

## MATHEMATICAL MORPHOLOGY THEORY APPLIED IN CARTOGRAPHY

F. Leonardi, R. G. Stroppa, Fb. Leonardi, E. A. Silva

### ABSTRACT

The aim of the present work is to propose a routine to feature extraction from digital images using the mathematical morphology theory. This can help to minimize a great deficiency in cartographic updating area. So, the Sensing Remote Images are contributing to minimize this problem. One of the techniques used is mathematical morphology theory with the aim extracted from the features of interest. The extracted features can be used in conventional processes of cartographic products updating. It was used the toolbox of mathematical morphology developed by SDC Information Systems and that works in MATLAB platform. In a simple place the *Matlab* software has attended many requirements in the extracted features. With its were extracted the interest features that can be used in cartographic process updating. The results are presented and analyzed. The results obtained are positives and show the potential use of mathematical morphology theory in Cartography.

### 1 INTRODUCTION

In Brazil, a lot of areas with a poor cartographic cover requires be updated. Besides, even in areas with total cartographic cover, the products are usually outdated for more than two decades depending of the area. Therefore, it is evident the needs of cheaper and faster ways to update cartographic products in Brazil.

The Remote Sensing images can be considered as a source of data for studies in several areas such as cartography, urban areas and agricultural environments. Such use can be justified due speed, efficiency and periodicity in obtaining data and by its low cost.

Remote Sensing is an important agent in the task of cartographic products updating. Another important component is the Digital Processing Image (DPI) techniques, which involves digital images manipulation support by a computer.

Among the several PDI tools previously proposed, the one chosen to develop this research was mathematical Morphology, which has been explored firstly by Matheron, Serra and their collaborators, in the School of Minas of Paris.

Nowadays Mathematical Morphology (MM) is a powerful tool and widely used and has been object of research in universities and other worldwide centers. In addition, it is used with updating cartographic products purpose such as charts and maps, and in order to determine extraction and treatment feature. Thus, there is a general consensus that mathematical morphology is an excellent basis to extract the features of interest in the digital images.

## 2 OBJECTIVES

The general aims of this research are to present the results obtained from application of Mathematical Morphology in the extraction and treatment of linear features in images, seeking to aid the processes of cartographic products updating. Also, to verify the potentiality as mathematical morphology tools, available in the toolbox of MM couple to the software MATLAB, through the application of routines associated with the task of extracting of interest features.

## 3 METHODOLOGY

For the extraction of the interest features were applied routines of mathematical morphology on satellite images. The software MATLAB 5.3 was used as platform for the Mathematical Morphology toolbox, which contains the used operators. The operators were applied on the image with the aim to test their efficiency from obtained results, which can be used, in the updating of cartographic products.

The test image was collected from the QUICKBIRD satellite through of the multispectral band with spatial resolution of 2.40 meter. The interest feature in the image is the Brazilian Jockey Club in Rio de Janeiro, Brazil.

In the first stage, the used operators were: *hdome*, *threshad* and *histeq*. This stage consisted of several tests where, in each one, new parameters were used, which in the end of the process was elected as best possible results.

The operator *hdome* removes random noise in the input image ( $f$ ) through the detection of peaks with higher contrast than the prescribed threshold ( $h$ ) in the structuring element ( $b_c$ ) chosen. The expression 1 demonstrates mathematically the operator.

$$h - \gamma b_c \cdot h(f) = \gamma b_c \cdot f - h(f) \quad (1)$$

The operator *threshad* creates the image  $y$  as the threshold of the image  $f$  by the images  $f_1$  and  $f_2$ . A pixel in  $y$  has the value 1 when the value of the corresponding pixel in  $f$  is between the values of the corresponding pixels in  $f_1$  and  $f_2$ . The expression 2 demonstrates mathematically the operator.

$$(f_1 \leq f \leq f_2)(x) = \begin{cases} 1 & \text{if } f_1(x) \leq f(x) \leq f_2(x) \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

The operator *histeq* enhances the contrast of images by transforming the intensity values in an image, or the values in the colormap of an indexed image, so that the histogram of the output image approximately matches a specified histogram.

On the other hand, in the phase of the extraction, the following operators were used: *areaclose* and *areaopen*.

The operator *areaclose* removes any pore (i.e., background connected component) with area less than  $a$  of a binary image  $f$ . The connectivity is given by the structuring element  $B_c$ . This operator is generalized to gray-scale images by applying the binary operator

successively on slices of  $f$  taken from higher threshold levels to lower threshold levels. The expression 3 demonstrates mathematically the operator.

$$f \bullet (a)_{B_c} = \bigwedge_{B \in \mathcal{B}_{B_c, a}} f \bullet B$$

$$\mathcal{B}_{B_c, a} = \{X \subset E : X \text{ is } B_c\text{-connected, Area}(X) \geq a\} \quad (3)$$

Function *areaopen* removes any component connected to the image (F) with an area less than the threshold (A) limit. The connectivity is given by the structuring element BC. The expression 4 demonstrates mathematically the operator.

$$f \circ (a)_{B_c} = \bigvee_{B \in \mathcal{B}_{B_c, a}} f \circ B$$

$$\mathcal{B}_{B_c, a} = \{X \subset E : X \text{ is } B_c\text{-connected, Area}(X) \geq a\} \quad (4)$$

After extraction of the relevant cartographic features, they were analyzed, taken into account if the image presented or no excessive segmentation.

