WATERSHED THRESHOLD AND GRAY LEVEL MORFOLOGY APPLIED TO OBJECT DETECTING IN REMOTE SENSING AND PETROGRAPHICS IMAGES

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Abstract

This work proposes a methodology to perform a semi-automatic segmentation. A watershed technique is used to extract the threshold values for image limiarization. After this step, a segmentation process is applied to limiarized image. For isolated object, a simple gradient with opening operators is used. For objects in contact, a distance transform is used for creating label markers for the watershed segmentation process. In both cases, a set of gray level morphological operators is used to simplify the original image and improve the segmentation process. Finally, the complete procedure is used to detect objects in remote sensing and petrography's images.

Introduction

The main idea of digital image processing is to build a proceeding set (computing) in order to analyze the data taken by a sensor (orbital camera, microscope and scanner), and turn interpretation process easier. These process include areas delimitation, objects characterization, map confection, and so forth (Gonzalez,1987 e Silva, 1999). One of method used to image processing is the mathematical morphology and their operators. The mathematical morphology has started in 1964, by Matheron and Serra in the Mines Superior School of Paris (Serra, 1986 and Banon & Barrera, 1988). The goal of mathematical morphology is to describe quantity geometric structures and run like an image processing techniques, having itself basic tools like boundary detection and the morphological filters. Basically there are two types of mathematical morphology, the binary technique which is applied to binary image and gray level morphology which is applied to gray level images. Morphology has been applied in medicine, engineering, cartography, geology, petrography and atmosphere studies (Dong, 1997; Ishikawa at all, 2004 e Lucia at all, 2004, Bouchet et. all, 2007). In this work, a watershed threshold technique, with gray level morphological operators are used to separate objects in remote sensing and petrography's images.

Theory Basis

Basic operators

Following Banon's notation (1999), an image *I* is a subset of a Cartesian product set *g,* where *E(m,n)* represents the pixel´s locations domain and *K* is a gray levels subset.

$$I \in g(E(m,n) \times K), K \subset \mathbb{Z}^{+}, \quad \textbf{(1)}$$

m and *n* represents the number of rows and columns of the pixel´s grid, whereas *K* is related to radiometric resolution of *I*. Most of petrography and multispectral images works with 8 bits resolution, which means that k is a set of integer numbers varying from 0 to 255. We can define the basic gray levels operators, erosion and dilatation, like:

$$\begin{aligned} A \odot B(x) &= MAX\{y : B_x + y \le A\}, \\ A \oplus B(x) &= MIN\{A(z) - B_x(z) : z \in D[B_x]\}, \end{aligned} \quad \textbf{(2)}$$

Where A and B are gray level images; *B* is known as the element structuring. This structuring element is completely known with respect to its pixels distribution. The effects of erosion are: the reduction of particles, elimination of structures smaller than structuring element, disconnection of next structures , increasing holes. In the dilatation it happened opposite effects, the size is increased, holes are closed and next structures are connected.

We can construct more sophisticated operators by applying erosion and dilatation, using the same structuring element:

$$\begin{aligned} A \circ B &= (A \oplus B) \odot B, \\ A \bullet B &= (A \odot B) \oplus B. \end{aligned} \quad \textbf{(3)}$$

In equations (3), the first is named opening and second one is the closing. The opening act as a filter, removing all objects least than the structuring element, smoothing peaks, disconnects objects and so forth. The closing is used to close holes, connect objects and smoothing external edges.

Another class of operators is the edges detectors. The most common is the morphological gradient which is defined as:

$$\nabla_{b_e,b_i}(A) = (A \oplus b_e) - (A \odot b_i), \tag{4}$$

where b_e and b_i are structuring elements. This edge detector depends on the size and shape of structuring elements and it is used in morphological segmentation.

