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SEMIAUTOMATIC METHODOLOGY FOR CARTOGRAPHIC FEATURES EXTRACTION USING HIGH-RESOLUTION REMOTE SENSING IMAGES

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Abstract: One topic of interest in the cartographic area that encourages many researches is the detection of interest features from remote sensing images. This topic is a challenge for the researchers because the complexity of the image scenes. A supervised detection process delimits the feature using the user's knowledge to recognize it. Normally, the user provides samples of the feature for the process that uses its information to determine the pixels that represent the interest features. Therefore, this paper proposes and presents a supervised methodology for cartographic features detection. This methodology combines the use of growth region technique to detect the main feature, with mathematical morphology to enhance the extraction. The detection is based on the samples provided by a user on the original image to segment the image. After, the algorithm performs the morphological closing and finally the area closing. Both operators improve the extraction by removing small holes detected inside of the interest feature obtained by the growth region methodology. The proposed methodology was validated by a statistical method established in the literature. Results have been demonstrated that this methodology can be applied to extract cartographic features of interest present using remote sensing images.

Keywords: Cartographic features extraction; high-resolution images; mathematical morphology.

METODOLOGÍA SEMIAUTOMÁTICA PARA EXTRACCIÓN DE CARACTERÍSTICAS CARTOGRÁFICAS UTILIZANDO IMÁGENES DE SENSORES REMOTOS DE ALTA RESOLUCIÓN

Resumen: Uno de los temas de interés dentro del área de cartografía que es de alto interés es la extracción de determinadas características de la imagen. Este tema representa un desafío para los investigadores debido a la complejidad de las escenas de imágenes. Un proceso de extracción supervisado delimita la característica usando el conocimiento del usuario para reconocerla. Normalmente, el usuario proporciona muestras de la característica para que el proceso utilice esta información para determinar los píxeles que representan dichas características. En este sentido, el presente trabajo propone una metodología para la extracción de características cartográficas. Esta metodología combina el uso de la metodología de crecimiento de región para extraer la característica, con morfología matemática para mejorar el resultado. La extracción se basa en las muestras proporcionadas por un usuario para segmentar la imagen. Después, el algoritmo realiza el cierre morfológico y, finalmente, el cierre por área. Los dos operadores mejoraran la extracción eliminando pequeños huecos detectados en el interior de la característica de interés obtenido en la segmentación. La metodología propuesta se validó mediante un método estadístico establecido. Los resultados han demostrado que esta metodología puede ser aplicada para extraer características cartográficas de interés presentes en imágenes de sensores remotos.

Palabras claves: Extracción de características cartográficas; imágenes de alta resolución; morfología matemática.

1. INTRODUCTION

Nowadays there are several researches developing methodologies to detect specific targets in a digital image. It is not different in the Cartographic area and one important cartographic target is road. Road detection researches can use digital images provided by aerial photographs or satellite remote sensing imagery. The road detection researches are very important for cartographic spatial data acquisition and update, since it can be performed in a fast and efficient way and it is indispensable to the development of a Geographic Information System (GIS) (Ishikawa, Silva, & Nóbrega, 2010). The targets detection methodologies consist of two basic tasks. The first one is defined as the recognition of the interest target of the image, while the second task is defined as the delimitation of the interest feature. In addition, we can split the targets detections methodologies in two types, automatic and supervised methodologies. The automatic detection methodologies perform both tasks of targets detection methodologies. In the other hand, the supervised methodologies perform just the delimitation task while the user, normally providing interest samples for the supervised detection methodology, performs the recognition of the interest target (Dal Poz, Zanin, & do Vale, 2007). Some road detection methodologies use linear techniques, once the roads have, normally, linear structures. However, it is became a restrictive domain, so, no-linear techniques, such as

Mathematical Morphology (MM), are more efficient due to the capacity to remove noise and preserve the target's geometric structures (Ishikawa et al., 2010).

