Development of Pre-Module Image Processing in CARTOMORPH

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ABSTRACT

This paper proposes to provide the module preprocessing CARTOMORPH software, public domain for morphological image processing in the field of cartography. It is based on the application of mathematical morphology techniques in digital images to highlight the features of interest in the original images to be processed, before the process of feature extraction in satellite images of medium and high resolutions.

Keywords: Digital image processing, Mathematical morphology, Morphological filters, Algorithm programming.

INTRODUCTION

Cartographic products are of fundamental importance for planning and managing projects in various areas. The remote sensing images have contributed decisively to assist in the updating of cartographic products. So, this work aims to highlight the features of interest in the original images to be processed before the feature extraction process in orbital images.

There are many digital image processing that could be chosen for the development of this toolkit. The choice was the theory of mathematical morphology since it is the most suitable one. Importantly, all processing of the images was performed in the TOOLBOX tools, mathematical morphology developed by SDC Information Systems, which coupled with the MATLAB software wheel box. It is also interesting to point out that a limitation of such software, which occurs in most software packages, libraries or toolkits for morphological image processing, is that all of these are of particular software domain, restricting access to users. Therefore, the MATLAB and TOOLBOX were only used as the basis of the work, to continue the development and implementation of public domain CARTOMORPH software, specifically the implementation of morphological operators in the pre-digital image processing software

module for application in the field of cartography.

THEORETICAL

Mathematical morphology

A Mathematical Morphology emerged in 1964 from the research[3,4] at the School of Mines of Paris, where around 1964 and 1968 the first theoretical notions were established. It aims to describe quantitatively the geometrical structures and function as a technique in the design of algorithms in digital image processing, providing basic tools such as edge detectors and morphological filters.

According to[2], Mathematical Morphology potential lies in the fact of quantifying the intuition of the researcher, analyzing the geometric structure of images from a perfectly defined and known structuring element set. Currently, mathematical morphology theory is widely used and researched in universities and research centers around the world, so an excellent base to study the geometry of the signal as it allows quantifying shape and size. It has been gaining prominence among the techniques of digital image processing, being investigated in various areas of knowledge, such as medicine, biological, pattern recognition, among others. A wide variety of processing and image analysis systems has been developed in the branch of mathematics to assist in troubleshooting morphology.

Structuring element

According to[2] the structuring element is a fully defined and known set concerning its shape and size, which is compared from one processing set, to the unknown image set. The result of this transformation allows evaluating the unknown set. The morphology acts on digital images from structuring elements generally defined on a rectangular grid In Figure 1 and 2 below,

some types of structural elements can be verified.

Dilatation in gray levels

According to[6], the expansion in the gray levels of an image, can be defined as the maximum value of the image in the window defined by the structuring element. Dilation in gray levels, verifies that the structuring element is centered above the function.

According to[2], the visual effects of the expansion in gray levels are bleaching the image enlargement and increase of clear standards, connecting the next clear standards, reduction or elimination of dark patterns, and separation of dark patterns next. Figure 3 shows the result of applying the visual expansion in gray levels.

Morphological reconstruction in gray scale

According to[1], concepts of connectivity using conditional dilation, morphological reconstruction and reconstruction filters are applied to both gray scale images, as for binary images. For conditional dilation is used:

$$f \oplus_g D = (f \oplus D) \wedge g$$

From the above equation, one can construct a sequence of n conditional dilations, yielding the equation:

$$(f \oplus_g D)^n = (((f \oplus_g D) \oplus_g D) \oplus_g \ldots \oplus_g D)$$

So, obtaining the morphological reconstruction of the g by marker f:

$$g \, \triangle_D \, f = (f \oplus_g D)^\infty$$

According to[1], the signal reconstruction is illustrated in Figure 4, using a 'short' structural element D with g and f being the conditioning for the signal and marker, respectively. Note how the reconstruction D, spreads the marker under the local minimum signal conditioning. If D is longer, so it can raise the reconstructed signal above the minimum.

The Figure 5 illustrates a superficial view of image reconstruction.

H-Maxima

According to[1], erosion by a structuring element point value of h is equivalent to one pixel of ha from the signal subtraction. The reconstruction by dilation of f starting f subtracted from h, is called H-Maxima and defined by:

$$HMAX_{h,D}(f) = f \; \triangle_D \; (f - h)$$

According to[1], the H-Maxima filter follows a criterion of contrast and it functionally removes all components of height below level h. Figure 6 illustrates this effect.

