DETECTION OF HIGHWAYS IN HIGH RESOLUTION IMAGES USING MATHEMATICAL MORPHOLOGY TECHNIQUES

A. S. Ishikawa [a], E.A. Silva [b]

[a, b] UNESP - São Paulo State University, 305 Roberto Simonsen St., Brazil, 19060-900
[a] aline.ishikawa@gmail.com
[b] erivaldo@fct.unesp.br

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ABSTRACT:

This paper seeks to apply routine for highways detection through the mathematical morphology tools in high resolution image. The Mathematical Morphology theory consists of describing structures geometric presents quantitatively in the image (objectives or features). This explains the use of the Mathematical Morphology in this work. As high resolution images will be used, the largest difficulty in the highways detection process is the presence of trees and automobiles in the borders tracks. Like this, for the obtaining of good results through the use of morphologic tools was necessary to choose the structuring element appropriately to be used in the functions. Through the appropriate choice of the morphologic operators and structuring elements it was possible to detect the highways tracks. The linear feature detection using mathematical morphology techniques, can contribute in cartographic applications, as cartographic products updating.

1. INTRODUCTION

Cartographic documents in different scales are fundamental tools to know the environment in way local, regional and global, and to help in the socket of necessary decisions for the planning and administration of resources. The current situation of the world cartography indicates that, for many areas of the planet, don't exist cartographic documents that they supply information with appropriate quality, being this a so much common problem for developed nations as for developing countries (Estes; Mooneyhan, 1994).

The Brazilian Cartography presents great deficiency in cartographic products updating. This happens due to the existent emptiness, incorrect scales, products that aren't adapted to the established quality pattern or for lack of an effective politics gone back to the territory mapping. Aiming at to reduce that mapping lack in great scales, the cartographic community is addressing efforts in the search of alternative methodologies so that the cartographic products can be updated with larger speed, efficiency and smaller cost. This process is of great importance for the obtaining of reliable and economically viable cartographic bases, without the need to accomplish conventional procedures, that you are costly and slow.

A fundamental factor in the process of cartographic updating is the changes detection, which according to Colwell (1974) it consists of the modifications recognition happened in the terrestrial surface through the time. Among the techniques of changes detection, it was chosen for this paper the integrated use of Remote Sensing products and Digital Image Processing (DPI) techniques. Among the several tools of DPI, it was chosen the Mathematical Morphology (MM) for the interest features detection in orbital images. The MM is a technique very used and researched in Universities and Research Centers of everyone, tends as base to study the sign geometry, being a powerful tool for images analysis, mainly where geometric aspects are relevant.

Considering the country wide national cartography deficiency, this work seeks to contribute for the automation of the Cartography field through the integrated utilization of Remote Sensing data and Digital Image Processing techniques. The main objective of this work was to apply a routine for highways detection in high resolution images (QuickBird) through the Mathematical Morphology tools, with views to the cartographic updating.

2. MAIN BODY

2.1 Mathematical Morphology

The Mathematical Morphology (MM) was originally developed by Matheron and Serra at the École des Mines in Paris. It is a set-theoretic method of image analysis providing a quantitative description of geometrical structures.

According to Soille (1999), MM can be defined as theory for the analysis of spatial structures. It is called of morphology, because it consists at analysing the shape and form of objects. It is mathematical because the analysis bases on set theory, integral geometry, and lattice algebra. Goutsias and Heijmans (2000) mention that, the main idea of the MM is to analyze the shape of objects in an image by probing the image with a small geometric template (e.g., line segment, disc and square) known as the structuring element.

2.1.1 Structuring Element

Facon (1996) defines the structuring element as a completely defined and known set (form and size). The basic principle of the mathematical morphology lives in the operation of sets among the image tests and the structuring element known, obtaining the relative information to the geometry and the topology of that set.

