

PARAMETER TESTS FOR IMAGE SEGMENTATION OF AN AGRICULTURAL REGION

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Abstract

Segmentation, mainly the operation of object extraction from the total image, is the initial and a very important step of object-based image processing since it directly affects the performance of the processing, quality of the product and the accuracy of the results. In this study, the segmentation parameters of Definiens, widely used GEOBIA software, were tested by comparing the segments obtained by various combinations of values. As the study area, an agricultural region was selected and the results were evaluated in scope of extracting the field boundaries. The tests were conducted by producing 27 segmented images of the SPOT 4 data acquired on April 26th, 2007. The performances for the given conditions (combination of criteria) were compared to each other and the criteria of value selection that can be used for different aims were outlined. The results can be used in further studies for estimating the optimum values in accordance with the purpose.

Keywords: image segmentation, segmentation parameters, parameter tests, agricultural remote sensing.

1. INTRODUCTION

Remote sensing can be defined as any process of gathering information about an object, area or phenomenon without being in contact with it. Human seeing and understanding is the best examples of data collection and information extraction procedures of remote sensing operation.

In remote sensing, for a very long time, traditional pixel-based image processing methods have been used. For the recent decade, object-based image processing method, a new way of image analysis have been developed and tested by the researchers worldwide. It can be said that recent studies have proven the superiority of the object-based image processing method over traditional methods.

The new concept is based on a principle close to human seeing and understanding activity. The complex mental process that each human performs depends on extracting the objects from the view first, and then comparing the view of objects and their relationships with the existing knowledge of memory. The decision-making of the procedure makes use of shape, texture and contextual information of objects and their mutual

relationships efficiently to produce meaningful information. Similarly, in object-based image processing approach, segmentation is the initial step of the process, which meaningful objects are created. After this step, classification and analysis take place.

Segmentation can be defined as the subdivision of an image into separated regions, mainly for the purpose of extracting the desired objects of interest for a certain task. The segmentation operation is performed to form objects by grouping pixels according to some criterion of homogeneity. [1] In object-based image analysis, image segmentation is a crucial process since it directly influences the accuracy and quality of the result [2].

For many years, procedures for image segmentation have been one of the main research areas in the field of image processing and a variety of algorithms have been developed to generate image objects. Each algorithm has its advantages and disadvantages. Image segmentation methods can be thought to be categorized in two main domains: *i*) knowledge driven methods (top-down) and *ii*) data driven methods (bottom-up). In top-down

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approaches, the objects desired to be extracted are known, however the extraction is undefined. Therefore, first a model of the desired objects is defined, and then the extraction is performed. In bottom-up approaches the segments are generated based on statistical methods [1]. In top-down methods, difference is an important parameter, in other words it is based on the foreground-background contrast, whereas in bottom-up methods, the work is done based on similarity which pixels with similar intensity are clustered together [3].

As the technique, one of these two processes is followed: *i)* region-based methods that use some measure of homogeneity criterion, *ii)* edge-based methods based on separation of objects by finding edges between neighboring pixels, *iii)* pixel-based methods. Region-based approaches can be operated as 'region growing' or 'region split and merging'. Edge-based methods create image objects based on contours of gray levels. 'Watershed analysis' -a popular one- and the 'connectivity-preserving relaxation-based' segmentation methods are examples of edge-based methods. In watershed analysis, the aim is to find the "watershed lines" in an image in order to separate the distinct regions [4]. Connectivity-preserving relaxation-based segmentation is usually referred to as an active contour model, starts with some initial boundary shape represented in the form of spline curves, and iteratively modifies it by applying various expansion operations. Pixel-based methods are counted as thresholding and clustering. Histogram thresholding is one of the most popular segmentation techniques, extracting the object from the background by selecting the threshold that separates the image histogram [5]. Clustering is related to grouping and organization due to several key factors, such as similarity, proximity, good continuation. However, still many of the computational issues of perceptual grouping remain unresolved [6].

In the literature, there are many articles on segmentation, such as discussions on recently developed algorithms, tests that are performed for comparing different methods, results of segmentation applications with using various values of parameters and/or executing segmentation operation on different kinds of data [3], [7], [8], [9], [10].

In this study, the segmentation algorithm implemented in Definiens software was used and segmentation parameters were tested for an agricultural region in scope of extracting field boundaries with the highest accuracy. In the literature, generally the work which referred as "Object Based Image Analysis" originate around the software known as eCognition and/or Definiens ([11], [12], [13], [14]), therefore the segmentation can be defined as a standard one and the definitions, method and algorithms indicated in the article are dependent to the forementioned software.