MATERIALS AND METHODS

Used materials
✓ Digital images of the area of interest;
✓ Software CARTOMORPH, under development by the group of studies linked to mathematical morphology, from the Faculty of Science and Technology (FCT) - UNESP, Presidente Prudente;
✓ Software MATLAB R2013a, developed by MATHWORKS;
✓ Software TOOLBOX, developed by SDC MORFHOLOGY and compatible with the platform of MATLAB;
✓ Software EXCEL, developed by Microsoft.

Test areas
For the morphological processing developed in this project, we have used five images of different sections that contained the feature of interest of the project (roads), with the aim of comparing the results of preprocessing, in the best kind of preprocessing for this feature type. The Figure 7 below shows each of the five images used in the processing.

Methodology
As previously mentioned, the manipulation of the images was performed in TOOLBOX mathematical morphology and CARTOMORPH software's. The operators were applied on the image in order to highlight the features of interest in the original images, before the extraction of cartographic features of interest process. So processing began through the OTSU method, which has helped identifying the threshold value used in the proposed treatments.

Having set the thresholds, the process of applying the previously selected morphological operators (mmhmax, mmvmax and histeq) through MATLAB TOOLBOX and, with the corresponding thresholds for each of the images began. In order to better understand what was done at this stage, an image was picked and the three routine proposals (mmhmax, mmvmax and histeq), with the threshold found for each of the images were applied.

After processing, a mathematical proof of the results was necessary in order to identify what the morphological operator to be implemented in CARTOMORPH would be. For the mathematical proof, it was required to read two passages in each image, and with the help of the EXCEL software, developed by MICROSOFT, the necessary calculations were held. In this proof, it has been observed the values of the pixel on the highway and of the vegetation around it, in order to identify the difference between the shades of gray, to identify the best routine preprocessing. The best routine is the one which shows the greatest difference between the pixel value of the pixel highway and the vegetation. In order to find the average difference, three vegetation and three highway points were taken on each of the two selected portions on each image. Importantly, the same points were used in the various types of processing for each

stretch of the highway images. Figure 8 below presents a summary flow chart of the process described.

The morphological operator chosen to be implemented in the CARTOMORPH software, was corresponding to mmhmax, from the TOOLBOX mathematical morphology. The development and implementation of the algorithm in the CARTOMORPH software, have evolved based on the support literature available and also with the "help" from the MATLAB software and the mathematical morphology TOOLBOX. Figure 9 and Table 1 shows pseudo-code operator implemented in CARTOMORPH.

With the deployment complete, the new morphological operator has been established, for instance, being called "cmHmax", with the "cm" nomenclature, representing CARTOMORPH. The next step, we started a new stage of the research project, which consisted in processing the five selected images using the thresholds previously identified through OTSU method in the CARTOMORPH.

After processing the five images with the morphological operator "cmHmax", implemented in CARTOMORPH, they were then submitted to a new mathematical proof, aiming to prove the efficiency of the algorithm implemented in CARTOMORPH. For the mathematical proof of the efficiency of the algorithm, it was necessary to read two passages in each image, and with the help of the EXCEL software, the necessary calculations were held. In this proof, the values of the pixel on the highway and on the vegetation around it have been observed, in order to find the differences in tone between the pixels, to identify the possible improvement of the image for further processing. Just as before, the image enhancement is given, because the image shows a greater difference between the pixel value of the highway and the pixel value of

vegetation, in other words, the pixel delta between the highway and the vegetation. In order to find the average difference, three highway and three vegetation points were taken on each of the two portions selected by each image. Importantly, the same points were used for each of the five images stretch of highway. Figure 10 below shows a flowchart.

RESULTS AND DISCUSSIONS

Applying the commented routines in Methodology in the images, the following results were obtained, and the Figure 11, Figure 12, Figure 13, Figure 14 shown below, show the original image (Highway 3), the processed image with the mmhmax (TOOLBOX), the processed image with the mmvmax (TOOLBOX) and processed image with histeq (TOOLBOX), respectively.

After performing all procedures described above, we obtained several results that were taken as the basis for the choices and decisions made during the development of this work. So, for purposes of illustration, we used the first image (Highway 3) as an example, so showing the results obtained for this image.

Using data from the Highway 3 image, Table 2 was originated and shown below, thus presenting a summary of the results obtained for the image.