Morphological Segmentation

Image segmentation is a set of processes which aims to isolate objects in the image from the background, i.e., partitioning the image into disjoint regions, such that each region is homogeneous with respect to some property (Haralic & Shapiro, 1985). A very used segmentation technique is the watershed transform. Roerdink and Meijster (2001) define a watershed line of a Image *A* as a set of points which do not belongs to any catchment basins *CB,* i.e.:

$$W_{shed}(A) = D \cap \left(\bigcup_{i \in I} CB(m_i) \right)^c, \tag{5}$$

where m_i is the *i*-regional minimum, *I* is a set of indexes and *D* is image domain. The main idea of this method comes from geography: imagine that a landscape being immersed in a lake, with holes pierced in local minima. The catchment basins will be filled up with water starting at these local minima, and, at points where water coming from different basins would meet, dams are built. When the water level has reached the highest peak in the landscape, the process is stopped. As a result, the landscape is partitioned into regions or basins separated by dams, called watershed lines.

The Distance Transform

The distance transform (DT) provides a metric or measure of the separation of points in the image. The main idea is that the DT operator stores the erosions of an image *A* by a family of structure elements $B(r)$, usually a disk of radius *r.* The pixels that are of a distance below or equal to *r* from the background, are the pixels removed by the erosion. Each iso-line means erosion by a structuring element with a greater radius *r.* Equation (5) shows the basic idea of distance transform:

$$DT_B(A) = A \odot B(r). \tag{6}$$

One of DT application is the particles segmentation (Vicent & Dougherty, 1994), where it is necessary to separate particles in contact.

Methodology

The proposed methodology consists of four steps:

1. Selection of image and target objects

In this first step, we choose the images, the targets to be identified and areas of study. In Figure (1) we have a TM, bands 4 (near infrared). We can note that the darker areas represent areas of low or no vegetation (savanna and deforestation for example), while the light areas are associated with dense vegetation (Guerra & Safira, 2009). The band choice is directly linked to the type of object to be studied, in which case, the zones are savannas therefore infrared band is more appropriated. To enhance the contrast and eliminates noise and undesirable small objects it should be necessary to apply closing and opening operators.

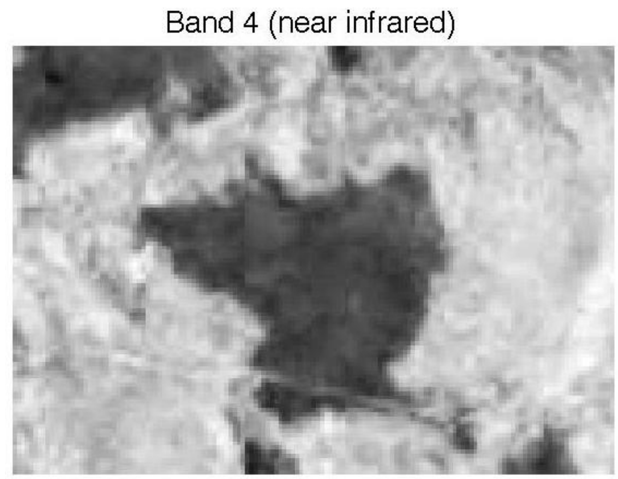


Figure 1: Image in TM band 4 (near infrared) on the study region. It is observed that the light regions represent areas of high vegetation cover while the dark regions represent the low vegetation cover.

2. Watershed Thresholding

Next step is to select the limiarizations values for object segmentation. We use the watershed technique applied to gray-levels distribution function, i.e., the histogram of band 4. By following Dougherty and Lotufo (1993), the image histogram is negated so that we can detect the regional minima which separate the major pixels populations. Figure (2) shows the histogram and the inverse or negated histogram.