For the obtaining of good results through the use of morphologic tools is necessary to choose the structuring element appropriately to be used in the functions. The element estruturante is the key for the success of the operations, since it is chosen in an appropriate way.
The choice of the element estruturante depends on the geometric form object to be extracted in the image. For instance, linear structuring elements are appropriate for the linear objects extraction. It can also be considered several rotations of the structuring element to extract the wanted forms from the objects contained in the image. For instance, it is wanted to extract the highways, the ideal would be to use a structuring element with mask in form of line segment, however this element should be rotated in several directions to answer the multiple orientations of the highways. The size of the structuring element depends on the characteristics that you want to extract in the image. Structuring elements larger preserve larger characteristics while smaller elements preserve smaller details in the image. Some examples of structuring elements are shown in the Figure 1.

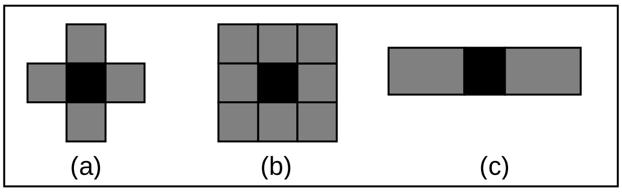

Figure 1. Structuring elements: (a) cross, (b) square and (c) line.

The type and nature of detected information depend of the structuring element and studied image choice. The shape and size of the structuring element must be adapted to the geometric properties of the image objects to be processed.
The Mathematical Morphology presents as principle two basic operations: Erosion and Dilation, from which all other morphological operations are derived.

a) Erosion: According to Soille (1999), the erosion of a set X by a structuring element B is denoted by $\varepsilon_B(X)$ and is defined as the locus of points, x, such that B is included in X when its origin is placed at x:

$$\varepsilon_B(X) = \{x \mid B_x \subseteq X\} \tag{1}$$

This definition indicates that the structuring element B slides on the image and it compares the neighborhood of each pixel with the neighborhood of the central point (that most of the time will correspond to the physical center of the structuring element) preserving the pixels where the neighborhoods coincide. In general, the erosion presents the following effects in their results: decrease of particles, elimination of the inferior size grains than of the structuring element, increase of the holes and it allows the separation of close grains.

b) Dilation: According to Soille (1999), the dilation of a set X by a structuring element B is denoted by $\delta_B(X)$ and is defined as the locus of points x such that B hits X when its origin coincides with x:

$$\delta_B(X) = \{x \mid B_x \cap X \neq \varnothing\} \tag{2}$$

For this definition, when the structuring element is verifying the image, the neighborhood of the central point should have a intersection with the relevant points of the image, capturing more pixels. The application of this operator produces the following effects: increases the objects in the image, fills out small holes and connects close objects.
Erosion and dilation can be used in a variety of ways, in parallel and series, to give other transformations including thickening, thinning, pruning and many others.

c) Thinning: According to Soille (1999), the thinning of a set X by a composite structuring element B is denoted by $X \bigcirc B$ and defined as the set difference between X and the hit-or-miss transform of X by B ($HMT_B(X)$):

$$XOB = X \setminus HMT_B(X) \tag{3}$$

The hit-or-miss transformation of a set X by a composite structuring element $B=(B_1, B_2)$, is the set of points, x, such that when the origin of B coincides with x, B_1 fits X and B_2 fits X^c .

$$HMT_B(X) = \varepsilon_{B1}(X) \cap \varepsilon_{B2}(X^c) \tag{4}$$

d) Pruning: According to Soille (1999), the pruning transformation is implemented through the detection of final points and their removal up to the idempotency, in other words:

$$PRUNE(X) = (X\ AFIs\ E)^{(\infty)} \tag{5}$$

Where E is related to the structuring element used to detect final points and ∞ indicates that the sequential thinning is iterated up to stability.
When the pruning is taken into stability, the only parts of the skeleton not suppressed are the closed arcs or “ties” of the skeleton.