In the literature, we found several researches trying to develop new methodologies to detected roads in remote sensing image. Some of them use linear techniques, while others use morphological techniques trying to keep the geometric structure of the targets (Gaetano, Zerubia, Scarpa, & Poggi, 2011; Santiago, Silva, Nogueira, & Leonardi, 2012; Wang & Shan, 2012). However, there is not a defined methodology to work with different types of images and interest features. Therefore, this paper proposes a supervised methodology to detect cartographic features of a digital remote sensing image. The proposed methodology consists of the use of some samples of the interest feature, provided by the user, to calculate a range of values that belong to it. After, the growth region methodology (Silva, Cardim, & Best, 2012) is performed to detect the interest feature as a first step. In addition, the methodology uses mathematical morphology operators to improve the result of the detection. The development of this methodology is justified by the necessity of detect cartographic features from remote sensing images using an efficient and fast way. This way, having an efficient methodology, the cartographic community can use it to acquire and update the spatial data.

The remaining part of this paper is organized as follows. Section 2 provides the definitions and the explanation of the methodology proposed in this paper. Section 3 presents the results obtained using the proposed methodology. The Section 4 provides an analysis of the results while the Section 5 presents the conclusions about the proposed methodology and the obtained results.

2. METHODOLOGY

The applied methodology consists of acquire samples of the interest features from the user to perform the growth region technique, which look for pixels that belong to the interest feature from initial points according to a range of values. The samples, provided by the user, are used as initial points and to calculate the range of values that the growth region technique will use to detect the interest feature. From the initial points, the technique search, in the neighborhood, for other points that belong to the range defined and continue doing it for the neighborhood of the points detected as part of the interest feature (Silva et al., 2012). Figure 1 presents the functionality of the growth region technique, but the values are just an example.

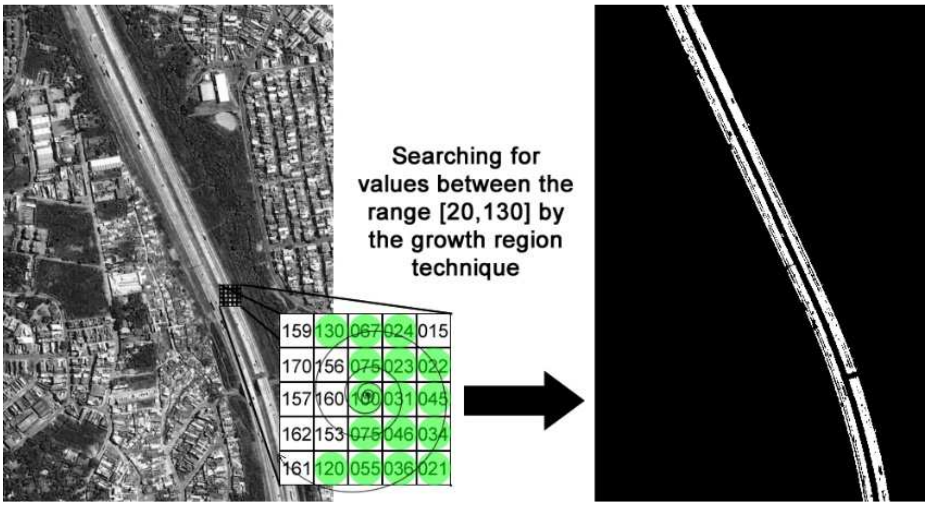

Figure 1. Growth region technique.

The growth region technique described before is considered as supervised, since the user must provide some samples to the algorithm before the processing. The growth region can be considered as a segmentation step, since it will result in a binary image with a base detection of the interest feature.

This first step results in a segmented image, which has some imperfections in the detected cartographic features. The next steps of the proposed methodology use operators of the mathematical morphology theory (MM) to eliminate these imperfections. The MM is capable of process the digital image doing modifications in the image and preserving the geometric structures of the interest features at the same time.

