

# INFLUENCE OF IMAGE SEGMENTATION PARAMETERS ON POSITIONAL AND SPECTRAL QUALITY OF THE DERIVED OBJECTS

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## ABSTRACT:

With the launch of very high spatial resolution sensors, a good positional quality can be expected from spatial imagery. Furthermore, efficient segmentation algorithms can increase the productivity and reduce the subjectivity of manual delineation. However, segmentation algorithms rely on a combination of parameters. This study used two indices to assess the quality of a segmentation in a forested landscape for 32 parameter combinations. The study area was a forest of Southern Belgium covered by an IKONOS image. A manual delineation based on a 1 : 10 000 vector database was used for the validation. The segmentation algorithm from the eCognition® software was used to produce the image objects. These image objects were then evaluated in terms of (1) positional accuracy and (2) feature consistency prior to classification. The positional quality assessment quantified the errors of location along the edges thanks to estimates of the positional accuracy and precision, that is bias and range of errors. Beside this, the consistency of object features was compared using a distance measure in a 6 dimensional feature space. The general tendency was an increased class-by-class discrimination and a lower edge precision when the scale parameter increased. Furthermore, when using a shape parameter, the compactness often improved the overall segmentation quality. However, the separation of deciduous and coniferous forests, which was the lowest of all classes, did not significantly increase with scale parameter. A small scale parameter seems therefore to be advisable.

## 1. INTRODUCTION

With the availability of very high resolution satellites (SPOT 5, FORMOSAT, IKONOS-2, QuickBird, OrbView-3), automated and semi automated methods have been developed in order to extract useful information for large scale mapping. Together with a higher level of detail, very high spatial resolution (VHR) images often have a bigger within class spectral variability. This becomes a hindrance to per pixel classification but has been taken advantage of in textural analysis (Kayitakire et al, 2002). The use of image-object in the classification conveniently reduces the within class spectral variability and incorporates extra knowledge, like shape and context, that contributes to a more accurate classification. (Flanders, 2003; Benz, 2004).

While per-field classification has proven its advantages in VHR remote sensing, the segmentation step is a key to its efficiency (Peterson, 2004; de Wit and Clevers, 2004). Due to the heterogeneity of pixel value in VHR forest images, region-based segmentation performs better than edge-based (Pekkarinen, 2002). Several methods of morphological mathematics (region growing, region splitting, pattern recognition and semi-variogram), have been developed to delineate more accurately forest stands from remote sensing data (Dorsen et al, 2003; Wang et al, 2004 ; Flanders, 2003 ; Leckie et al, 2003).

The so called “multiscale segmentation” implemented in eCognition® software as described in Baatz and Schäpe (2000) is a performant segmentation algorithm used in many studies. However, the segmentation process relies on three parameters that need to be adjusted by trial and error. The consistency of

the image segmentation is assessed in many ways. Carleer et al. (2005) proposed an empirical method where the segmentation process is considered as a classification in order to build a confusion matrix. They also proposed a generalisation index consisting in the ratio between the number of image objects and the number of reference objects. When looking at the object level, the positional accuracy of the edges becomes a key element. Radoux & Defourny (2005) developed a method to assess the edge precision independently of the object area. Edge precision is indeed used as a quality standard to define the acceptable scale at which a cartographic product can be displayed (e.g. USGS standard).

The aim of this study is to quantitatively assess the effect of segmentation parameters on the quality of image-object prior to classification. This quality assessment is based on indices of object edge positional accuracy and object features consistency.

## 2. DATA AND STUDY AREA

This study used a panfused IKONOS image of the 7 June 2004. It included four 1 m resolution multispectral bands, namely blue, green, red and near-infrared. Each band had 11 bit radiometric resolution. The viewing zenith angle was of 19 degree. This image was orthorectified with the rational polynomial function model using GCP's from a DGPS survey and a DEM interpolated from 5-m contour line. The total RMSE calculated from independent GCP's was of 1.7 m.

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A 12 km<sup>2</sup> cloud free subset of the image was considered for this study. This area was located in Southern Belgium near the city of Spa-Francorchamps. It was chosen for its fragmented forested landscape alternating small coniferous and deciduous stands. A total of five coniferous species and eight deciduous were present with oak (*Quercus* sp), beech (*Fagus sylvatica*) and spruce (*Picea abies*) accounting for more than 85%. This landscape structure and this species composition were close to the ones of the major forests of Southern Belgium.

A 1:10,000 reference dataset from the Belgian National Geographic Institute (NGI) covered the entire area. The reference database of this study used the NGI vector database as a skeleton for visual delineation. This delineation was performed on screen with a constant display scale of 1:5,000 (figure 1.) in order to match forest stand edges on the image with. Edges between trees and clear cuts were added to the database. The resulting polygons were classified by photo-interpretation assisted by the existing vector database and completed by a field survey. Three associations of land cover were distinguished, namely deciduous forest, coniferous forest and “non forest” which included clear cuts, crop fields and bare soils.