Soon afterwards, the images were put overlapped to the digital maps. Such a process had the aim to provide the potentiality of the use of the morphologic tools in cartography.

The topographic map regarding the Brazilian Jockey Club was converted from the analogical format to the digital through a scanner A4 using the software Adobe Photoshop 7.0. For the georeference, nine control points were used, which corresponded by the crossing among parallel and meridians of the topographic map.

In the images of the Brazilian Jockey Club the filters conventional Gradient and Sobel were applied and the results were obtained from visual comparison using the morphologic extraction process and the conventional methods.

From this comparison it was concluded that the morphologic results were the best one.

#### 4 RESULTS AND ANALYSIS

The tests were accomplished based on IKONOS image from Brazilian Jockey Club (BJC). Illustrations 1 show the image IKONOS in tones of gray (gray scale).



Illustration 1-Image in tones of gray

After the original image conversion to gray tones, it was processed with the main objective to improve the quality of the present features of interest in the image. For that, the operator *histeq* was applied. This operator, through the use of histogram image, has the objective to increase the contrast between the features using an equalization of the gray tones. The figure 2 presents the obtained results.



Illustration 2-Application of the operator *histeq*

In the sequence the operator *hdome* was applied as threshold 25. The *hdome* function is able to rebuild an image in gray tones for the subtraction of a integer and positive value. In other words, it removes the picks with larger contrast than the threshold. The result of this operator's application can be seen by the Illustration 3.



Illustration 3-Application of the operator *mmhdome*

Afterwards the operator *threshad* with thresholds 30 and 200 was applied on the image 3. This operator converts an image from tones of gray to a binary image, using two values, one maximum and the other minimum. Such values are obtained by the histogram analysis of the image. The pixel values that are out of the stipulated interval by the threshold is considered as value "0" (black) and the values inside of the threshold will receive value "1" (white). The image 4 represents the result of this operator's application.



Illustration 4-Result of the application of the operator *mmthreshad*

The exhibited result in the Illustration 4 presents the obtained binary image. So, it's possible to apply the other operators with the purpose to eliminate the noises surrounding the interest feature. Then, the operator *areaclose* was applied using threshold 47800. The operator application removes the largest noises, as shown in, the Illustration 5.

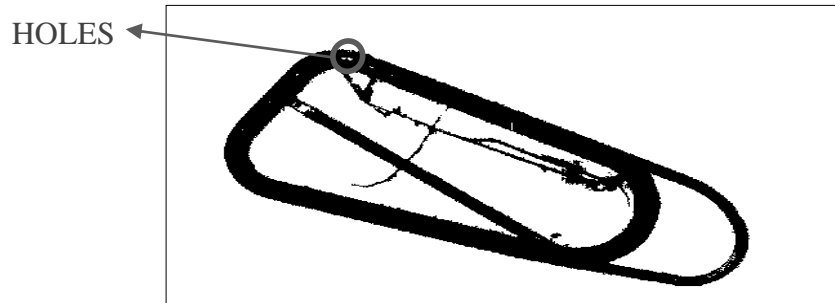


Illustration 5-Result of the application of the operator *mmareaclose*

In a deep view of Illustration 5 can be noticed the occurrence of internal “holes”. To eliminate these internal holes was applied operator *areaopen* with threshold 295. The result is shown in the Illustration 6.

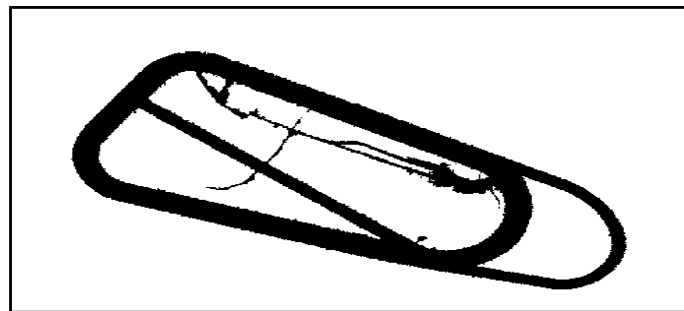


Illustration 6-Result of the application of the operator *areaopen*

The illustration 6 displays the feature totally detected. The noises in prominence were eliminated starting from a post-processing in the software Adobe Photoshop 7.0, whose result can be seen in the Illustration 7.