The MM is defined for two basic operators, the erosion and the dilation operators. To perform those operators, we need a previous defined structure named as structuring element (SE). The SE is a defined and known set, which is compared with the unknown set of the digital image (Facon, 1996). The two basic operators work similarly and the structuring element is used to define the geometric structure used in the operations. In the dilation, the center point of the structuring element will result in the maximum value of all the pixels belonging to the SE, while in the erosion the center point will result in the minimum value (Soille, 2003). The dilation has the effect of expand the targets, fill small holes and connect nearby targets. In the other hand, the erosion’s effects is to eliminate targets smaller than the SE, to expand holes in the targets and to separate nearby targets (Facon, 1996).

Having the two MM basic operators described, we can also describe the operator called closing. The closing operator is defined by the dilation followed by the erosion operator (Soille, 2003). The main effect of this operator is to use the dilation properties to fill small holes and connect nearby target, so, return the targets to the original size applying the erosion operator, but preserving the filled holes and connected targets.

The second operator performed is the area closing. This operator identifies each connected target of the background and calculates the area of each one. This way, area closing eliminates the targets of the background with an area smaller than a determined value by converting these targets in foreground. The main effect of this operator is to eliminate small holes, inside of the interest feature, according to the minimum area value defined by the user.

Using those three operators, growth region, closing and area closing, the methodology used in this paper to detect targets of interest in remote sensing image can be resumed in the flowchart showed by Figure 2.

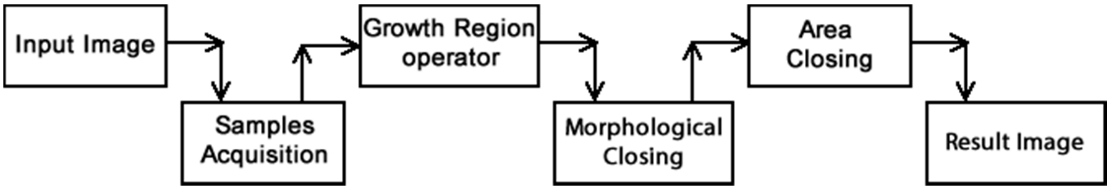

Figure 2. Flowchart of the proposed methodology.

The methodology consists of the use of samples provided by the user to apply the growth region operator, which performs a kind of segmentation doing a base detection of the interest feature as showed by Figure 1. Acquiring the base segmentation, the morphological closing can connect some structures separated by the growth region operator. In addition, the last step, the area closing, fill the small holes inside of the interest feature detected, considering that some small objects can be over the interest feature during the image acquisition.

The proposed methodology was implemented in, and using, the CARTOMORPH project, which is a library of functions focused on the remote sensing images processing to develop methodologies of cartographic features detection.

Furthermore, to validate the proposed methodology, we used a set of images from the Faculty of Science and Technology (FCT/UNESP) database and we choose one of them to present the results in this paper. This image is showed by Figure 3 and was obtained from the panchromatic band of QuickBird Satellite with spatial resolution of 0.6m. This image has part of a highway of São Paulo city as the interest feature.

Figure 3. Original panchromatic image.

3. RESULTS

This section presents one example of cartographic feature detection using the proposed methodology. As mentioned before, the example image is part of an image acquired by the QuickBird satellite with 0.6m of spatial resolution and Figure 3 presents it. The example image has part of a highway of São Paulo city in Brazil as the interest feature.

The first step of the methodology is the interaction with the user to provide samples of the interest feature for the system. It can be done providing a binary image, where white pixels represent the samples of interest. For the example, Figure 4 presents the image of samples provided by the user.

Figure 4. Image of samples.

Providing the samples, the growth region operator was applied resulting in a segmentation of the original image with a basic detection of the interest feature. Figure 5 presents the result obtained for the example after performing the growth region operator.

