Review Article

Edges Extraction with Mathematical Morphology Tools and Canny Filter: A Comparison

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ABSTRACT

A comparative Mathematical Morphology tools with Canny filter is developed for extracting edges with IKONOS-2 satellite PCA fused image of Cavouco's lake of the campus of Federal University of Pernambuco (UFPE). MATLAB was used for extraction edge with Canny filter. To obtain the gradient, the inner edge and the outer edge of the lake, with Mathematical Morphology (MM), the SPRING software was used. Moreover, to obtain the profiles to perform the comparison among the edges, ENVI's software was used. MM defines internal or external edge of the object and Canny identify only the outside edge of the objects.

Keywords: Mathematical morphology tools, Canny filter, IKONOS-2, MATLAB, ENVI's software.

INTRODUCTION

Mathematical Morphology (MM) is a nonlinear method of image processing. This theory was developed in the sixties by Matheron and Serra researchers at the Ecole Nationale Supérieure des Mines de Paris. Since then, many other studies have been made and contributions were added to this area of study and can be found, for example, in[1,2,5,8-11]. Nowadays articles like[13,14] shows examples of MM application.

Feature extraction and edges detection of Remote Sensing image is fundamental importance in Cartography and Geoprocessing because of the vectorial information. The analog representation of the edge (manual representation) is unique, but in the digital case it is necessary to consider the neighborhood-4 or neighborhood-8. Many edge detection consider the neighborhood-4 or neighborhood-8, but do not consider if the representation is of the inner, the outer, or the both border of an object.

The basic operators of MM are erosion image f by a structuring element B ($\varepsilon_B(f)$) and, dilation image f by a structuring element B ($\delta_B(f)$). Image f can be binary or in grayscale. The edges of an object can be represented byneighborhood-4 or neighborhood-8 depends on the *B* but, on the other hand, it would be possible to define if the desired border is the inner, the outer or the both one.

Canny edge detection method was developed by John F. Canny and where is used a multi-stage algorithm to detect a wide range of edge intensities. Initially, a smoothing operation is used, with the convolution of a gaussian mask with the original image. The method uses a threshold with hysteresis having two threshold values. This feature of the method provides better immunity to noise, allowing it to detect the edge segments where the gradient is low value[4].

This article describes a comparison of the use of mathematical morphology operators for images in gray levels and Canny filter for extraction of Cavouco's lake edge with high-resolution fusion PCA IKONOS-2 image. This lake is situated into the UFPE (Federal University of Pernambuco), Brazil.

Table 1 shows the parameters of OSA instrument of IKONOS-2. Panchromatic band has 1m and multispectral bands have 4m of spatial resolution. Fusion method merge spatial resolution with spectral resolution to obtain a synthetic color image (RGB) with high resolution spatial and spectral. PCA fusion method was chosen in this paper.

PCA (Principal Components Analysis) technique transforms multivariate data with correlated variables in uncorrelated variables supposing these uncorrelated variables are linear combinations of the original ones. Assumption that an image *I* with *n* original bands (B_1, B_2, …, B_n), PCA technique of *I* will obtain PC_1, PC_2, …, PC_n like a linear combination of B_i where i=1, …, n. Where *n* is the number of input multispectral bands. In PCA fusion method, the first principal component (PC1) is replaced with the panchromatic band, which has higher spatial resolution than the multispectral images. After that, the inverse PCA transformation is applied to obtain the image in the RGB color model. The fusion method based on PCA can be found in[6,7].

METHODOLOGY

A PCA fusion with IKONOS-2 image (bands 1, 2, 3 and panchromatic band) was used (Figure 1(a)). The acquisition data was from 2013.04.15 of the original IKONOS-2 image. The PCA result generates a color synthetic image R= B_3, G= B_2, B= B_1.

The methodology uses monochromatic image B_3. The chosen monochromatic band is defined by highest water's absorbance in visible range and consequently shows the lake more defined. Figure 1 (b) shows the red fusion component (B_3) used to obtain the edges.