2. MATERIAL

2.1 Study Area:

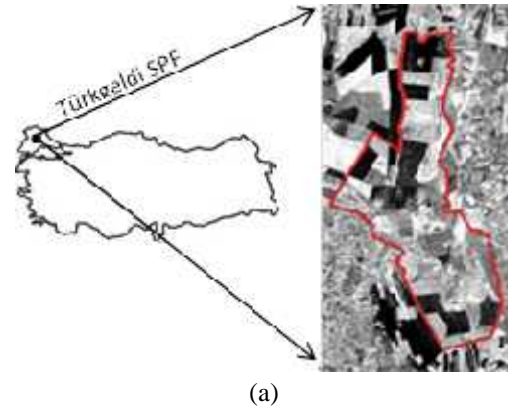


Figure 1. Study area.

Turkgeldi State Production Farm (SPF) is located on E 27.12°, N 41.41°, in the Thrace region of Turkey, 65 kilometers from Kirklareli, and 9 kilometers from Luleburgaz district [15]. 19.05 square kilometers of the SPF is used for agriculture, gardening and livestock. Mainly wheat and additionally clover, vetch, sunflower and corn are the crop types planted in the region.

2.2 Satellite Data:

As satellite data, a SPOT-4 image acquired on April 26th, 2007 was used. SPOT 4 provides data that involves four bands in multispectral mode: Band 1: 0.5-0.59 μm , Band 2: 0.61-0.68 μm , Band 3: 0.78-0.89 μm , Band 4: 1.58-1.75 μm , all having 20 m spatial resolution [16].

2.3 Field Map:

The crop type map belonging to 2007 was taken from Turkgeldi SPF. The field boundaries were extracted from the map, to use as a reference data for the evaluation of segmentation process.

3. BACKGROUND

Segmentation

In Definiens, three kinds of segmentation algorithms are used for creation of basic image objects (Figure 2) [17]: *i*) Chessboard segmentation: Entire image is splitted into square objects, *ii*) Quadtree segmentation: Entire image is splitted into image objects of maximum size as described by the parameters, *iii*) Multi-resolution segmentation: Entire image is segmented to user defined resolution, meeting the optimized color-shape, smoothness-compactness criteria.

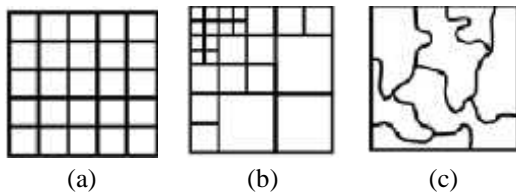


Figure 2. Segmentation types (a) chessboard, (b) quadtree, (c) multi-resolution. ([17])

The chessboard and quadtree segmentations are mostly used as a first step to divide the image into main parts to make the remaining process easier, and then the multi-resolution segmentation takes place. The patented multi-resolution segmentation algorithm can be defined as the main procedure to create image objects.

Multi-Resolution Segmentation

In Definiens software, a region merging approach to segmentation called “Fractal Net Evolution” was implemented [18], which become one of the most popular approaches in object-based image segmentation [10]. This patented multi-resolution segmentation algorithm which is a bottom-up region-merging technique, is the main procedure to extract image objects. In this process, to achieve adjacent image objects of similar size and comparable quality, the procedure starts at any point in the image with one-pixel objects and the segments are grown in each step till the final result is reached [1], [17]. Zhang et al., 2010 summarizes

the process as [2]: *i*) It starts with determining individual adjacent pixels as initial objects *ii*) the spectral heterogeneity change h_{color} and the shape heterogeneity change h_{shape} are measured between the two neighbor pixels (objects) to determine whether they need to be merged together, or not, *iii*) the process continues iteratively until a user defined threshold is reached.

The technique applied is a local optimization procedure, it minimizes the average heterogeneity and maximizes the respective homogeneity. The subdivision operation of segmentation is controlled by the composition of homogeneity, which is composed of color (h_c) and shape (h_s). Shape is formulated by a composition of smoothness (h_{ss}) and compactness (h_{sc}) parameters. The relations are defined as in Eqn.1 – Eqn.5:

$$h_s = 1 - h_c \text{ (Eqn.1)}$$

$$h_s = h_{ss} + h_{sc} \text{ (Eqn.2)}$$

$$h_c = \sum_b w_b \cdot \sigma_b \text{ (Eqn.3)}$$

$$h_{ss} = l/k \text{ (Eqn.4),}$$

$$h_{sc} = l/\sqrt{n} \text{ (Eqn.5)}$$

In the Equations, b stands for band, w defines weight and σ is the standard deviation, l is the actual length of the object’s outline, k represents the shortest length of the bounding box, and n gives the number of pixels of the object.