2.2. Data Used

The test image chosen corresponds is a panchromatic image of the high resolution satellite QuickBird, with spatial resolution of 61 cm. This contains as main feature a part of the Raposo Tavares highway, located in the area of Presidente Prudente city (SP), Brazil. The Figure 2 presents the original image.

Figure 2. Original Image.

2.3 Method

This paper consisted of using morphologic operators with the objective of to detect highways in high resolution images. For this, the Mathematical Morphology toolbox developed by SDC Information Systems, coupled to the software Matlab 7.0 was used in this experiment.
Initially, with base in the type of present structure in the image, the morphologic operators and structuring elements more appropriate were selected to process the image with intention of to detect highways in other words, to detect elongated image structures. The flowchart of the Figure 3 illustrates the stages accomplished for the highways detection.

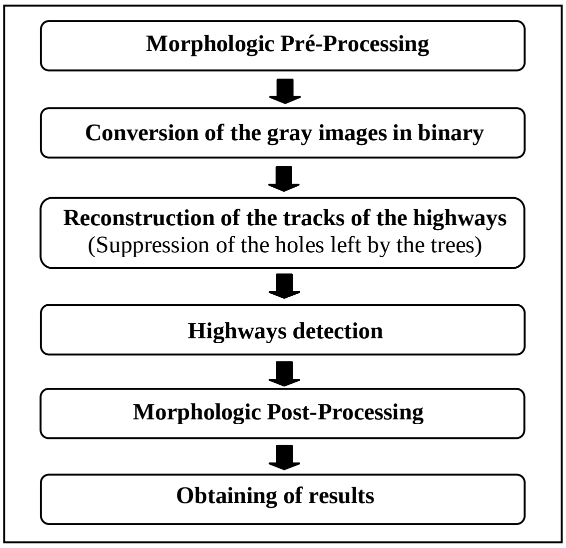

Figure 3. Flowchart of the developed routine.

Firstly, the developed routine consisted in accomplishing a stage of Morphologic Pre-processing where the brightness and contrast values were altered, enhancing the interest features. This stage is of great importance, because it allows the elimination of many noises that aren't part of the interest feature, making possible the detection process. The next step was to convert the gray image in binary. In the sequence, due to the presence of trees in the borders tracks, these were rebuilt with the intention of obtaining its original plan. Being the tracks without the presence of the "holes" left by the trees, the next step was to accomplish its detection. For this, the tracks were thinning and afterwards they went by the pruning process, where the resulting segments of the thinning stage were eliminated. Finally, with the intention of obtaining the best result to be represented in the Cartography, a stage of Morphologic Powder-processing was accomplished, which consisted in dilatation the highway tracks seeking to obtain them with its original thickness. For proof ends, the image containing the highway detected was put upon on its original image, verifying if there was some position displacement of the feature detected.

2.4. Presentation and Analysis Results

Initially, a stage of Morphologic Pre-processing was accomplished with the objective of increasing contrast of the highway tracks, contributing for the features detection process to be successfully performed. For this, the first operator used was the opening for reconstruction. This operator accomplishes the reconstruction of an image starting from the eroded original image that works as markers. The structuring element used was the *mmsebox* (square mask). In the sequence, with the intention of enhancing the features tracks, the addition operator was applied with the value 120 by the whole scene. The result obtained is illustrated in Figure 4.

Figure 4. .Image with the enhanced tracks.

The next step was to convert the gray image in a binary image. The image was binarizated with a threshold 90, transforming all of the pixels that have digital number below this threshold for the value "0" (black) and the ones that were above in "1" (white). The choice of this threshold was made in agreement with tests accomplished through of the image histogram analysis. In the sequence, seeking to eliminate the noises that aren't part of the interest feature, the erosion operator was applied on the image through structuring element mmseline (mask line) with the intention of disconnecting the noises close to the highway tracks. The disconnected noises were eliminated through the operator opening, which removed components with inferior size to 500 pixels. The obtained result is display in Figure 5.