MATLAB was used for extraction edge with Canny filter and to obtain the edge of binary image with Mathematical Morphology (gradient, inner edge and outer edge of the binary image). On the other hand, to obtain Mathematical Morphology edges of the monochromatic image, the SPRING software of INPE (National Institute of Space Research) was used. Moreover, to obtain the profiles, ENVI's software was used. As a result, we obtained a comparison between the methods of extraction of edges.

Results with mathematical morphology

Figure 1 presents the campus UFPE with IKONOS-2 image and the local photography. With the monochromatic band (Figure 2 (b)) it was done a binary edge result (Figure 3) and monochromatic one (Figure 4). Section 2.1.1 and 2.1.2 describe these results.

Binary image

Initially the binary image (f) of red band (B_3) of the color PCA fused image is obtained and showed in Figure 2(b). To define the lake (water) class, it was used the parallelepiped classification method that determine the mean (μ) and the standard deviation (σ) of this water supposing samples. The binary image was obtained by interval like:

$$\text{if } (\mu - \sigma) \leq B_3(x, y) \leq (\mu + \sigma) \text{ them } fb(x, y) = 255 \quad (1)$$
$$\text{else } f(x, y) = 0.$$

Where x, $y$are the position of the pixel into the image.

The next step is to apply the dilation and erosion operators of binary image f. IMDILATE and IMERODE from MATLAB makes the dilation and erosion respectively of the binary image (f) by a structural element. In this case, structural element is a square 3x3 (B) (neighborhood-8).

To extract the outer edge is obtained by:

$$f_1 = \delta_B(f) - f, \quad (2)$$

The inner edge is obtained by:

$$f_2 = f - \varepsilon_B(f), \quad (3)$$

And the gradient is obtained by:

$$f_3 = \delta_B(f) - \varepsilon_B(f) \therefore f_3 = f_1 + f_2. \quad (4)$$

Figure 3 shows the outer and inner edges, and gradient. Area of Figure (a) and (b) are different and area of Figure 3 (a) and (c) are equal. For more details of it can be found in[3].

Image gray levels

Edges of the grayscale images can be obtained too by Mathematical Morphology. The red band B_3 of the image is used to obtained the results shown in Figure 4. Structuring element used was a square 3x3 (neighborhood-8). These results were obtained with SPRING (INPE).

Canny method

For the Canny method was also employed to image the red band (B_3). MATLAB has a function of t EDGE Canny method for obtaining the default parameters edge *cm*. The results of the outline of objects existing in it was shown in Figure 5 (b).

Canny comparative canny with mathematical morphology

Figure 6 shows the edges extracted by Mathematical Morphology gray levels and with Canny filter. Figure 7 shows the profile representing the position of the inner edges, outer edges and Canny filter.

CONCLUSIONS

This study compared the use of Mathematical Morphology and Canny method in the image edges extraction with an image PCA fused IKONOS-2. We have seen that there are differences in the detection and extraction of edges using Canny and with Mathematical Morphology. The extraction with Canny has a tendency to show the outer edge of the object and with MM it would be possible to choose if the result will be a inner, outer or both edges.

The Mathematical Morphology in binary case is very useful to extract the external, internal and gradient edges. However, in the example of this paper, the classification to obtain binary image generates a confusion because of the parallelepiped classification. Some shadows of buildings and trees were classified like a water of the lake. MATLAB has tools like extraction of connected component (BWSELECT), closing holes (BWFILL) and then facilitate the extraction to choose only the desired object. In addition, tools like IMERODE and IMDILATE of

MATLAB are binary implementation of the erosion and dilation operators.

Edge extraction with monochromatic image has an advantage of do not necessary generate a binary image and consequently do not need a classification before to obtain the edges. In this case, to obtain the results, it was used SPRING software (INPE) to generate the MM edges, ENVI to get the profiles and Canny filter from MATLAB. Figures 7 and showed the difference of edge obtained with gray level image with MM and Canny filter.