The change of heterogeneity S is calculated by Eqn.6:

$$S = w_s h_c + (1 - w_s) h_s \text{ (Eqn.6)}$$

Scale parameter (SP), a threshold that influences the average object size, and layer weights (w), a factor value regarding to the importance of the layer, are the other parameters used in segmentation.

All parameters can be combined as illustrated in Figure 3, namely ‘composition of homogeneity criterion’.

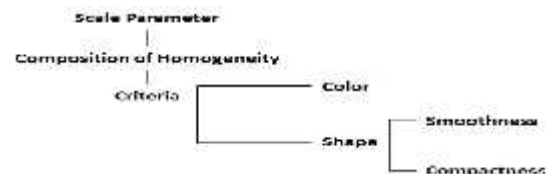


Figure 3. The composition of homogeneity criterion [17]

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Literature

Some of previously made suggestions for parameter selection of segmentation step in Definiens software are given as below:

In eCognition manuals it is mentioned that [17]:

Scale: It should be as large as possible, but small enough to ensure the separation between different land cover classes. **Color:** It should be weighted as high as possible, while the shape parameter should be weighted only as high as necessary. **Compactness:** The importance given to compactness has to depend on the properties of objects of interest.

Baatz et al., 2004 suggest emphasizing the spectral information as much as possible, and keeping the shape information as much as necessary [23].

These kinds of guidance are useful for the analysts. But they are general. In this study it is aimed to output similar kind of advices for a specific application area. First a parameter test was applied and then the results are evaluated.

4. PARAMETER TESTS

Segmentation algorithms may either be applied to the original images, or after the application of transformations and image enhancement such as filters [25]. In this study, it is preferred to conduct the application on original images.

The input of a single band was preferred to perform the parameter tests. Band 3 was used, since vegetation has high reflectance on infrared portion

of the electromagnetic spectrum and the performance will be measured by accuracy of field boundary extraction which is directly related with the discrimination of vegetation and other land surfaces.

As segmentation scale, three different values were tested: *i)* 100, *ii)* 50 and *iii)* 20. Visualizing segmented images at different scales, different levels of abstraction can be observed.







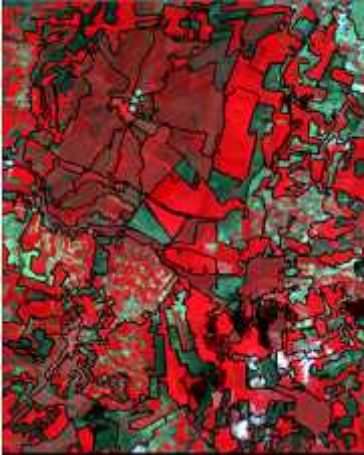


For color-shape, and compactness-smoothness parameters, value combinations (for high: 0.8, average: 0.5 and low: 0.2) were tested. In Table 1, the parameter values are given for each condition named as A, B, C, D, E, F, G, H and I. The segmented images of each condition are given by Table 2, 3 and 4 for scales 100, 50 and 20, respectively.

Table 1. Conditions used in segmentation tests.

Segmentation Parameters	Conditions								
	A	B	C	D	E	F	G	H	I
Color	0.8	0.8	0.8	0.2	0.2	0.2	0.5	0.5	0.5
Shape	0.2	0.2	0.2	0.8	0.8	0.8	0.5	0.5	0.5
Compactness	0.8	0.2	0.5	0.8	0.2	0.5	0.2	0.8	0.5
Smoothness	0.2	0.8	0.5	0.2	0.8	0.5	0.8	0.2	0.5


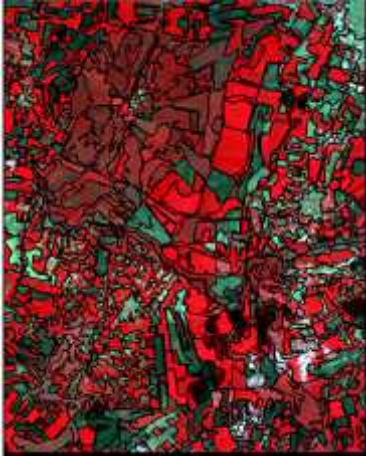
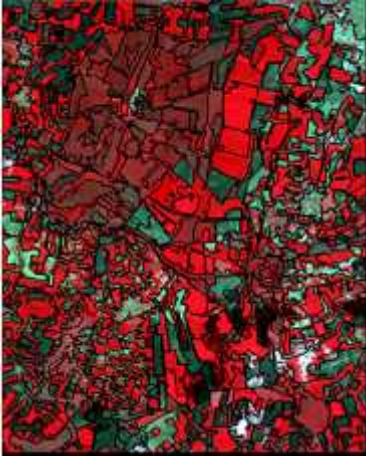