After the implementation and processing of images as the morphological operator cmHmax, implemented in the CARTOMORPH software, we have obtained the following images to Highway 3, taken as an example. Figure 15 shows the original image and Figure 16 shows the image resulting from the morphological processing operator implemented in CARTOMORPH.

From all the results obtained, Table 3 could be generated, which shows a summary of all the average values of the deviations obtained for the original and the processed image with the operator implemented in the

CARTOMORPH software, in the Highway 3 image processing, used as an example. On the image, it can be noted that both the first snippet, as well as in the second, the algorithm implemented in the CARTOMORPH software, has presented better results of average difference between pixels, which means that there was an enhancement in the feature of interest on the processed image.

CONCLUSIONS

Based on these results, the feasibility of using the tools of Mathematical Morphology in the processing of cartographic features of remote sensing images can be noted.

The application of appropriate operators in the features of interest has provided good results. Another item to note is that all thresholds adopted in the experiments, used as the basis of OTSU method, which automatically calculate such thresholds without making the user empirically define the threshold. The appropriate choice of these thresholds is of utmost importance, so that the results obtained are the best possible.

It can also be noted that the morphological operator preprocessing implemented in the CARTOMORPH software (cmHmax) HAS shown good results, so that in all cases there has been an increase in the difference delta (Route-Vegetation), leading to the conclusion that the cmHmax assists positively in the process of highlighting the feature of interest.

ACKNOWLEDGEMENTS

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Table 1. Symbols and the corresponding description in pseudo-code implemented in
CARTOMORPH

SYMBOL	DESCRIPTION
IO	Original image
h	Threshold used (obtained by the method of Otsu)
dilation	Dilation process - 3x3 - element cross
^	Minimum operation between the images. The objective function is to traverse the two pictures and make a comparison, pixel by pixel, the same coordinates in both. The pixel with the lower value will be stored with the same coordinates in the new image.
$Id_{(n)}$	Dilated image (n)
$Id_{(n+1)}$	Dilated image (n+1)
$Im_{(n)}$	Image resulting from the process applied minimum
$Im_{(n+1)}$	Image resulting from the process applied minimum
$Im_{(n)} = Im_{(n+1)}$	If the images are same, the process ended. If the images are different, assigns $Im_{(n+1)}$ to $Im_{(n)}$ and resumes the process until the condition of equality be satisfied

Table 2. Summary of general operators to highway 3 image

HIGHWAY 3	
OPERATOR - POSITION	**AVERAGE DEVIATION**
MMHMAX - Clipping 1	41,00
MMVMAX - Clipping 1	41,00
HISTEQ - Clipping 1	37,67
MMHMAX - Clipping 2	18,67
MMVMAX - Clipping 2	18,67
HISTEQ - Clipping 2	16,67

Table 3. Overall Summary of results for the highway 3 image

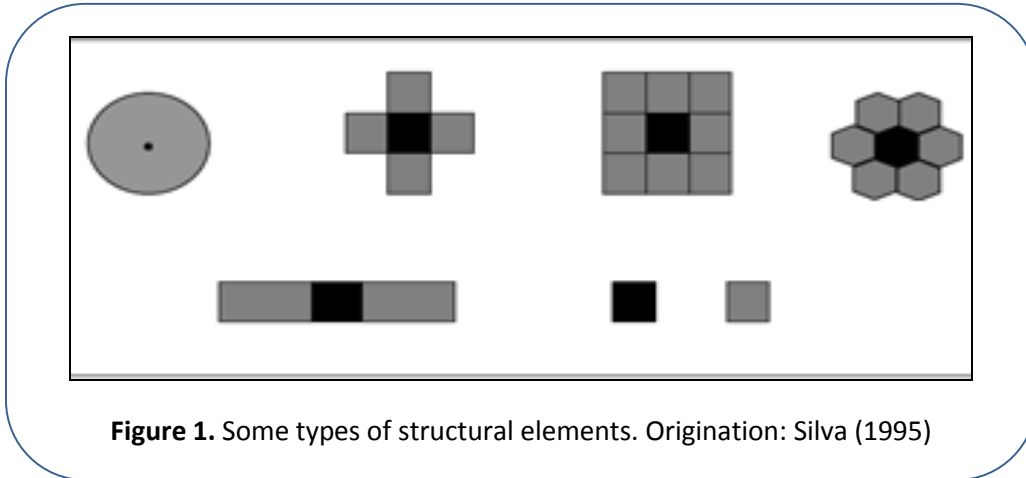| HIGHWAY 3 - difference Δ			
	ORIGINAL IMAGE	IMAGE PROCESSED WITH CARTOMORPH	VALUE OF DELTA (CARTOMORPH - ORIGINAL)
CLIPPING 1	87,00	102,33	15,33
CLIPPING 2	38,33	49,00	10,67