With the parameters used for the Canny, it was observed that the outside edge are extracted. Mathematical Morphology would be more appropriate when it is necessary to define if the edge is internal, external or both of an object.

ACKNOWLEDGEMENTS

The authors thank the Department of Cartographic Engineering, UFPE and the National Scientific and Technological Development (CNPq), PIBIC/CNPq, the project FACEPE APQ-1405-1.07/12 and FAPESP Process FAPESP 2012/05414-5 for IKONOS-2 image used in this work.

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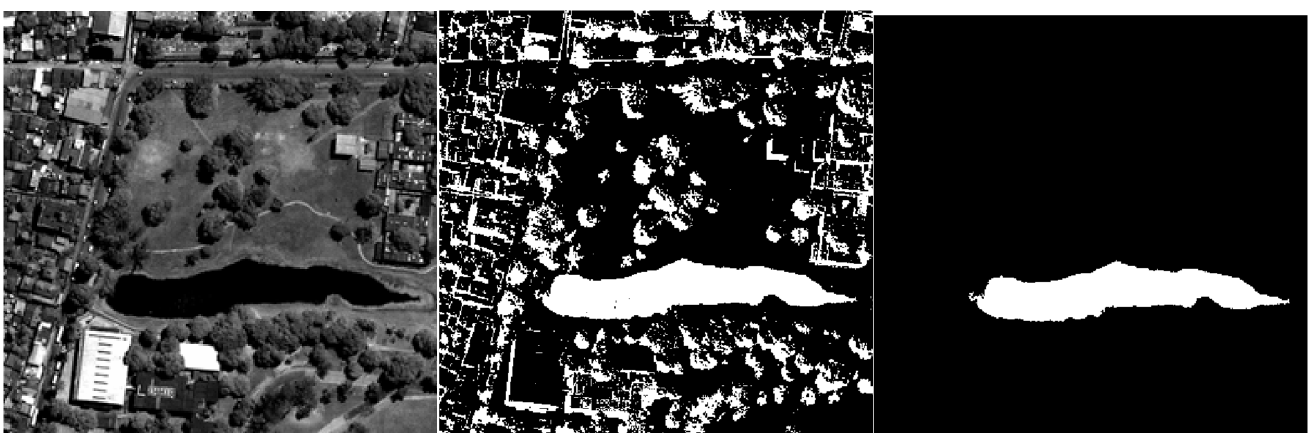
Table 1. Some performance parameters of the OSA instrument

Parameter	Value	Parameter	Value
Spectral range PAN (µm)	0.45 - 0.90	Off-nadir pointing angle	±30º in any direction
Spectral range MS (µm)	0.45-0.53, (blue) 0.52-0.61, (green) 0.64-0.72, (red) 0.76-0.86, (NIR)	Stereocapability	along-track
Spatialresolution	1 m PAN (0.82 m at nadir), 4 m MS (3.2 m at nadir)	Swath width (single image) Nominal strips	11.3 km x 11.3 km 11 km x 100 km (length)
Pixel quantization	11 bit	Field ofregard (FOR)	±350 km at 1 m GSD

From: eoPortal Directory[12].