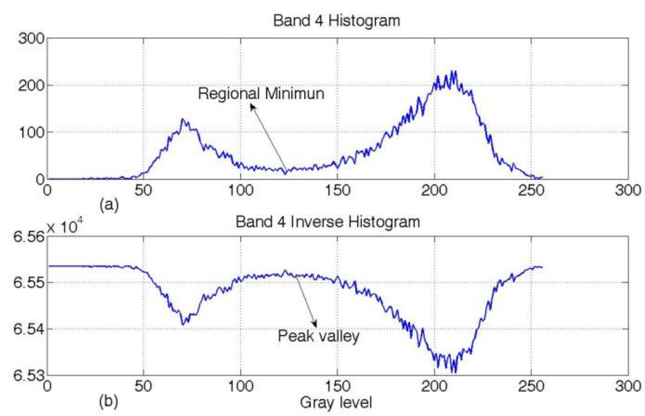


Figure 2: In (a), the histogram of band 4 showing the regional minimum separating the two most pixels populations. In (b) the negated histogram showing the peak valley related to regional minimum in (a).

In Figure (2), the histogram shows two pixels populations which could be related to savanna (from 45 to 110) and forest (130 to 255). In order to get the threshold values, it is necessary to negate the histogram and applies the watershed transform, so that we can get the peak value. Because of watershed over segmentation, the histogram an its inverse should be filtered so that we can guarantee the regional minimum catching. The filtering process is made by an opening and a closing operators, using a box structuring element with 25 neighborhoods pixels. Figure (3) shows the results and the threshold value.

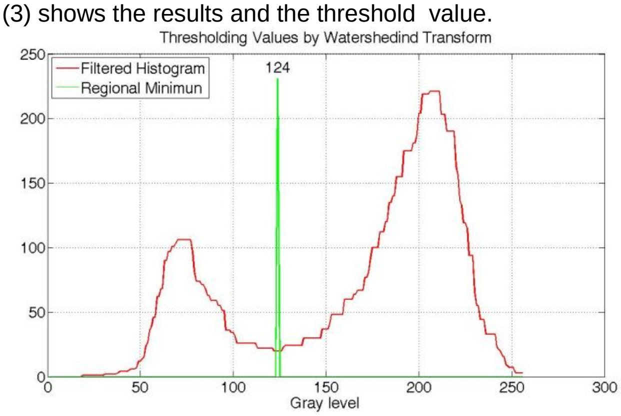


Figure (3): The regional minimum (green) of histogram (red) point to the threshold value. Note that this value separates the two more pixels populated regions.

3. Construct the Limiarization function

The threshold value got from regional minimum is the top of a object class savanna. For the bottom of this class we can set it up as zero. Now, the limiarization function can be built as:

$$\begin{cases} B_{ij} = 255, \text{ if } A_{ij} \in [L_i..L_s]. \\ B_{ij} = 0, \text{ if not.} \end{cases} \quad \textbf{(5)}$$

In relation (5) A_{ij} represents each pixel of the original image, B_{ij} is the *(I,j)* pixel of limiarized image and $[L_i..L_s]$ is the limiarization interval. In this example, the limiarization limits are $L_i = 0$ and $L_j = 124$ respectively.

4. Apply segmentation process

Finally, the limiarization function is applied on the band 4 image, so that the region savanna can be separated. In addition to this, a gradient operator or even the watershed segmentation can be applied to limiarized image in other to catch the object edge. Figure (4) shows the final results with gradient operator.

Remarks over these steps

These procedures should be applied successively for getting complete objects type delineations. The gradient is used to trace the edges over the limiarized image and the watershed segmentation should be used to improve the edges tracing. In each step it could be necessary to apply standard morphological operator to remove noise or undesirable particles. The final result is a thematic image with segmented objects and their edges, both in different colors. Because The threshold values depends on the pixels populations, the choice of values depend on the knowledge we have about the objects contained in the image, therefore, like every image processing task, the results should be validated by a specialist. The same process can be used in others types of images such that the petrography one, which we will see in the results section.