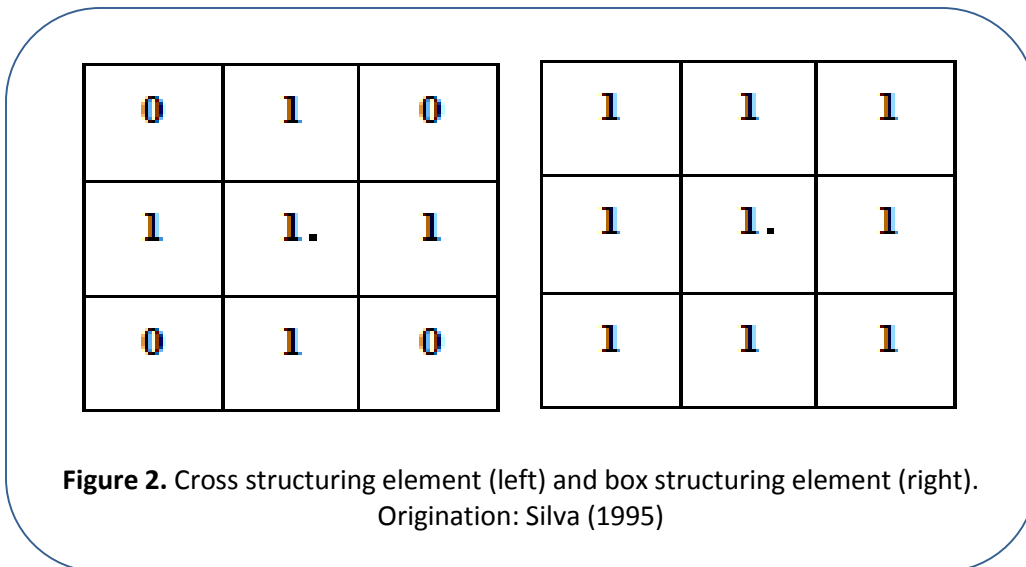**Figure 1.** Some types of structural elements. Origination: Silva (1995)

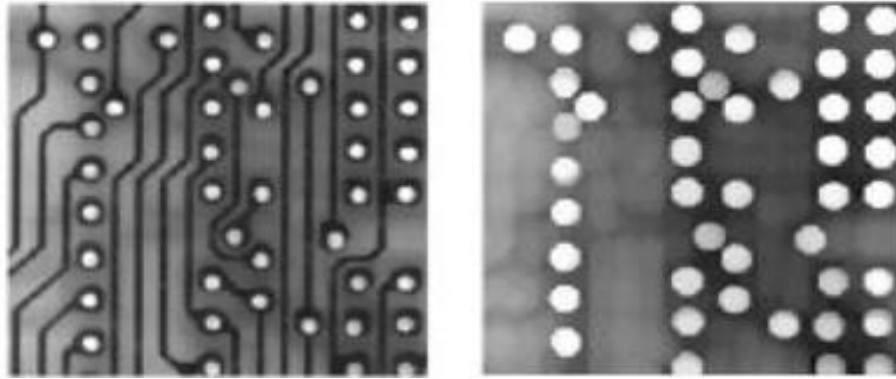**Figure 2.** Cross structuring element (left) and box structuring element (right). Origination: Silva (1995)