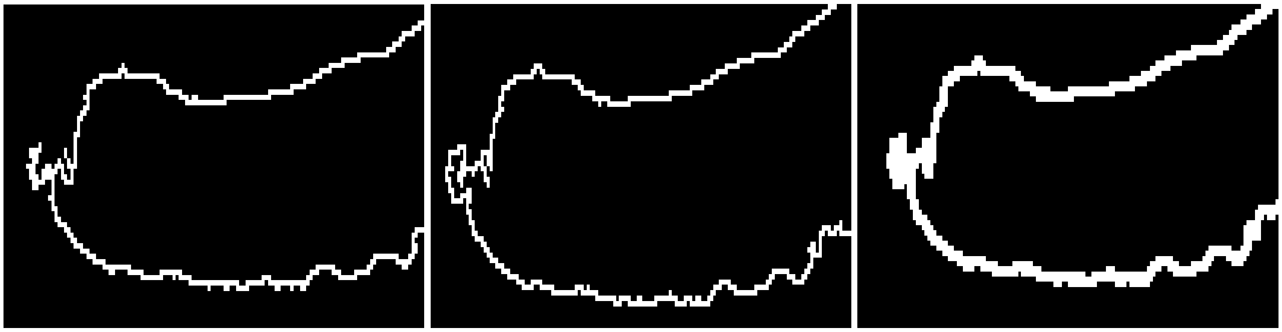
(a) (b)

Figure 1. Cavouco's lake - UFPE. (a) Cropping of the campus UFPE IKONOS-2 color PCA fusion image with acquisition date of 2013.04.15. (b) Local photograph obtained from the Cavouco's lake on 2014.04.07



(a) (b) (c)

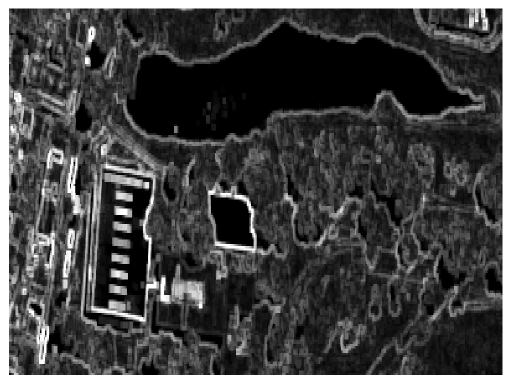
Figure 2. Monochromatic and binary image. (a) Red BandB_3 from PCA fusion image. (b) Binary Red band (*fb*). (c) Binary image of the Cavouco's Lake (*f*)



(a) **(b)** **(c)**

Figure 3. Cavouco Lake edge obtained by Mathematical Morphology with structuring element B (3x3). (a) Internal Edge f_1. (b) External Edge f_2. (c) Gradient f_3

(a) Red Band B_3PCA fused (f)



(b) Gradient $f_3 = \delta_B(f) - \varepsilon_B(f)$

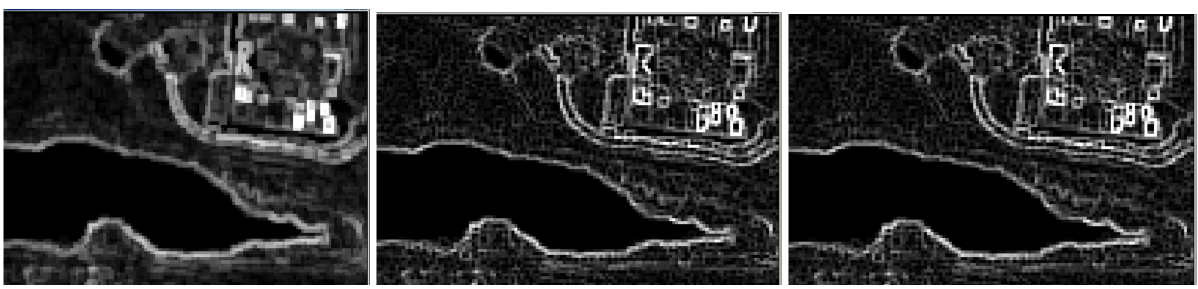
(c) Inneredge $f_2 = f - \varepsilon_B(f)$

(d) Outer edge $f_1 = \delta_B(f) - f$

Figure 4. Edge obtained by Mathematical morphology in gray scale

(a) (b)