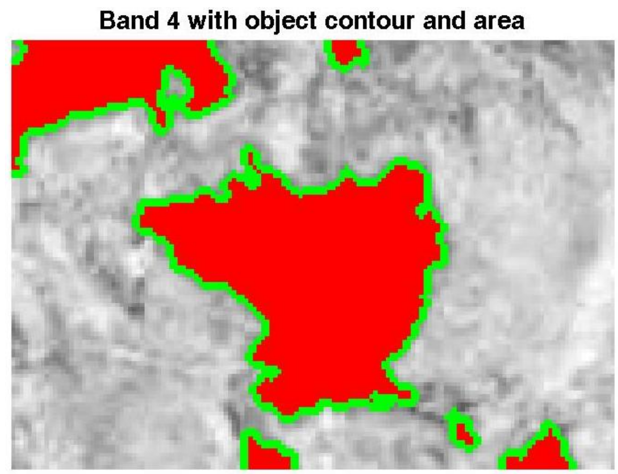


Figure (4): The objects savannas (red) and their edges (green) superposed with band 4 image.

Results and discussion

Now, we apply the methodology in petrography and remote sensing images. In Figure (5.a) we have a petrography image of a well core lamina. This image shows two phase objects, a highlighted porous media with blue color and a grain phase in gray scale. The blue color is a effect of an inject contrast. Most of The grains are connected and there are some ones with a different roughness and partially covered with contrast. In addition to this, we note that there is a lack of a contrast throughout the whole scene. Therefore, it should be necessary to apply a contrast filter in other to emphasize the phase differences.

This image is a simple RGB type, so, we can use a gray scale version of it by either separating a single component or a gray-level conversion of the RGB composition. Due to a better separation between the two phases we chose the R component of RGB image and applied a contrast adjustment filter. In Figure (5.b), the dark region is a porous phase, whereas the clear is the grain one.

For getting the threshold values we have to take the histogram of chosen image. Because of the histogram roughness it is necessary to smooth it by applying a simple morphological filter, i.e., a closing followed by an opening operator with a vertical linear structuring element. A smoothing histogram is fundamental for successful regional minima catchment. After applying the watershed transform on the filtered R component histogram we have located 5 regional minima.

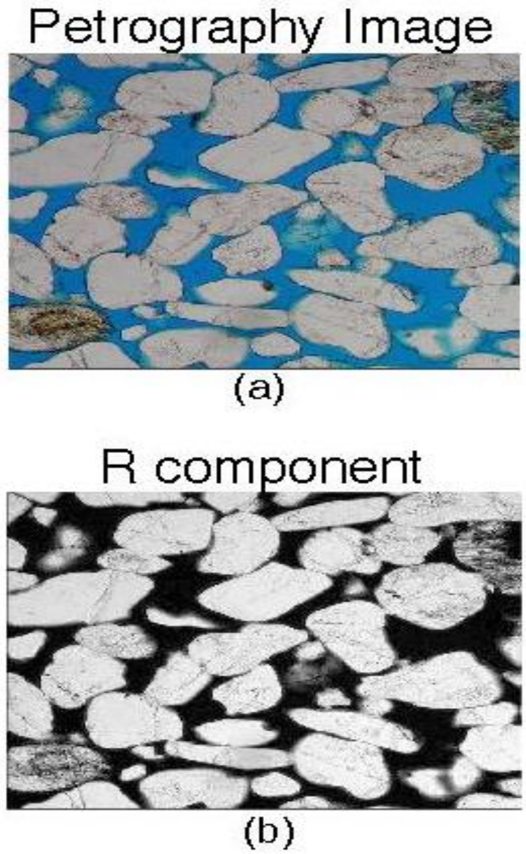


Figure (5): In (a), a petrography image of a well core lamina. In (b), the filtered R component. This image shows two phase objects, a highlighted porous media with blue color and a grain phase in gray scale.

As we can see in Figure (6) the regional minimum highlighted in green is quite near to histogram left limit and should be discarded. The others in blue are candidates for threshold values.