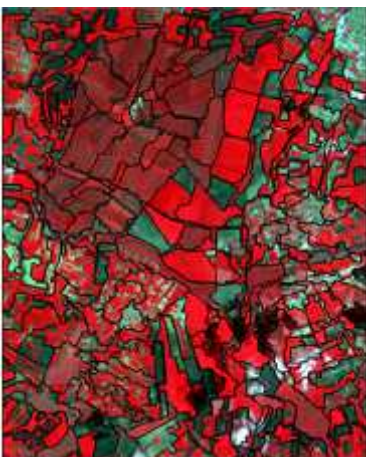



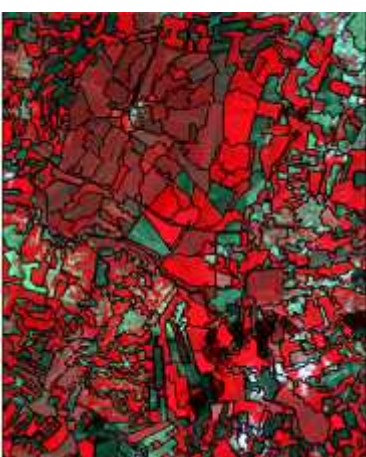
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Table 2. Segmented images for SP 100.

Condition A	Condition B	Condition C
		
Condition D	Condition E	Condition F
		
Condition G	Condition H	Condition I
		

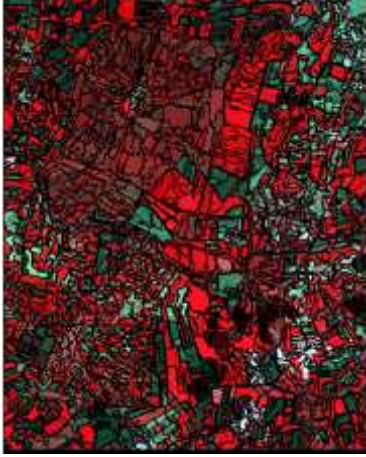

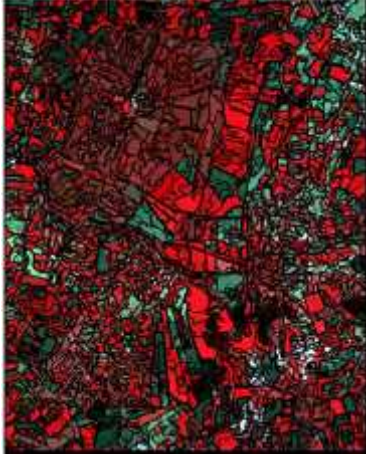
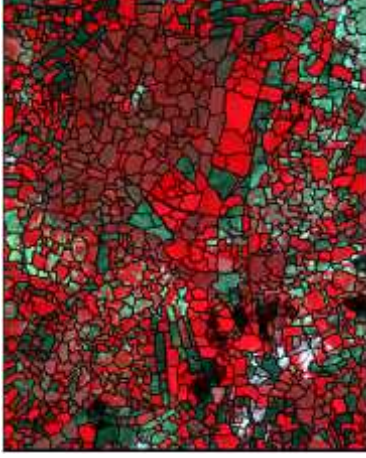

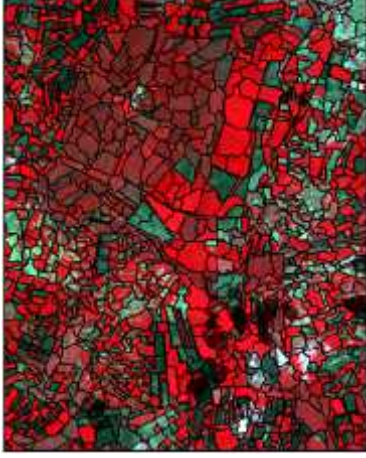



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Table 3. Segmented images for SP 50.

Condition A	Condition B	Condition C
		
Condition D	Condition E	Condition F
		
Condition G	Condition H	Condition I
		

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Table 4. Segmented images for SP 20

Condition A	Condition B	Condition C
		
Condition D	Condition E	Condition F
		
Condition G	Condition H	Condition I
		

5. FINDINGS

Segmentation evaluation can be applied by direct and/or indirect methods. As one of the direct methods, visual analysis can be executed. Another method may be using a measure to quantify the goodness of the segmentation as Tian and Chen, (2007) developed. In their study the measure, termed Gs, takes into account both the overlapping areas and the mismatching areas to compare the reality and the produced image objects [10]. As an alternative it is possible to proceed with the classification of the segmented image, and then indirectly assess the segmentation results through the classification accuracies [9].