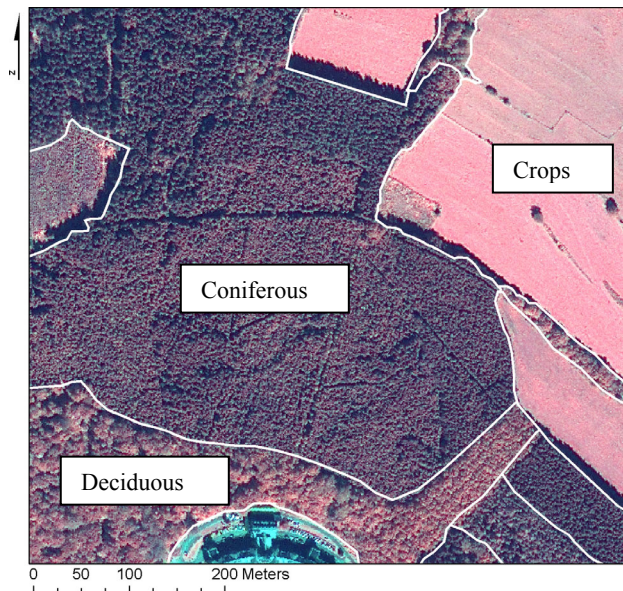


Figure 1 : Visual delineation used as reference dataset.

### 3. METHODOLOGY

The method proposed here for image-object quality assessment includes three steps, namely (1) the segmentation, (2) the class separability assessment and (3) the edges positional quality control. The image was segmented 32 times allowing to test parameter combinations. Object features were then extracted to compute the class separability. The three above mentioned classes, namely deciduous, coniferous and non forest, were used at this stage. The method of positional quality control implemented in Radoux & Defourny (2005) was then applied to quantify the errors along the edges between each class.

### 3.1 Image segmentation

The delineation of homogenous land cover objects was performed using the segmentation algorithm introduced by Baatz and Schäpe (2000) and implemented in e-Cognition ® software. This algorithm is based on region-merging. Each pixel is first considered as a separate object. Those objects are then iteratively merged by pairs to form larger objects. The merging decision is based on a local spectral homogeneity criterion, describing the similarity between adjacent image-objects. The pairs of objects with the smallest increase in variance are merged. The process terminates when the smallest increase is above a user-defined threshold (scale parameter). A second parameter weights the contribution of colour and shape in the variance measure. The last parameter splits the shape factor in compactness and smoothness (Definiens, 2002). These parameters were combined in order to test their effect on the segmentation quality. The image was segmented using scale parameter of 25, 30, 40 and 50. Out of this range, objects were obviously too small or too big. For each scale parameter, shape parameters were introduced as shown on table 1.

Compactness	0	0.5	1
Shape			
0		Y	
25	N	Y	N
50	Y	Y	Y
75	Y	Y	Y

Table 1. Combinations of shape and smoothness parameters for each scale parameter. “N” means “not tested” and “Y” means “tested”. Please note that compactness parameter is not when shape parameter is null.

### 3.2 Separability assessment

The class separability was measured using the Bhattacharyya distance between two classes (Carleer & Wolff, 2006). It used all polygons included in each of the three classes of interest, that is at least 30 000. This distance included two terms. The first term compared the means of the classes while the second term compared their variance. Once again, the high number of polygons used to estimate these means and variances is high enough to ensure a good representativity.

$$B = \frac{1}{8} * (\mu_1 - \mu_2)' * ((\Sigma_1 + \Sigma_2)/2)^{-1} * (\mu_1 - \mu_2) + \frac{1}{2} * \ln \frac{(\det(\Sigma_1) + \det(\Sigma_2)) / 2}{(\det(\Sigma_1) * \det(\Sigma_2))^{1/2}}$$

Where  $\mu_i$  and  $\Sigma_i$  correspond to the mean and the covariance matrix of the class  $i$ , respectively.

These matrices were built using six object features, namely mean and variance in the green, red and near-infrared bands. The mean value mimicked a pure pixel of coarser resolution while the variance was a basic texture index.

### 3.3 Positional quality of the edges

The positional quality of the edges was evaluated based on the concepts of accuracy and precision as described in Mowrer & Congalton (2000). The first estimator was the bias and the second, the mean range. Based on the method presented in Radoux & Defourny (2005), these estimators were derived after intersecting the image objects with the reference dataset. The area of the non-matching polygons was counted as negative when it induced an underestimate of the reference object area and as positive in the other case. The bias was then calculated by adding the signed areas for each interface type, and the mean range was defined as the sum of the unsigned area, minus the absolute value of the bias.