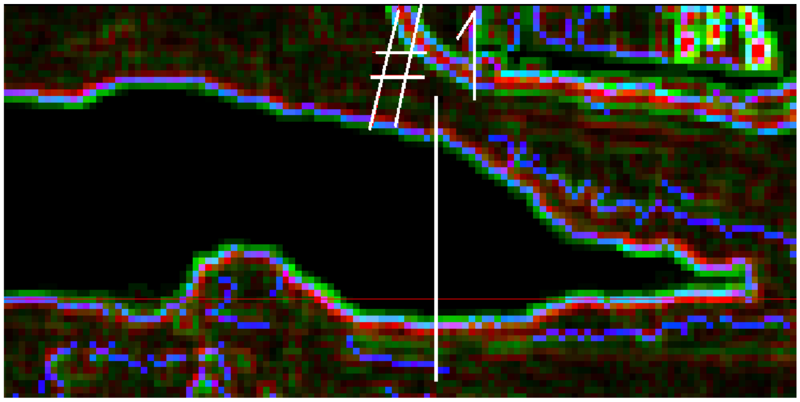
Figure 5. Borders from the Canny method (a) red image and Cavouco detail. (b) Contours of existing objects in the band of red, obtained by the Canny method



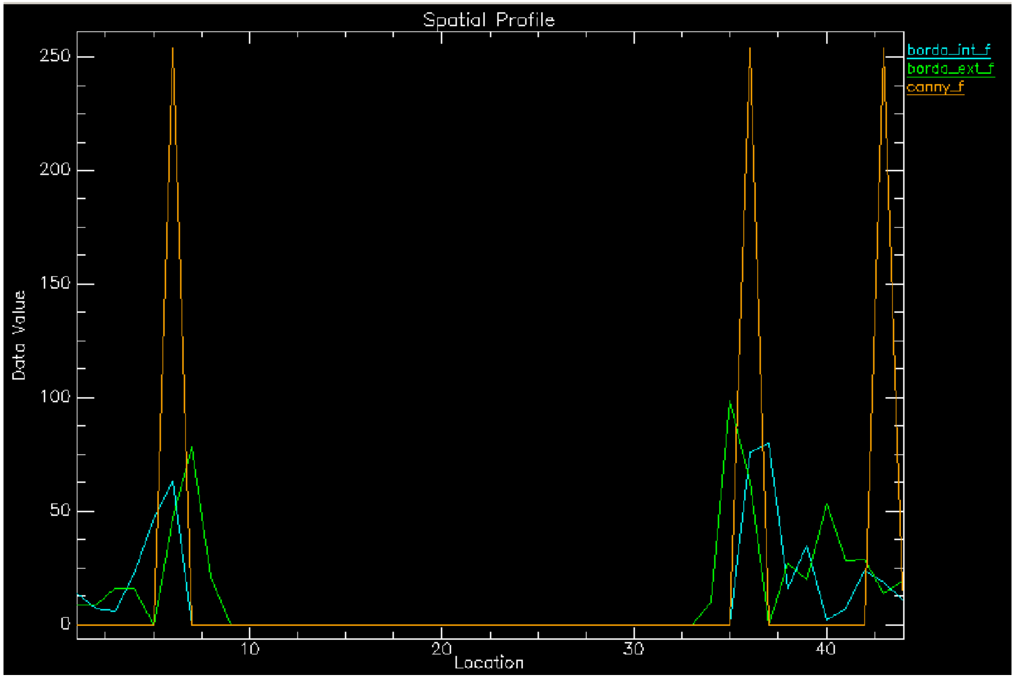
(a) (b) (c)

(d)

Figure 6. Image Cavouco area. (a) gradient $f_3 = \delta_B(f) - \varepsilon_B(f)$. (b) outer edge $f_1 = \delta_B(f) - f$. (c) inner edge $f_2 = f - \varepsilon_B(f)$. (d) Canny filter



(a)



(b)

Figure 7. Result profile. (a) Image with the outer edge composition, inner and Canny and indicating the vertical profile # 1 (white line). Image Profile Canny_*f* where is the edge by Canny (orange line), borda_inf_f is the outer edge (cian line), and the borda_ext_f is the inside edge (green line)