Figure 3. Visual result of dilation in gray levels. Origination: SDC Information Systems
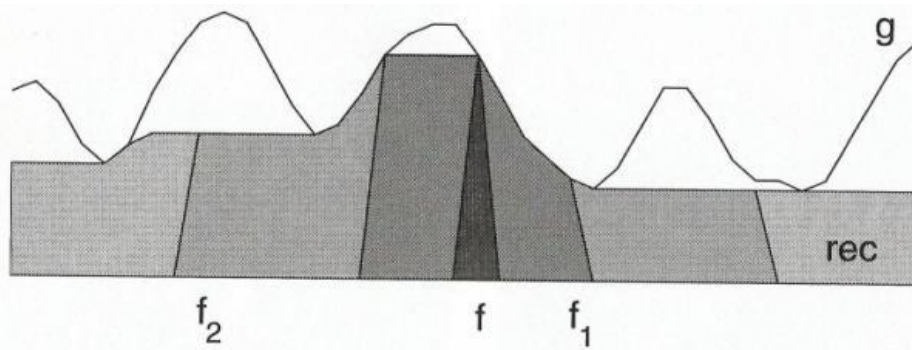
Figure 4. Sign of morphological reconstruction. g: signal conditioning; f: marker; $f_1 = (f \oplus_g D)^4$; $f_2 = (f \oplus_g D)^{12}$; rec = g Δ_D f. Origination: (Dougherty and Lotufo - 2003)
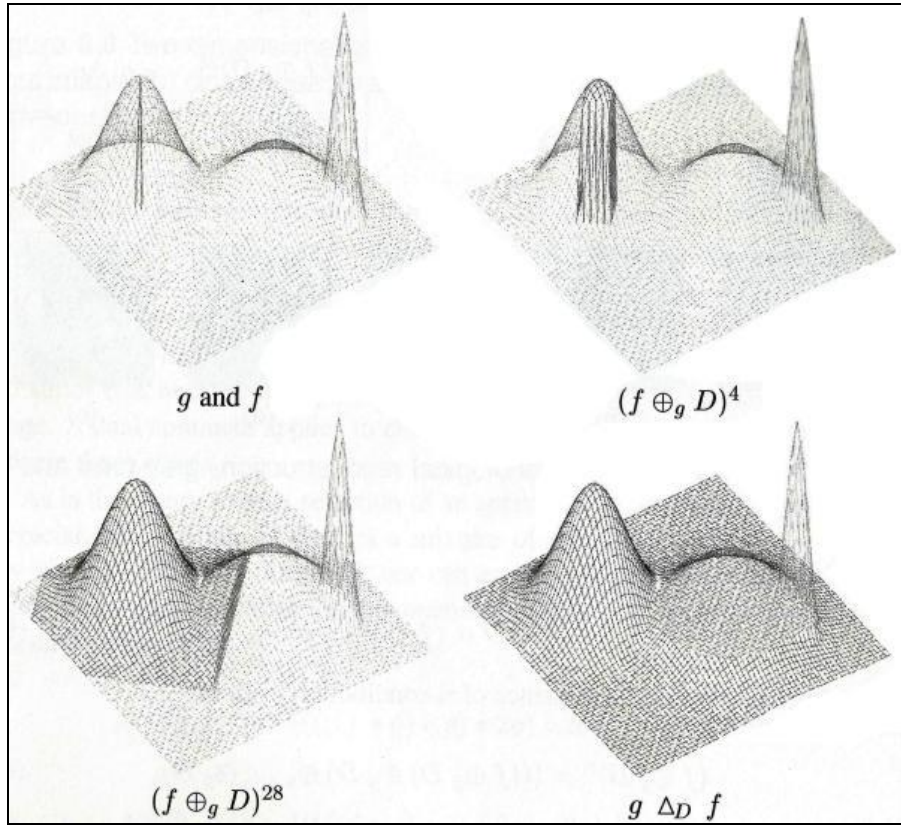
Figure 5. Morphological reconstruction gray scale illustration of surfaces.
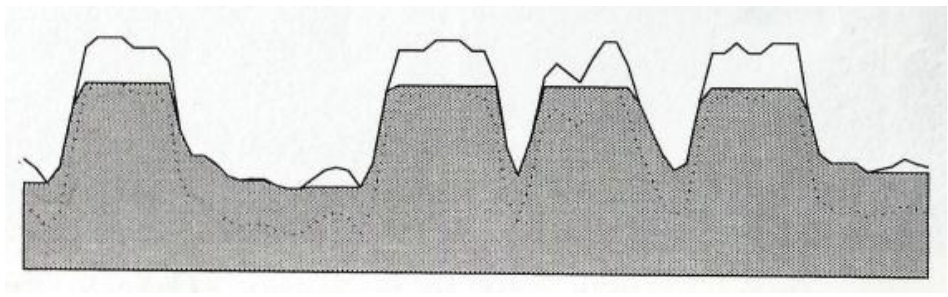Origination: (Dougherty and Lotufo - 2003)