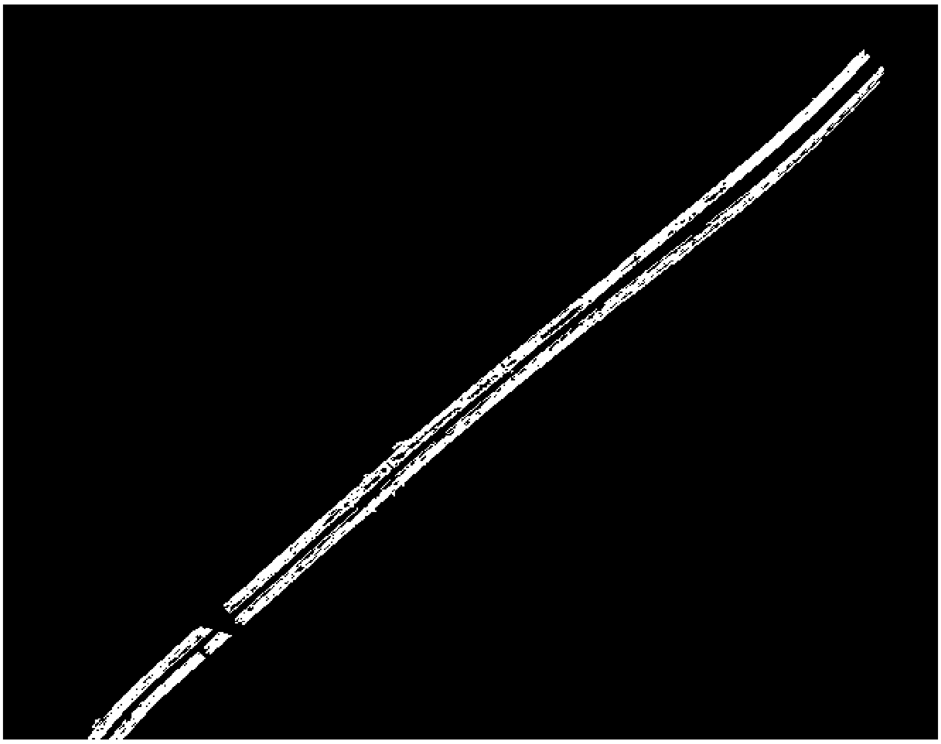

Figure 5. Result of the growth region.

After apply the growth region operator, the morphological closing can be applied to connect separated components and fill small holes inside of the detected feature. The morphological closing operator was performed using a structuring element of size 3x3 of box type, in other words, all points of the SE of 3x3 size is considerable. Figure 6 presents the result of the morphological closing operator in the example.

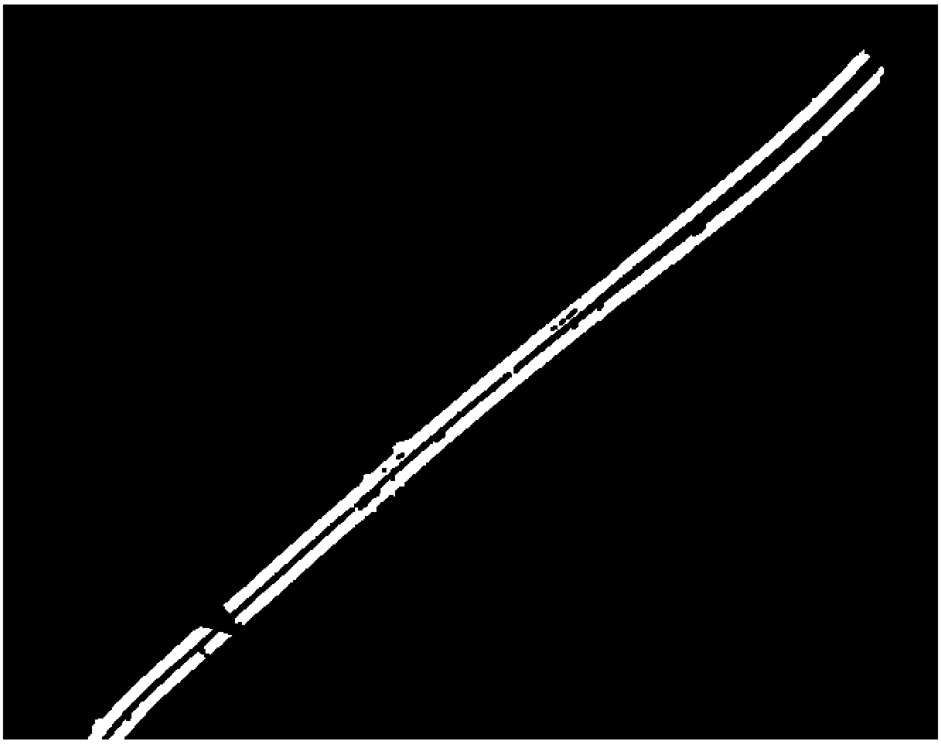
Figure 6. Morphological closing result.