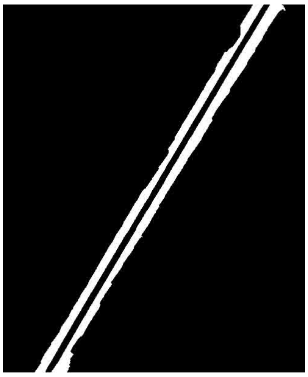

Figure 5. Elimination of the noises around the feature.

By analyzing the result showed in Figure 4 it can be noticed that the highway present continuity loss. This happened due to the presence of trees in the borders tracks in the scene acquisition instant, hiding information regarding the plan of the same ones. This way, it was necessary to accomplish a reconstruction of the tracks in order to obtain them with its real plan. Then, the morphologic opening operator was applied through the structuring element *mmseline* (line mask). For the use of this structuring element was necessary to define two parameters, the line thickness and orientation, like this, with base in the accomplished tests, it was defined the values 40 and 125 respectively. The obtained result is exhibited in Figure 6.

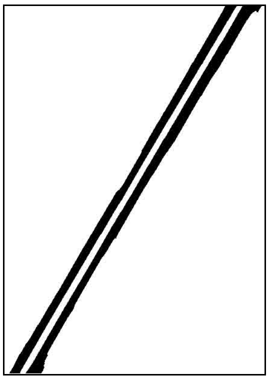

Figure 6. Reconstruction of the tracks

For the highway tracks detection, the image was thinning and the result submitted to the pruning operation. The pruning consisted of removing the segmentation left by the thinning process. The result is shown in Figure 7.

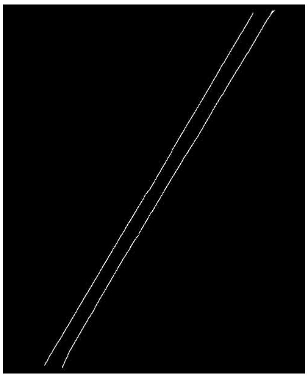

Figure 7. Result of the pruning process.

The next step was to apply a dilation on the image through the structuring element *mmsebox* (square mask), seeking to obtain the tracks with its original thickness. The Figure 8 presents the obtained result.

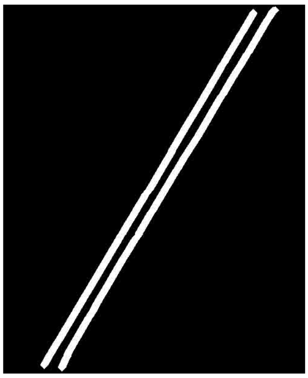

Figure 8. Image dilated

Analysing the Figure 8, it is verified that the employed morphologic processing was adapted for the highway detection in high resolution image. The quality of the obtained registration proves the efficiency of the Mathematical Morphology technique in the area of Cartography seeking to the future cartographic products updating. With regard to the application of morphological operators, the work could be considered as concluded, presenting as the best result, as already explained, the result obtained in Figure 8.

3. CONCLUSIONS

The experiences accomplished with the tools of the Mathematical Morphology, with intention of reaffirming its use potential in the area of Cartography, they were well happened. It is observed that the obtained final product assisted to the objective proposed in to demonstrate the viability of the morphologic tools in the process of features detection in high resolution images, with view the cartographic products updating.

The key for the obtaining of good results lives in the appropriate choices of the structuring elements and thresholds values for the several stages of the detection process. For so much, it is necessary that the user has minimum notions of mathematical morphology for the choice of the best structuring elements to be adopted and also, have knowledge on digital image processing so that it can choose the thresholds values appropriately to be used by the morphologic operators employees in the processing.

In the Cartography the obtained results are of extreme importance once, they were resulting of the application of alternative methodology for the features detection in digital images. The detected features can be used in conventional processes of cartographic products updating.

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