Using Techniques of Mathematical Morphology and Digital Image Processing in Extracting Contours to Determine the Decrease in Reservoir Area of Water Supply for Cities

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ABSTRACT

Due to the representation of the environment, the map must accompany the changes happening in the real world. To detect these changes, it is necessary to keep cartographic products updated.There are many techniques available for this task and the ones performed in this work were combined with the Remote Sensing Digital Image Processing (DPI).. In this work, we used the theory of Mathematical Morphology to extract the contour of a dam in the state of São Paulo to demonstrate a decrease in the volume of water and the consequent problem of water in the municipality of São Paulo and its surroundings supply. It has been chosen as the features of interest, two sub-images Landsat 8.One image was taken before the drought and the other during a normal rainy season;the dams are located around the city of São Paulo - SP - Brazil. The aim of this study was to indicate a more appropriate morphological routine to extract the outline of the calculation aiming dam of the reservoir area at two different times, normal and very dry adverse conditions. The results were interesting and confirmed the potential use of morphological tools in feature extraction that can be used in the process of updating of cartographic products and assisting in planning decision making.

Keywords: Mathematical morphology, Cartographic features, Update, Digital image processing, Remote sensing.

INTRODUCTION

There are many areas in Brazil with outdated cartographic coverage. Alternative, rapid and low-cost methods that assist in the update are extremely important.

The remote sensing images can be considered as a source of data for studies in many areas, such as cartography, urban planning, agriculture and environment. Such use can be justified by the speed, efficiency and timeliness in obtaining the data and the cost.

Remote sensing is an important tool for updating cartographic products.

Another important component is the technique of Digital Image Processing (DIP), which includes support for manipulating digital images by computer.

In this work, we used the theory of Mathematical Morphology to extract the contour of a dam in the state of São Paulo to demonstrate a decrease in the volume of water and the consequent problem of water in the municipality of São Paulo and its surroundings supply. The results were interesting and confirmed the potential use of morphological tools in feature extraction that can be used in the process for updating cartographic products and assisting in planning decision making.

OBJECTIVE

The objective of this study was to indicate a more appropriate morphological routine to extract the dam outline aiming the calculation of the reservoir area in two different times, under normal and very adverse dry conditions.

THEORETICAL

Mathematical Morphology

The Mathematical Morphology originated from the joint research of[1]. The first theoretical notions were established between 1964 and 1968, at the same time the MathematicalMorphologyCenter was created at the Paris Mines School, located in Fontainebleau (France). According to[2], Mathematical Morphology (MM) can be defined as a theory for analysis of spatial structures. It is called morphology because it aims at analyzing the shape of objects. It is mathematical in the sense that the analysis is based on set theory, integral geometry and Boolean algebra. However, the MM is not just a theory, but also a powerful technique for image analysis.

The method of image analysis by Mathematical Morphology aims to analyze the geometric structure of images from a known and defined rectangular grid, called structuring element.

Toolbox

The "toolbox" is a specific set of files that has the MATLAB platform and consists of morphological operators, developed by[3].

Structuring Element

According to[4], the structuring element is a fully defined and known (shape, size) set, which is compared from one processing set to the unknown image. The result of this transformation allows to evaluate the unknown set. This tool also has some advantages such as simplicity of implementation. This work was used as the structuring element mask pad (*secross*), and full masks (*sebox*). Figures 1 and 2 show the structural elements used.

Basic morphological operators

Erosion

Binary erosion of a set X by a structuring element B is denoted εB (X) and is defined as the position of the points x, so

that B is included in X when its origin is located at x[2]:

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

The structuring element Bx corresponds to the structuring element B centered at pixel x. According to the equation (1), the structuring element B slides on the X image, by comparing each pixel to the neighborhood of x. If the pixel B corresponds to the same position in the neighborhood of x, the pixels are preserved where the surrounding match. In general, the binary erosion presents the results in the following effects: decrease of particles, elimination of grain size lower than the size of the structuring element, increasing the holes and allows separation of near grains[4]. As the example in figure 3.

