

Satellite Imagery Segmentation: a region growing approach

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Abstract. This work presents a segmentation method based on a region growing approach. It has been implemented in the geographic information and image processing system (SPRING) which has been developed at INPE. The technique is applied to segment images which are being used to assess land use changes in the Amazon region. Segmented Landsat-TM images are shown to illustrate the technique.

Keywords: Image Segmentation, Region Growing, Euclidean Distance.

1 Introduction

Image segmentation is a basic task in image analysis whereby the image is partitioned into meaningful regions whose points have nearly the same properties, e.g., grey levels, mean values or textural properties.

The segmentation process is one of the first steps in the remote sensing image analysis: the image is partitioned into regions which best represent the relevant objects in the scene. Region attributes such as area, shape, statistical parameters and texture can be extracted and used for further analysis of the data.

The segmentation task can be accomplished in two ways: 1) dividing up the images into a number of homogeneous regions, each having a unique label, 2) determining boundaries between homogeneous regions of different properties. These segmentation techniques are known as region-based segmentation and edge detection, respectively.

Each approach is affected differently by various factors. For some applications edge detection approach has not been successful. The prime cause is the presence of small gaps in edge boundaries which allow merging of dissimilar regions. Other disadvantages are that these techniques are also often very sensitive to local variations intensity and the contours obtained are usually not closed. Therefore, in order to yield closed boundaries the edges must be linked up.

On the other hand, region-based segmentation always provides closed contour regions which is a requirement in many applications. Besides, it is very

simple and effective in many applications. Errors in the regions boundaries are the main drawback of this approach: edge pixels might be joined to any of the neighboring regions. Among region-based segmentation approaches are region growing methods which will be discussed in the next section in more detail.

Other segmentation techniques combine the edge-based and region-based information taking into account their complementary nature (Le Moigne and Tilton, 1995) or use ancillary information to guide the segmentation procedure (Mason et al, 1988). The selection of any of these segmentation approaches greatly depends on the type of data being analyzed and on the application area.

Within this framework, this paper describes a region growing segmentation method which has demonstrated technical feasibility for images of forest and agricultural regions. This algorithm has been developed at INPE and implemented in the Geographic Information and Image Processing System- SPRING (DPI et al, 1995). It has been intensively used in the segmentation of Amazon region images to assess land use changes. Some resulting segmentation of Landsat-TM images are also shown.

2 Region growing approach

Let X denote the grid of sample points of the image, and P let be a logical predicate which measures the homogeneity of a region. The segmentation can be defined (Zucker, 1976; Schoenmakers et al , 1991) as a partition of X into disjoint non-empty regions R_1, R_2, \dots, R_n so that the following conditions hold:

- i. $R_i, i=1,2,\dots,n$ is digitally connected, i.e., the regions must be composed of contiguous lattice points (see Rosenfeld (1970) for a discussion of connectivity in digital pictures).
- ii. $\bigcup_{i=1}^n R_i = X$.
- iii. $P(R_i) = TRUE$ for $i=1,2,\dots,n$.
- iv. $P(R_i \cup R_j) = FALSE$ for $i \neq j$, where R_i and R_j are adjacent (4-connected at some point).

Zucker (1976) has pointed out that these properties suggest many important aspects of the segmentation algorithms but do not lead to a unique algorithm for performing the segmentation. Many segmentation schemes have incorporated these conditions but Schoenmakers et al (1991) have proposed some changes in these constraints in order to adapt the algorithms with heuristics appropriate to each application, given the needs of the end-user.

The region growing technique is an iterative process by which regions are merged starting from individual pixels, or another initial segmentation, and growing iteratively until every pixel is processed. Roughly speaking, it can be described by the following steps:

1. Segment the entire image into pattern cells (1 or more pixels).
2. Each pattern cell is compared with its neighboring cells to determine if they are similar, using a similarity measure. If they are similar, merge the cells to form a fragment and update the property used in the comparison.
3. Continue growing the fragment by examining all of its neighbors until no joinable regions remain. Label the fragment as a completed region.
4. Move to the next uncompleted cell, and repeat these steps until all cells are labeled.

The drawback of this traditional scheme is that, at each iteration, one or several merges occur so that the resulting segmentation is dependent on the order of the merges. In order to solve this problem Tilton (1989) has proposed an iterative parallel algorithm in which only the best merges are authorized. At each iteration, a set of subimages is defined, and the most similar pair of spatially adjacent regions is merged in each subimage. The segmentation here proposed is simpler than Tilton's algorithm but it has been provided satisfactory results in the segmentation of some forest and agricultural images.

3 Segmentation algorithm

Our approach is based on the traditional region growing technique, with some modifications which partially solve the problem of the dependence on the order of the merges.

Before describing the segmentation scheme some notation and definitions used in this section is provided. \mathfrak{R} is used to denote the set of regions of the image, and $R \in \mathfrak{R}$ is an element of this set. Let $T(t)$ denote the threshold value below which two regions are considered similar at instant t , and let M_i be the mean value vector of the region R_i . Let $D(R_i, R_k) = \|M_i - M_k\|$ be the Euclidean distance between the spectral mean values of the regions R_i and R_k , and let $N(R)$ be the set of neighboring regions of R (not including R itself). The region R_k is the most similar neighboring region of R_i if $D(R_i, R_k) \leq D(R_i, R_\ell)$ for every $R_\ell \in N(R_i)$.