It is suggested by Definiens Imaging that “a strong and experienced source for the evaluation of segmentation techniques is the human eye”, mentioning that even a result is sufficient by a quantitative assessment, it still has to seem visually correct for the human eye [17]. For this study, visual analysis is chosen.

By visual analysis it is obviously seen that the objects produced in each case are different. Observing the 27 different segmented images and comparing the parameter values, the findings given below were reached:

Segmentation Scale:

Segmentation scale is a measure of object abstraction. Although there are some studies for automated methods, segmentation scale parameter is often selected depending on subjective trial-and-error methods [19], [20].

In this study, three different segmentation scale values (100, 50, 20) were tested and visually analyzed. The best fitting object size for segmenting the agricultural fields was obtained in scale 50. In scale 100, some of the fields were merged and couldn't be discriminated whereas in scale 20 over segmentation occur. This value cannot be generalized since it depends on the specific parameters such as field sizes of the region, satellite resolution etc. . The most important factor for the scale selection is the purpose of the study. As can be observed from the views of segmented images, each scale seems to be appropriate for different feature extraction purposes. If the study area is extended to a wider frame, many fields that are relatively smaller in size would also be involved in. In such a case, as each task requires its specific

scale, a multi-level segmentation may be preferred. Different scales could be used for different sized objects while the features of comparable sizes (such as forest, crop fields and urban) can be segmented in the same level. It has to be mentioned here that in a multi-level system, each segmentation other than the first one, will be operated using the parent segmentation boundaries as the basis. So, every image object will separately have child image objects that form the whole when pieced together.

Color, Shape, Compactness, Smoothness Parameters:

When the value of ‘shape’ factor is increased, fields with different characteristics can easily be distinguished well such as neighboring fields having different crop types, vegetation covered fields and harvested fields. However, the neighboring fields with the same crop type and belonging to the same planting term are not extracted successfully although there is road lying between them, because the algorithm searches for a line that is suitable to split the area into parts having sufficient difference in characteristic. However, a field boundary or track line of a road can be eliminated if the two sides have similar color values.

On the contrary, increasing the value of ‘color’ factor has an effect in discriminating the fields having same or similar kind of crops even with little dissimilarities, depending on efficient recognition of the roads between the fields.

Increase in ‘compactness’ value causes a well discrimination of sharp boundaries or clear urban structures, but it can also merge regions having very different characteristics since it ignores reflectance. It has a tendency to follow round closed polygons since it searches for compact regions. Therefore the results mostly do not give good results for legged shapes, such as passing over roads, railways, rivers. Although for some situations it can provide advantages, it has to be kept in minimum weight. The other disadvantage of giving weight more than needed is causing over-partitioning inside the same fields even for little variations. The variations in vegetation color can arise from the variations in reflectance of crops planted in different topographies, which is highly relational with the sunshine duration, or irrigation may have effects on reflectance as the same way.

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Increasing the 'smoothness' value can cause formation of segments consisting of mixed features such as crop fields including man-made structures.

6. CONCLUSION

Segmentation is an essential process for most subsequent image-analysis tasks [21], because, using the object-based approach, only a successfully segmented image will lead to convincing outputs.

The most common approach to determine the segmentation parameters is trial-and-error method until reached to a satisfactory result. The two problems that have to be clearly solved is to understand what is 'satisfactory' and how to 'measure' it [24]. The trial-and-error method is conceptually simple, however without an approach it's time consuming to establish the parameter value selection. Therefore the analyst should have the clear definition of what the expected and acceptable results are, considering the main aim. To provide meaningful objects by segmentation, the process should be conducted and evaluated according to the feature classes of interest. Value selection for segmentation parameters may be good for one feature class but poor for another. Hence, the to evaluate the outputs the optimal information for further processing and data analyzing operations have to be searched [22]. In this study agricultural purposes was the main concept, therefore field boundaries were used as the test measure in segmentation operation and evaluation process.

In scope of outlining a view that summarizes the effects of increase/decrease in parameter values, the results were interpreted and a general guide for segmentation process mostly usable for agricultural purposes were provided. To perform a comprehensive assessment of segmentations depending on different parameter values 27 conditions were tested and the results were illustrated. Convincing results were described with the parameter value effects. Although it cannot be claimed that the projected values can be generalized, a guidance of segmentation for field extraction was offered.

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