Dilation

The binary dilation of a set X by a structuring element B is denoted εB (X) and is defined as the position of the points x so that B touches X when its origin coincides with x [2]:

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

By this definition, according to [4], the structuring element Bx, positioned and centered in each pixel x of X, checks a possible intersection with the neighborhood of x. If true, the central point in the resulting image will be a relevant pixel (1), otherwise it is irrelevant (0).

By applying this operator, it produces the following effects the enlargement of image objects, filling of the small holes and the connection of nearby objects[4]. As shown in Figure 4.

From these basic operators all the other morphological operators can be constructed.

TEST AREA

For this work, two sub-images of Landsat 8, sensor TM band 5, dated 09/02/2013 and 07/02/2014, respectively have been used, corresponding to the dry images before and during drought. The reservoir under study is a major water supply for the city of São Paulo and is called Nazaré Paulista Reservoir.

METHOD

The present paper consisted in proposing a morphological routine to extract the contour of the reservoir in the two images, both in normal times and in times of drought. From this extract, the areas were subtracted to indicate the total area of the reservoir decrease. The proposed methodology can also be applied in cartographic updating process which aims to use the results in planning aimed at decision making[5]. A Mathematical Morphology toolbox coupled to MATLAB 7.0 software has been used for the application of the chosen operators.

Operators used

The operators used in this paper were *hdome*; *binary; areaopen; areaclose; neg; dil; error and secross*. The function of each of the operators used is explained in item 6.These operators were applied to the images in order to test their efficiency in achieving results that will be used later in the calculation of the reservoir contour during the two chosen epochs. For this calculation, it has been used the difference in pixels between the two images after processing, in order to update cartographic products. It is expected by the results obtained, the use of morphological operators on images to be viewed as an applicable method in Cartography activities on an ongoing basis.

PRESENTATION AND ANALYSIS OF RESULTS

Extraction of the contour of the reservoir in the two images: image with normal water volume and image with volume of water in the dry season

The *hdome* operator was applied in morphological preprocessing step on the original images, as illustrated in Figures 7 and 8.These operators are meant to enhance the brightness and contrast, highlighting the drainages to be detected.

After the preprocessing step, the images were binarized by using the binary operator. This operator converted the grayscale images to binary. The results obtained are shown in Figures 9 and 10

In sequence, the *neg* operator was applied aiming to reverse the tones of images so that the morphological operators can be applied. The results can be seen in Figures 11 and 12.

In Figures 11 and 12 an amount of undesirable noises around the reservoir is noticed in, the two moments and discontinuities of the same. Aiming to connect the points or regions of the feature of interest and power subsequently removing the noise without changing the feature of interest, we applied the *dil* operator with an expansion coefficient 2 and the structuring element *secross*. On the dilated images, the cleaning step with the area open morphological operator was performed, and with the images already free of noise, the *ero* operator was applied, which brings the image to its real size. Figures 13 and 14 show the results obtained with the application of the operators.

In order to ensure the veracity of the extractions an overlap of the images containing the extracted drainage on the original images has been performed. The figures 15 and 16 show the results of the overlap.

From the analysis of Figures 15 and 16 it seems that there was no positional offset between the features of the two images this fact proves the efficiency of the use of MM in cartography.

Calculation of areas

Knowing that the spatial resolution of each image pixel Landsat-8 is 30mx30m (900 m²), it was possible to determine the areas in the images of the reservoir on the two dates used in this paper.

Calculation of the reservoir

It has been used the image shown on Figure 13, being applied the area open operator in order to obtain the number of pixels of the reservoir.

An amount of 25872 pixels was obtained that multiplied by the pixel area has resulted in 23.2848 km^2 of reservoir in normal state, and 20565 pixels were obtained for the reservoir during the dry season, resulting in an area of 18.5085 km^2.

Calculation of the loss of the reservoir area

To calculate the reduced reservoir area due to the drought season, the total pixel subtraction of the reservoir before drought with the image during a normal period was performed, resulting in 5307 pixels which multiplied by 900m^2 provides us a decrease of 4.7763 km^2 in the reservoir area. This value indicates that the reservoir area shrank 20% of its area in normal times. This decrease causes a catastrophic effect on the collection of water withdrawn from the reservoir, causing large losses in the water supply in the cities served.