The morphological closing operator connects separated components and fills some holes smaller than the structuring element. However, there are holes bigger than the SE still inside of the detected feature. This way, the next step consists of the use of the area closing operator, which is performed using a cross structuring element of size 3x3, in other words, just the neighborhood 4 is considered. Another parameter necessary for this operation is the maximum size of the area to fill, which we choose and use 1500 pixels for all the tested images. The result of this operator for the example is presented by Figure 7.

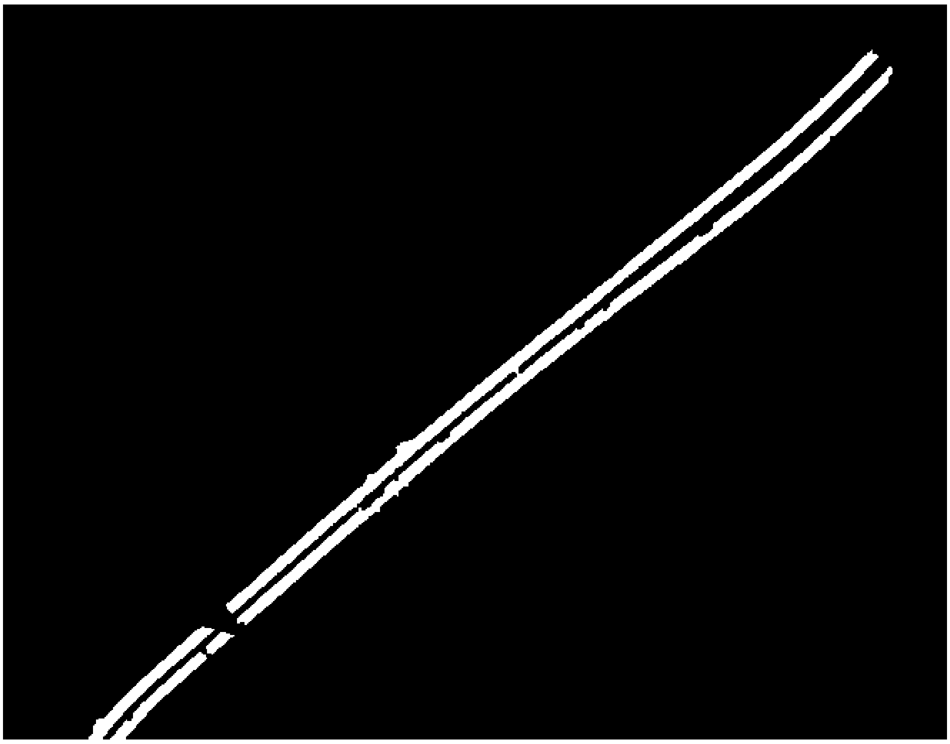

Figure 7. Area closing result.

The area closing result is considered as the methodology result. This way, we validate the result obtained by a statistical approach defined in the literature (Cardim, da Silva, & Dias, 2014; Wiedemann, 2003). According to the evaluation methodology, we must have a reference image, which is considered as the desired result, to compare with the result obtained by the proposed methodology. Figure 8 represents the reference image used for this example.