These two estimators were normalized by the total interface length in order to be expressed in map unit (m) and to be independent of the object size. The resulting areal values were then normalized by the total interface length. On the study area, the length of interfaces was of 27, 48 and 35 km for deciduous / non-forest, coniferous / non-forest and deciduous / coniferous edges, respectively. Bias and absolute errors resulted from no less than 3 000 polygons, giving a high representativity on the mean values.

## 4. RESULTS

### 4.1 Separability assessment

The class by class separability values were significantly different for each pair of classes and the influence of the scale parameter varied depending on the classes being considered.

The lowest averaged Bhattacharyya distance (0.7) was between the two forest classes and the highest value (2.08) was between coniferous and non forest. The separation index of deciduous forests and crop fields was equal to 1.16.

In the range of scale parameters addressed in this study, there was a strong positive correlation between scale parameters and Bhattacharyya distance for each pair of classes ( $R^2 > 0.97$ ). Increasing the shape factor always improved the separation of the classes, but this effect was of low amplitude between deciduous and coniferous (fig. 2).

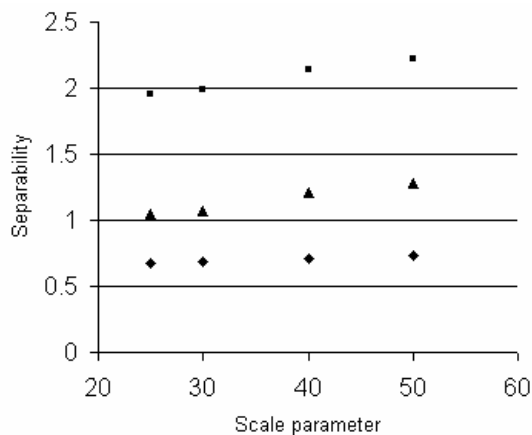


Figure 2. Bhattacharyya distance in function of the scale parameter for the three pairs of classes, namely deciduous / coniferous (diamonds), deciduous / non forest (triangles) and coniferous / non forest (squares).

The shape factor had an effect similar to the scale parameter, that is a tendency to improve the distinction between two classes when increasing, but in this case the effect was not significant and can thus not be generalized.

Concerning the effect of the compactness parameter, there was no important trend on the mean class separability despite the expected effect on object shapes. However, there was a significant positive effect of the compactness to discriminate between coniferous and deciduous forests (table 2).

Table 2 : Mean Bhattacharyya distances between the classes “coniferous” and “deciduous”. Compactness values are on the column and scale parameter on the lines.

Scale	Compactness 0	Compactness 0.5	Compactness 1	Mean
25	.65	.67	.71	.68
30	.68	.66	.73	.69
40	.67	.71	.74	.71
50	.69	.72	.75	.72
Mean	.67	.69	.73	.70

### 4.2 Positional quality of the edges

Edges accuracy was assessed thanks to bias and absolute error. Bias values were statistically different from zero but could be neglected from a cartographic viewpoint. The mean of all biases was indeed 0.3 m with a standard deviation of 0.36 m, remaining below the pixel size. This positive bias highlighted a slight tendency to overestimate the darkest of the 2 classes along an edge.

The absolute delineation error was different for each class. The planimetric quality ranked the three class-by-class groups in the same order as for the separability test, that is deciduous/non-forest, coniferous/non-forest and deciduous/coniferous. The absolute delineation error was correlated to the scale parameter with high  $R^2 (> 0.98)$ . The linear regression showed an increasing planimetric error with the scale factor (fig. 3).

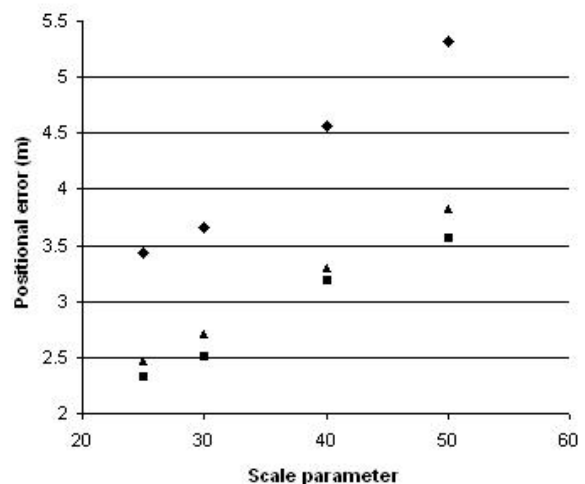


Figure 3. Positional error in function of the scale parameter for the three pairs of classes, namely deciduous / coniferous (diamonds), deciduous / non forest (triangles) and coniferous / non forest (squares).

The influence of shape and compactness parameters depended on the considered classes and on the scale parameter. There was no significant general trend, especially for the small scale parameters. However, a propensity to improve the positional accuracy by increasing the compactness parameter was observed (table 3).