CONCLUSIONS

We conclude that the work met the objective of indicating the decrease in the reservoir area at the present time, indicating the serious problem of water supply of cities around the reservoir. Thus, it appears that the use of morphological tool in area mapping as an alternative means for feature extraction is entirely feasible, since the routine developed

has shown a good combination of operators and morphological structuring elements, which allowed detections of the reservoir to be successfully performed.

It should be noted that the adopted thresholds were based on the analysis of the histograms of the images involved. The appropriate choice of these thresholds is one of the keys so that the results obtained are the best possible. By analyzing the results (Figures 15 and 16) we note that there was no positional offset between features. The extraction of drainage networks is important in the field of cartography, as these features can be used in conventional update processes of cartographic products which provide,, for example, updating courses of rivers which were diverted, delineation of the extent and reservoir area of hydroelectric power plants, water supply reservoirs, calculations of environmental impacts already occurring in the construction of dams etc.

ACKNOWLEDGEMENTS

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0	1	0
1	1.	1
0	1	0

Figure 1. Mask-shaped cross.

1	1	1
1	1.	1
1	1	1

Figure 2. Full shade.
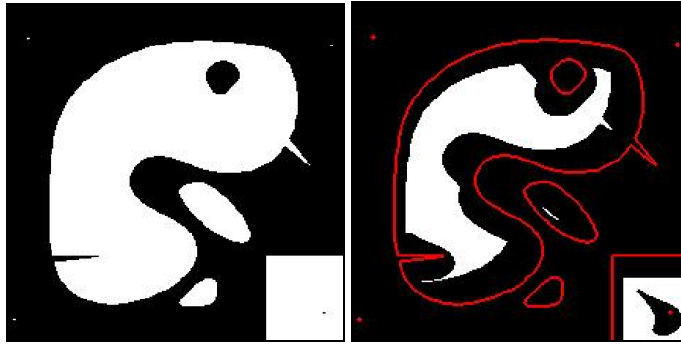
Figure 3. Result of applying the binary erosion operator.
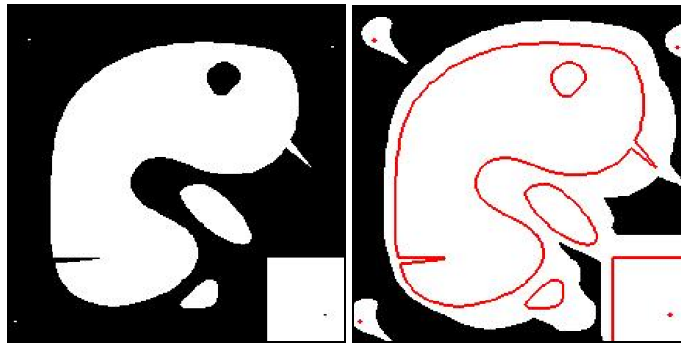FACON, 1996.

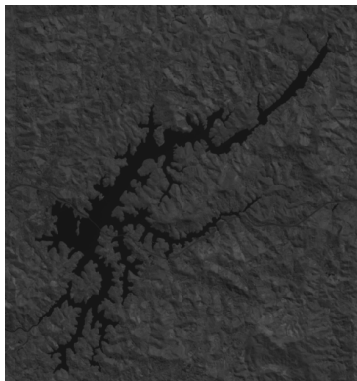**Figure 4.** Result of applying the binary dilation operator.
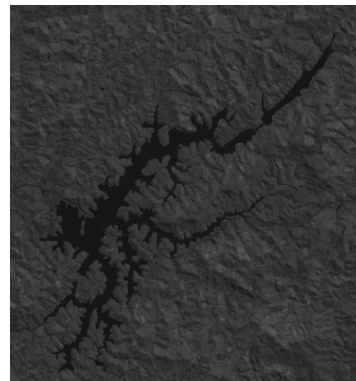FACON, 1996.

Figure 5. Original image 2013.