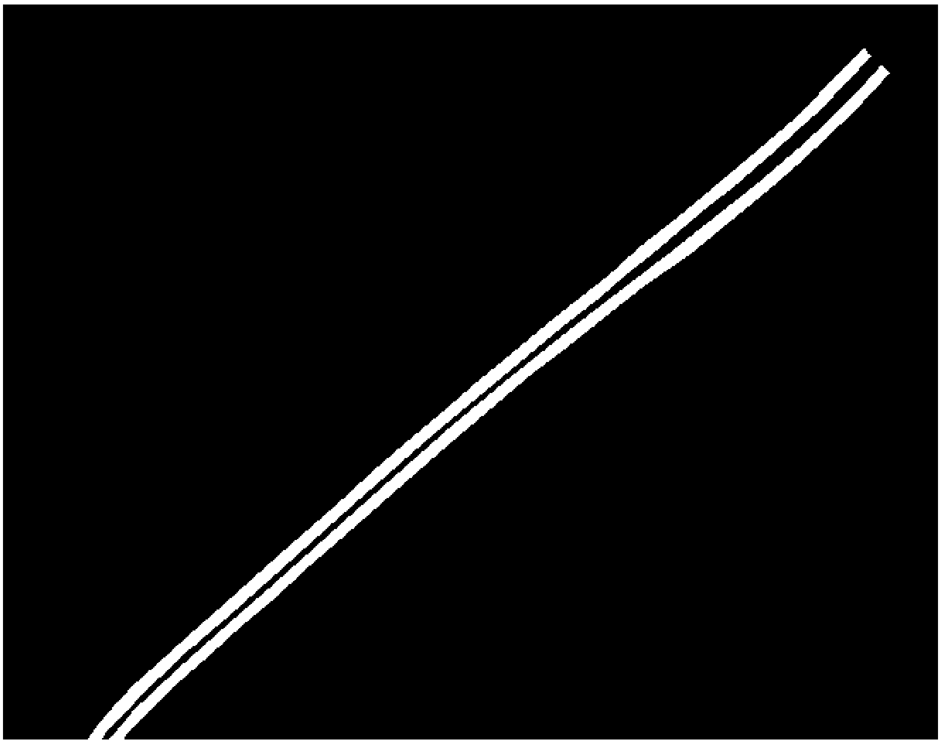

Figure 8. Reference image.

Following the statistical analysis methodology, we could obtain the statistical values about the result obtained with the detection methodology proposed for the presented example. Table 1 presents the main statistical values obtained for the example used in this paper.

Table 1. Statistical results.

Completeness	*0.953478*
Correctness	*0.944954*
Quality	*0.904264*

4. ANALYSIS OF THE RESULTS

Visually, we can check that the methodology proposed in this paper obtained better results adding the two additional steps than using only the growth region technique. The interest feature, a highway in the example, was well delimitated by the proposed methodology. However, we also can realize that there was a problem when something is obstructing the interest feature. Looking for the original image, presented by Figure 3, we see a viaduct over the highway of interest, so, the detected result, presented by Figure 7, did not detect the highway under the viaduct.

On the other hand, statistically, all the values about the detection quality, for the presented example, are over 90%. It indicates the efficiency of the methodology proposed in this paper detecting the feature interest with high statistical quality values. Looking for the other tested images, the statistical values of completeness and correctness are over than 80%. The detected images obtained show that the proposed methodology does not change the location of the interest feature, a common problem found in some methodologies described in the literature.

5. CONCLUSIONS

Intending to obtain a computational way to detect cartographic features from remote sensing images, a supervised methodology was developed and this paper presents the obtained results.

The proposed methodology are able to remedy the problems imposed by other research studies (Silva et al., 2012) that use only the growth region technique as a detection methodology. It can be visually and statistically verified by observing, respectively, the figures presented in this paper, and the high-quality values obtained by the proposed methodology. However, it is known that the results directly depend on the samples provided by the user. This way, providing wrong or poor samples, the methodology will not be efficient to detect the interest feature.

Concluding, the proposed methodology has demonstrated its efficiency detecting cartographic features from remote sensing images using samples provided by the user to identify the interest feature. The results confirm the need for researches about automation of cartographic features detection. The proposed methodology contributes for the literature providing an efficient methodology to detect cartographic features; performing it in a fast way; and not dependent of the cartographic feature type, in other words, the methodology is not restricted by the type of the interest feature, being able to detect, for example, roads and rivers.

However, as further works, we intend to improve the proposed methodology not to be limited when the interest feature is obstructed with some other target, being able to detect the entire interest feature, even when there is something over it.

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