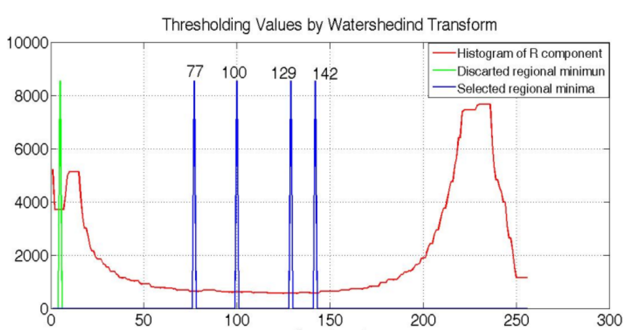


Figure (6): The selected regional minima (blue) of histogram (red) point s. The minimum highlighted in green was discarded due to its proximity to left limit histogram.

Now, for building the limiarization functions we have to choose the limiarizations limits, by means of select one or more regional minima obtained by watershed transform. Looking again to Figure (6), the regional minima in blue separate four pixels populations regions, but, the region associated with porous phase is the gray level interval [0..77]. Figure (7) shows the final results, after applying the limiarization function and segmentation process. Note that the grain phase is showed by shaded visualization image as a topographic model. This "surfing" vision emphasizes the two phase differences.

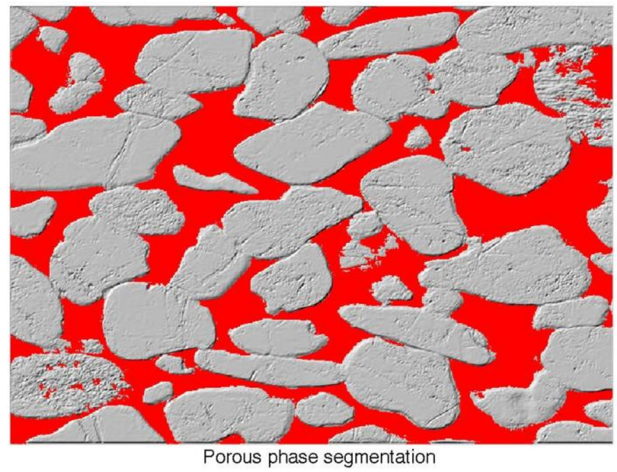


Figure (7): In red, the porous phase segmentation. The grain phase is represented by a topographic model for emphasizes the phases differences.

For separating grains phase, the chosen threshold interval was [142..255]. The segmentation results can be seen in Figure (8). We can see that the segmentation process was capable of catching all pixels associated with grains but it was not able to isolate all the objects. The gradient operator only get to detect the edges between porous and grains phase. For granulometry, mineralogy and others petrography studies such results are not desirable since it is impossible to extract metrics from individually grains. For overcoming this situation it is necessary to apply some more operators during segmentation process. If we see Figure (7) it is possible to note that the grains are in contact each other and some contacts are stronger than others. In addition to this, there are groves inside grains.