Figure 6. Reconstruction by expansion from the input signal subtracted by h.
The solid line represents the input signal; the dashed line represents the signal
subtracted by h and the signal along the shaded gray area is the H-Maxima.
Origination: (Dougherty and Lotufo - 2003)

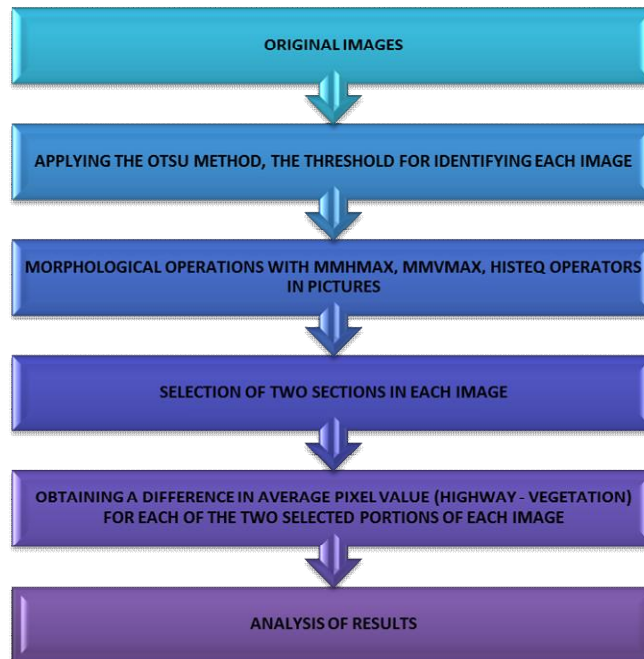**Figure 7.** Image entitled as HIGHWAY 3, used as an example in this article

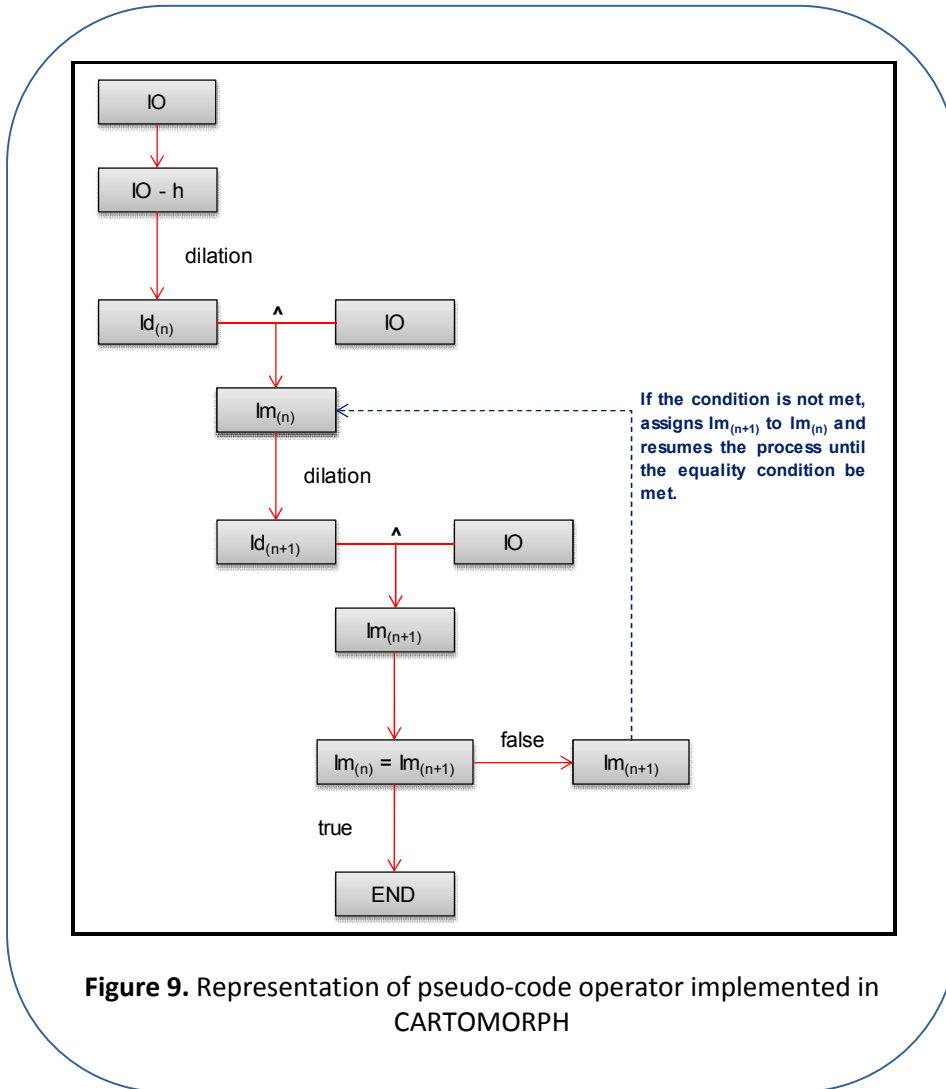**Figure 8.** Flowchart summary of the process carried out at this stage of the research project