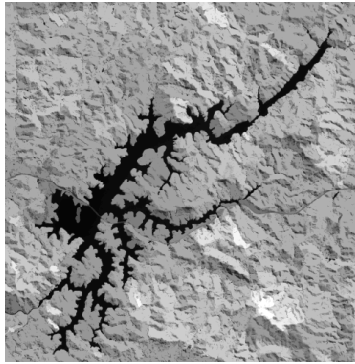

Figure 6. Original image 2014.
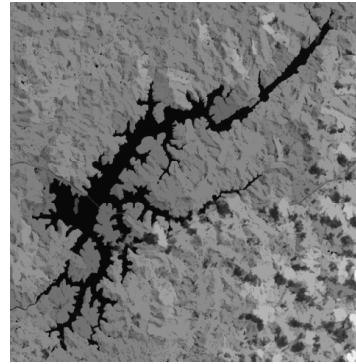
Figure 7. Result of applying the hdome.

Figure 8. Result of applying the hdome.
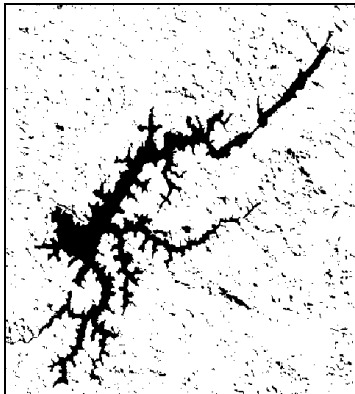
Figure 9. binary.
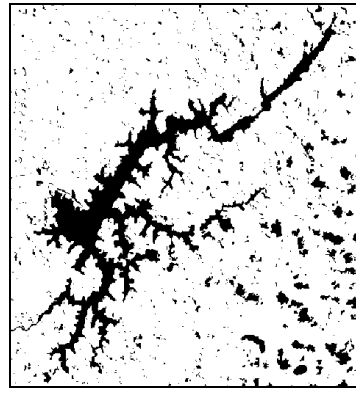
Figure 10. binary.
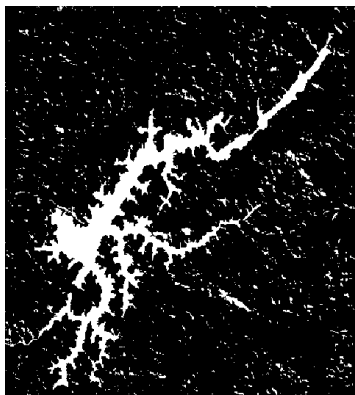
Figure 11. *neg*.
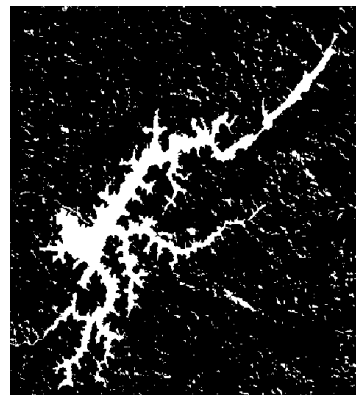
Figure 12. *neg*.
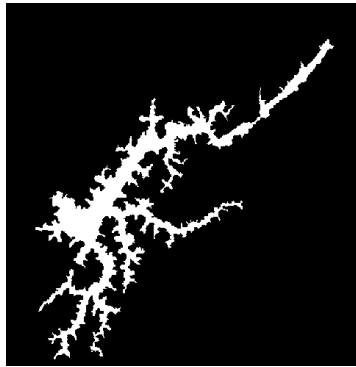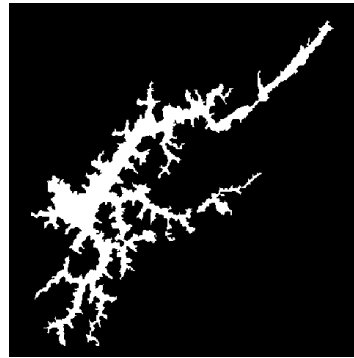
Figure 13. dil (secross)/areaopen/ero

Figure 14. dil (secross) /areaopen/ero.
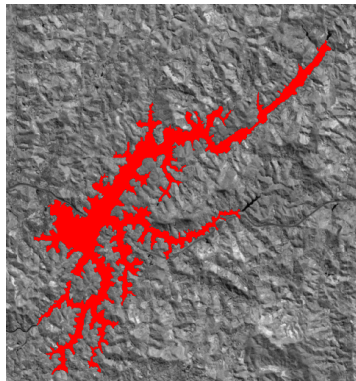
Figure 15. overlap.

Figure 16. overlap.