seen that the highest classification accuracy was produced by 20–0.1 scale/shape parameter setting whilst the lowest accuracy was produced by 300–0.9 scale/shape parameter setting. Segments constructed with the parameters giving the highest overall accuracy were employed in a classification process and the thematic map of the study area was produced (Figure 3). When the scale parameter was set to small values (e.g. 5, 10, 20) and the shape parameter was set to high values (e.g. 0.8, 0.9), segments with high heterogeneity were created. In other words, these segments included several spectral classes. On the other hand, when the scale and shape parameters were set to high values, large image objects (i.e. segments) were obtained. In this case, spectrally similar objects (i.e. bare soil and building) are likely to be misclassified as they are combined in a single image object.

Table 1: Classification results of different segmentation parameters. Note that compactness parameter was set to 0.5 for all cases.

Shape \ Scale	5	10	20	35	50	70	100	150	200	300
0.1	88.22	87.96	88.67	88.57	86.30	82.34	77.06	71.11	72.52	67.45
0.2	88.43	87.87	88.33	84.94	85.72	81.96	75.39	71.83	69.20	65.50
0.3	87.61	87.59	87.91	82.02	84.35	81.82	75.41	67.68	64.02	67.20
0.4	88.29	87.68	84.79	83.28	82.07	78.69	74.30	68.51	69.78	66.80
0.5	88.30	83.75	82.65	77.66	82.39	79.79	77.57	69.54	61.63	66.80
0.6	87.27	82.91	81.67	78.11	82.29	78.24	76.66	71.33	64.96	66.02
0.7	87.69	82.26	81.05	74.76	78.89	74.55	74.80	68.63	63.38	66.25
0.8	86.26	83.13	80.40	76.25	77.12	72.77	74.42	62.82	65.70	60.10
0.9	86.55	82.83	76.31	75.35	73.88	71.95	72.05	59.44	58.96	54.95

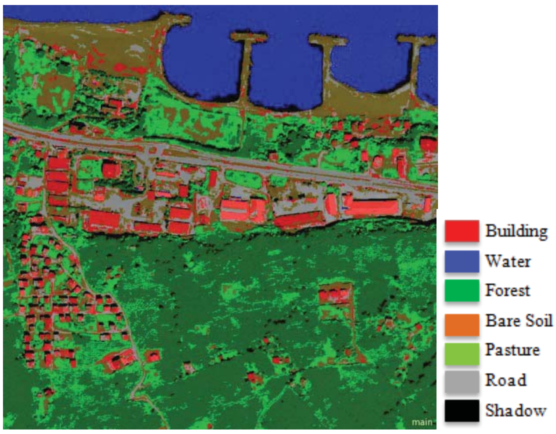

Figure 3: Result of image classification for optimum parameter (Scale=20, Shape=0.1, Compactness=0.5).

4. Conclusion

Determining optimal values for segmentation parameters is of considerable importance on the classification accuracy. In segmentation applications, trial and error strategies are usually employed to determine optimal or near-optimal setting of parameters. In this study, classification performance of object based classification was investigated with different scale and shape parameter settings. In all experiments, compactness parameter was kept constant due to the fact that it can affect the classifier performance at a lowest level compared to the others. Totally 90 combinations of scale/shape parameter were tested to get insight about the behavior segmentation algorithm, particularly multi-resolution segmentation.

Several important conclusions can be drawn from the results produced in this study. Firstly, results showed that higher classification accuracies could be obtained with small scale/shape parameter settings. With the increase in both parameters, but more importantly scale parameter, classifier performance is negatively affected. In this case, larger segments are constructed, which gradually disturbs the homogeneity of image objects. Secondly, it was observed that scale parameter was the most effective one in true construction of image objects. This can be easily seen from the accuracies estimated for different parameter settings presented in Table 1. Thirdly, it was found that optimal parameter values show variation depending on land use/cover characteristics; therefore, it is suggested that different parameter settings should be used for each class considering its spatial and spectral characteristics. To be more specific, coarse scales appear optimal for cover types with large polygons (e.g. forest lands), while fine scales can be suggested for cover types with small polygons (e.g. roads and buildings). Therefore, a hierarchical approach is required to perform using smart algorithms or approaches. More research with different data sets and class features is needed to validate the results and produce a complex formulation or guideline to the users of segmentation.

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