The stages of the procedure can be outlined in the following way:

1. In the beginning of the segmentation process, a list of regions $\{R_i, i=1,\dots,n\}$ is created (n is the number of pixels in the image). Initially each region is composed of only one pixel, so-called "seed". For each region R_i , its mean value vector and neighboring regions are stored.
2. For each region R_i its neighboring regions $N(R_i)$ are examined and:
 - the most similar neighboring region $R_k \in N(R_i)$ is chosen. If $D(R_i, R_k) < T(t)$ then R_k is called "the best neighbor" of R_i .
 - If the best neighbor of R_k exists and is R_i , then both regions are merged.
3. Every time one region is aggregated to another one it is taken out of the list.
4. The fragment mean value is updated every time one region is aggregated to it.
5. The same procedure is repeated until no joinable regions remain.
6. In the last step, small regions are merged with larger adjacent regions, in accordance with an area threshold value defined by the user.

In our implementation $T(t) = \alpha^t T(0)$, with $T(0) > 0$, $t = 0,1,2,\dots$ and $\alpha < 1$. This specification imposes that the initial merges are harder to accomplish than those at the end of the merging process, i.e., only very similar regions are merged first.

The similarity threshold value must be manually provided by the user and, therefore, a tradeoff is inevitable: if it is set too low the growing process will generate over-segmented regions, otherwise segments representing different land cover will be incorrectly merged together. The choice of this threshold value as well as the area threshold value will greatly depend on the specific application and data.

3 Results

The region-based segmentation algorithm has been tested mainly on forest and agricultural images with satisfactory results. In order to show here some results, the Landsat TM images of bands 3, 4, and 5 (path/rows 231.67, July 12, 1994) of two test sites were processed. These images cover an area in the Amazon region (Rondônia, Brazil).

Figures 1(a) and 2(a) show the original images (band 5) of the two different regions, namely site 1 and site 2, respectively. For visualization of the resulting segmentation, the original image overlapped with the regions boundaries are shown in the Figures 1(b) and 2(b) corresponding to sites 1 and 2, respectively. For the site 1 the bands 3, 4 and 5 were used in the segmentation process while only the band 5 was processed in the case 2. As we can observe the results obtained so far have been encouraging. The region boundaries have good correspondence with the contours of the landcover in the test images.

The technique here presented has been intensively used by remote sensing specialists to assess land use changes in the Amazon region (Alves et al, 1996; Batista et al, 1994; Santos et al, 1995). These works show more segmentation results.

4 Conclusions

There is still much work to be done on the problem of segmentation of satellite images. This is a critical problem since satellite images are very complex. Here we have presented a practical and simple segmentation scheme based on a region growing approach. In spite of its simplicity a preliminary assessment of the technique using images of Amazon region has shown satisfactory results. In the future we plan to apply the algorithm in other kinds of images and to perform a quantitative evaluation in more details. Improvements on the scheme proposed, such as the integration of the region-based and edge-based information, which has been proposed in many papers, are also planned.

Acknowledgments

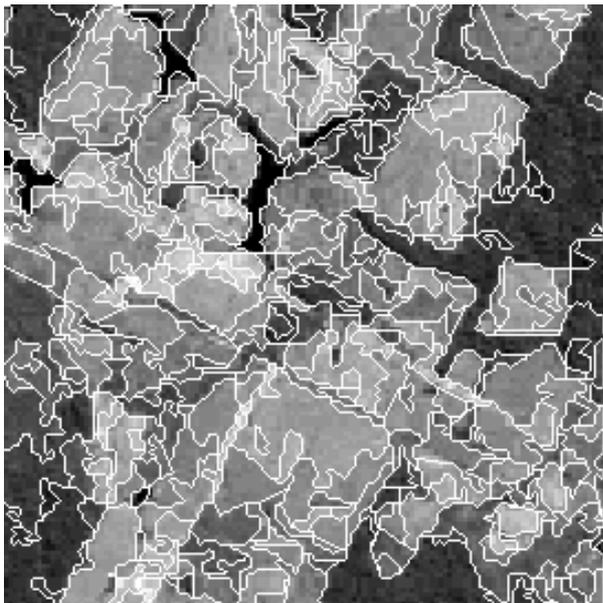
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(a)

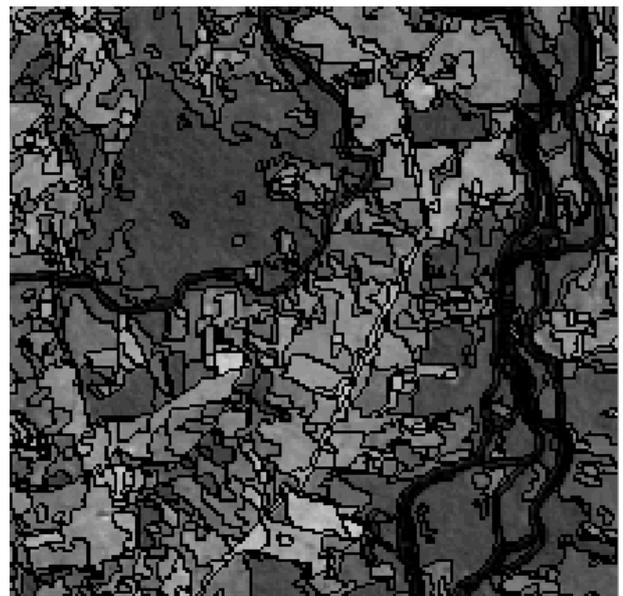


(b)

Figure 1. (a) original image (band 5) of the Amazon region (site 1) (b) edge boundaries superimposed with the original image.



(a)



(b)

Figure 2. (a) original image (band 5) of the Amazon region (site 2) (b) edge boundaries superimposed with the original image.