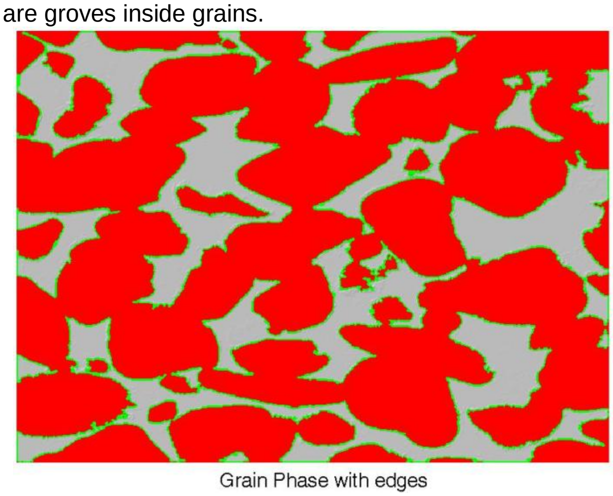
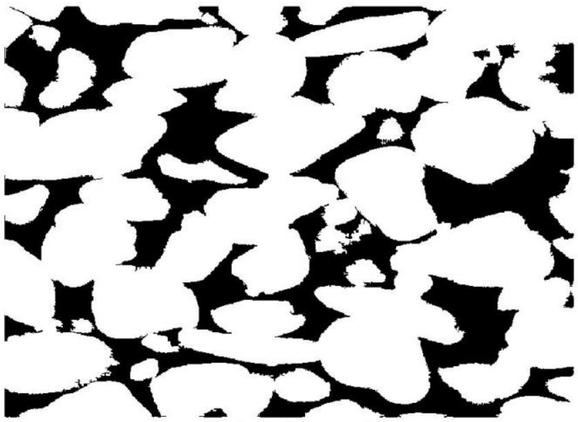


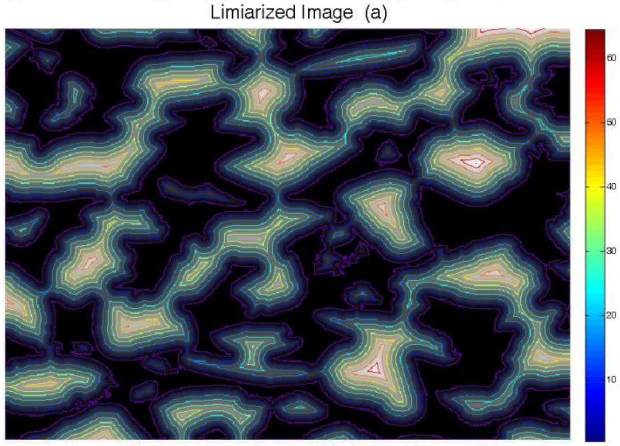
Figure (8): In red, the grains phase segmentation. In green, the catching edges. We can see that the simple segmentation process was not able to detect the contacts between grains.

In this case the groves should be associated with fractures, cracks or even cut problems during blades assembling.

We begin with a distance transform applied to limiarized image so that it is possible to extract the regional maxima associated with each object grain. Figure (9) shows the limiarized image and its transform with iso-lines.



Limiarized Image (a)

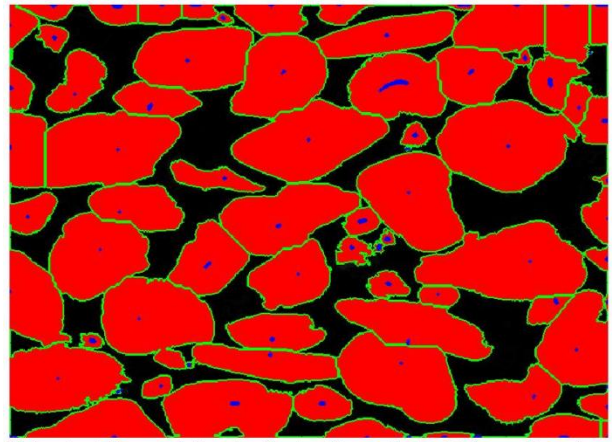


Distance Transform of Limiarized image (b)

Figure (9): In (a) the limiarized image. In (b) the distance transform of image in (a). The inners iso-lines have high distance values.

Each object has an inner iso-line so called regional maximum. The regional maxima are used as markers for the watershed segmentation. These markers are flags for the catchment basin establishment and a way to trace the contacts edges between grains. Figure (10) shows the final results after applying the distance transform. It is possible to note that the markers (in blue) works as a label for each object grain and as a regional minima pointers for watershed lines tracings. With isolated particles, it is possible to extract metric and statistical parameters for building a pattern spectrum signature of the rock, for instance.