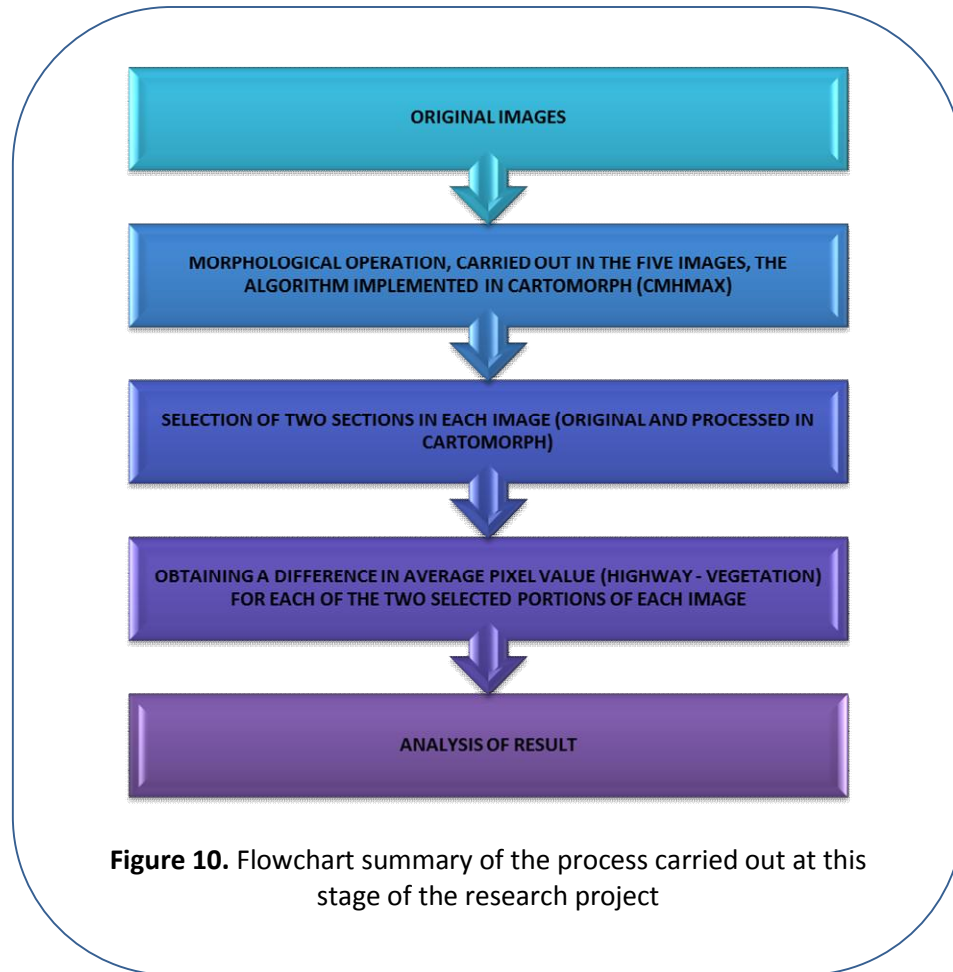**Figure 9.** Representation of pseudo-code operator implemented in CARTOMORPH

Figure 10. Flowchart summary of the process carried out at this stage of the research project

Figure 11. Original image, titled HIGHWAY 3

Figure 12. Image obtained with the morphological processing operator mmhmax

Figure 13. Image obtained with the morphological processing operator mmvmax

Figure 14. Image obtained with the morphological processing operator histeq

Figure 15. Original image

Figure 16. Image processing resulting