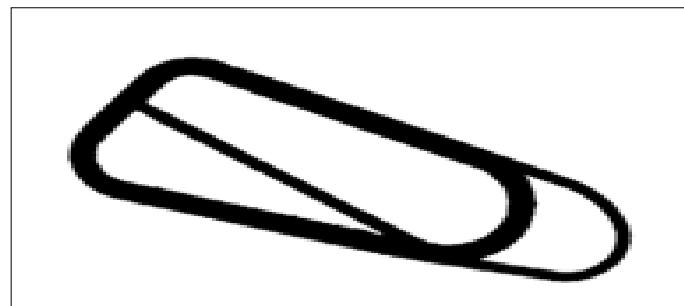


Illustration 7-Result of the post-processing



To confirm that the extracted feature utilizing the morphologic operators can be used as base for the updating of cartographic products, the obtained result was overlapped on the digital base. The final result can be seeing in the Figure 8.

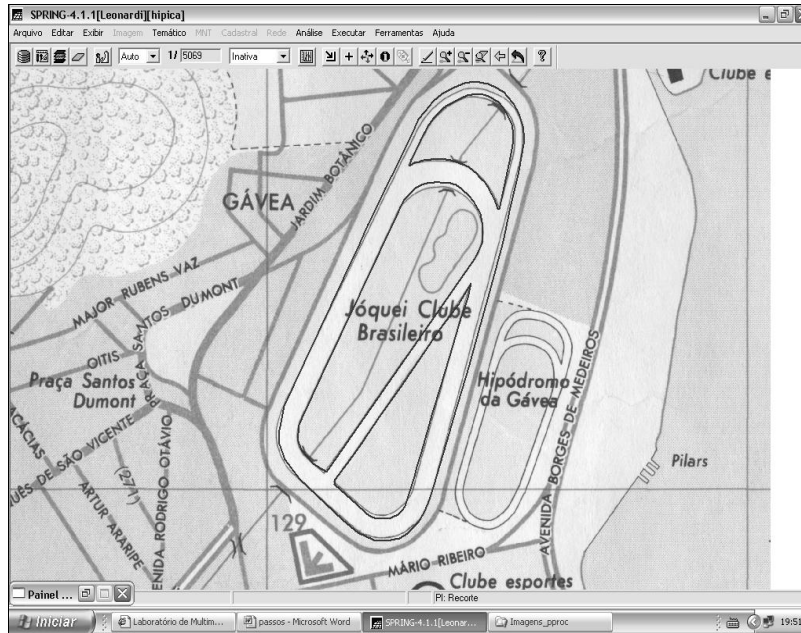


Illustration 8 - Result of overlap

From our findings it is possible to notice that there was a great match between the extracted cartographic features of the image (darker line) and the digital map of the tested area. This confirms that is possible to the morphologic tools contained in Toolbox of Mathematical Morphology as alternative technique to update cartographic products.

#### 4.1 Comparison between the proposed and conventional methods

The present work compare the final results obtained by the proposed morphological method with both conventional methods: Sobel and Gradient filters. The figure 9 shows the visual comparison of all images treated by different methodologies.



- a) Image in tones of gray   b) Filter Gradient   c) Filter Sobel   d) Morphologic Operators  
Illustration 9-Results of the application of the filters

It is clear that the results obtained by conventional methods presented a larger segmentation around the interest feature, which increases the difficulty in their application in updating cartographic and confirms the mathematical morphology potentiality in the extraction of cartographic features.

## 5 CONCLUSIONS

The obtained results pointed out that the use of the tools of the Mathematical Morphology can improve the final result of the features extraction processes, which can be used in conventional updating process.

It is worth to stand out that the choice of the operators and appropriate thresholds contributed to the extraction quality of the features. All of the adopted thresholds were based on the histograms analysis of the involved images.

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## REFERENCES

- [1] FACON, J. *Morfologia Matemática: Teorias e Exemplos*. Editora Universitária Champagnat da Pontifícia Universidade Católica do Paraná. Curitiba. 1996. xii. 320p: il.
- [2] MATHERON, G. *Radom sets and integral geometry*. New York: John Wiley, 1975.261p.
- [3] MEDEIROS, N. G.; SILVA, E.A e NOGUEIRA, J.R. Segmentação watershed utilizando a técnica de mínimos impostos. In: Colóquio Brasileiro de Ciências Geodésicas, 2003, Curitiba; p. 1-15.
- [4] NOVO, E. M. L. de M. *Sensoriamento Remoto: Princípios e Aplicações*. Editora Edgard Blücher Ltda. São José dos Campos, 1988. 308p: il.
- [5] SDC Information Systems. SDC Morphology "Toolbox" For Matlab 5. January 20, 1999.
- [6] SILVA, E. A. *Extração de feições cartográficas de imagens multiespectrais fundidas*. São Paulo:USP, 1995. 114p. Tese (Doutorado em Engenharia) - Escola Politécnica da USP, 1995.