In the petrography images, the segmentation process was applied to particles objects, the rock grains. Now, in the followed example, we will apply the process in a texture image. Figure (11.a) shows a NDVI image getting from landsat TM sensor.



Watershed Segmentation for Grains Phase Using Distance Transform

Figure (10): Watershed segmentation of phase grains. In green, the individuals grains edges. In blue, inside each grain, the regional maxima extracted from distance transform.

The normalized index vegetation (NDVI) is obtained from processing red and infrared bands. We are interested in mapping three classes of objects: water zone, low vegetation and forest.

NDVI image from Eixo-Forte em Santarém, oeste do Pará (a)

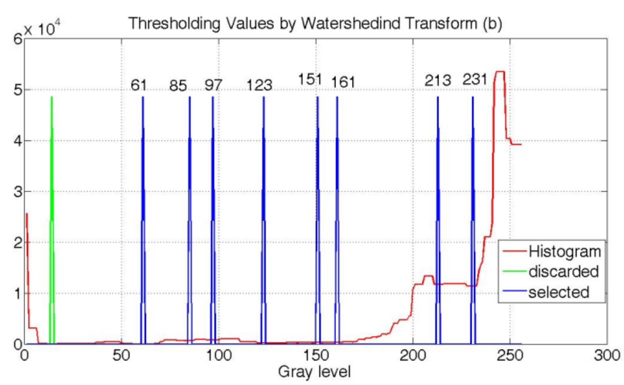
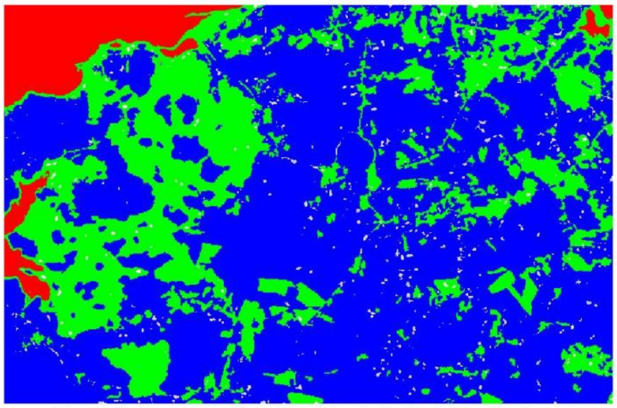


Figure (11): In (a) the NDVI image from Eixo-Forte, Santarém (Pará). In (b) the threshold values getting from watershed transform.

Figure (11.b) shows the histogram and the selected regional minima. For classifying the NDVI image, we have to construct three limiar functions. The threshold intervals obtained were: [0 .. 123] for water zone, [124 .. 231] for low vegetation zone and [232 .. 255] for forest and high vegetation zone. Figure (12) shows the final resulting after applying the morphological operators proposed in this methodology. The classes extracted from regional minima were showed by means of a thematic image, with colors representing each class; (red-water), (green –low vegetation) and (high vegetation).



Thematic Image resulting from Morphological classification

Figure 12: Thematic image resulting from morphological classification. In red, we have the water zone, in green the low covered vegetation zone and in blue, the forest and high covered vegetation zone.

Pixels which did not fall in one of the proposed classes were represented with gray color. Although this results look good by simple visual inspection, it is necessary to refine and validate the classification, if we use this thematic image in others works. In this work we were not worry to perform a very accurate classification procedure; the main goal is to show that it is possible to use the methodology for classification procedures.

Conclusions

The results obtained show that it is possible to segment textures and particles images with this semi-automatic methodology. Watershed transform is a good tool for extract threshold values. The areas of interest have been identified (rock grains, porous phase and vegetal coverage zones). An additional watershed transform should be applied to more complex images, mainly if we have particles in contact. The key of success in applying this methodology are the image quality, an adequate choice of threshold values and the application of a correct set of morphological operators which are responsible for a successful reconstruction.

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