Table 3 : Mean positional errors (m) for scale parameters 40 and 50 along the deciduous / coniferous edges.

Shape	Compactness		
	0	0.5	1
0		6.82	
25		5.98	
50	5.32	4.74	3.99
75	5.93	5.19	4.46

## 5. DISCUSSION

The proposed methodology integrated two complementary quantitative quality controls helpful to compare image-objects. It was applied on the sensibility analysis of parameters in the multiresolution segmentation implemented in eCognition® software.

The separability assessment using Bhattacharria distance had the advantage of being independent from the classification method. However, it could only be used as a relative measure as the actual classification accuracy remained unknown. On the other hand, the positional indices had a straightforward meaning related to cartographic standard and could therefore be used as absolute values. Furthermore, the small number of parameter combinations was restrictive in terms of result analyses, so that non linear relationship could not be tested.

The class-by-class comparison highlighted differences on object quality indices that could not be neglected. With the lowest separation distance and the largest range of positional errors, major confusions could be expected from deciduous / coniferous discrimination. As the scale parameter had no effect on the separability of those classes but induced larger positional errors, it seemed advisable to favour small scale parameters. However, compactness still had a positive influence on positional accuracy and class discrimination. A small shape factor dedicated to compactness could thus presumably improve the classification results.

The high positional error values with respect to the 1 m pixel size were often due to tree shade included in forest segments. With this concern, high smoothness percentage were more efficient to delineate elongated shaded areas in the case of big scale parameter (figure 4). Unfortunately, high smoothness parameter also created artefacts from shaded or darker areas through stand borders (figure 5). Without the influence of these two types of rough errors, the positional accuracy of the segmentation was in fact very good (less than 2 m).

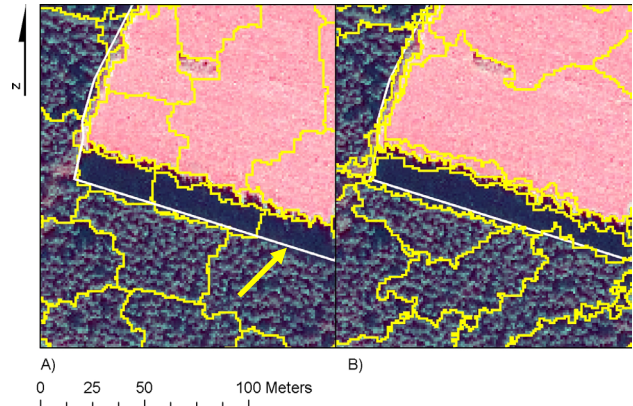


Figure 4 : Segmentation along the edge between coniferous stand and crop field. The shadow cast by the trees is incorrectly segmented with A) high compactness parameter and correctly delineated with B) high smoothness parameter.

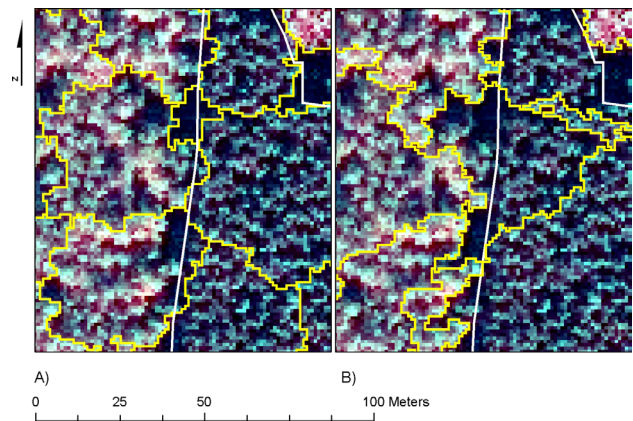


Figure 5 : Delineation error along the edge between deciduous and coniferous with A) high compactness and B) high smoothness parameter.

## 6. CONCLUSIONS

This method integrated two complementary indices to assess the image-object produced by automated image segmentation. It was applied to evaluate the effects of scale, shape and compactness parameters on a single level of the multiresolution segmentation implemented in eCognition®.

The overall tendency was an increased class-by-class discrimination and a lower edge precision when the scale parameter increased. Furthermore, when using a shape parameter, the compactness often improved the overall segmentation quality. However, the separation of deciduous and coniferous forests, which was the lowest of all classes, did not significantly improve with scale parameter. A small scale parameter seemed therefore to be advisable.

While the positional quality could be used as such, the use of the Bhattacharria distance is not representative of the diversity of features available in object-based classification. The conclusions of this study should therefore be applied with care. However, this work remains an objective comparison method and revealed the issue of edge quality and management of the shades. Solving of these issues is a key step towards automated large scale forest cartography from satellite images.

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