ROAD EXTRACTION FROM ALOS IMAGES USING MATHEMATICAL MORPHOLOGY

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ABSTRACT:

Over the past few years have seen the need to use remote sensing data to accomplish the complex task of automatic extraction of features. Among the sensor systems currently used for mapping can be highlighted the recent launches of new orbital satellites, for example, the Advanced Land Observing Satellite (ALOS). The problems currently involved in the extraction of features like road presents the following issues: The roads may be partially hidden and stretches of road may not be recorded due to limitations of the sensors. Given the need for analysis of the potential of ALOS images, development of methodologies for roads extraction, and the study of problems involved in the process, the aim of this paper is the roads extraction with ALOS images through the use of mathematical morphology. At first step, an initial selection of stretches of road is done using algorithms of mathematical morphology and segmentation. At this stage, most of other classes, such as vegetation were eliminated. However, at this moment the road had not complete obtained, performing inconsistently. This happens due to the spectral similarity between some sections of the road and vegetation present in the scene. Thus, to segment the image in order to eliminate the vegetation, parts of the road were also eliminated. In a second step, within the MATLAB environment, were developed a routine to complement the road obtained after the application of morphological operators. This routine used other techniques of mathematical morphology, and the Euclidean distance for complementation. At the end of the process, the road was complete, resulting in a road consistently. Further tests must still be performed, since the methods and techniques used to extract features modify by the area of study and the type of image being used.

1. INTRODUCTION

Given the continental dimensions of Brazil, a trend to research for a solution to the problem of outdated mapping in the country is the use of remote sensing data to accomplish the task of automatic extraction of features. According to Dal Poz et al. (2007), the problem of features extraction have been of fundamental importance for more than two decades at the automation of processes that extract cartographic features such as buildings, rivers, roads, etc. However, the developed solutions always depend on the type of sensor used to generate the images.

New images are being made available with the recent launches of new orbital satellites, such as the Advanced Land Observing Satellite (ALOS). According to the Brazilian Institute of Geography and Statistics (IBGE, 2007), the ALOS images are intended mainly to serve the scientific community and the non-commercial User, thus practicing a policy of cost where the images will have an affordable price. This cost policy is to make possible the mapping of a large country like Brazil.

The roads are features on maps which can be highlighted for its dynamism due to changes in their shape or texture, type - pavement or not pavement - and / or inclusion of new roads or road sections in the system. These changes are constant due the result of transformation resulting from the socio-economic growth. Soon, the roads are cartographic features that require constant updating.

The problems currently involved in the features extraction like road presents the following issues: first, the roads may be partially hidden; second, some stretches of road may not be registered due to limitations of the orbital images and third, the radiometric resolution of the selected road. The first issue is due to clouds that may be present in the images and shadows of structures such as buildings, bridges and cars as well as vegetation can hide parts of the road feature. The second question is a function of spatial resolution of the orbital images used for extraction. The third question refers to the radiometric similarity between different features, for example roads without pavement may present a feature similar to exposed soil. According Cleynenbreugel et al. (1990), one of the problems of roads extraction from satellite images is the spatial resolution of the image. This may involve many details of the roads were not visible in the images, so cannot be used for extraction.

Solutions to the problem of roads extraction have been studying in different ways. The way to approach the issue has been modifying according to new sensors developing. Nowadays high spatial resolution images and laser scanner data are used. The difference between the proposals for roads extraction due to the strategy used, for example: type and resolution of the images are being used, configuration of the experiments, methods of preparation and general assumptions (Wang et al., 2005).

Some solutions for roads extraction are described in the literature, as in Baumgartner et al. (1999) that used the same aerial image with different resolutions for an automatic road extraction based on multi-scale, grouping, and context. Wiedemann and Wessel (2003) extract roads from synthetic

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aperture radar (SAR) imagery. Clode et al. (2004), who used data only laser scanner for automated extraction of roads. Maillard and Cavaye (1989) developed methodologies for the extraction of roads using only the multispectral images. Zhang and Murai (1999); Mohammadzadeh et. al. (2004) introduces an extraction based on mathematical morphology. Among the existing solutions can highlight the use of Mathematical Morphology, which includes the study of topological and structural properties of objects from their images. (Gonzales; Woods, 2000).

Given the need for an analysis of the potential of ALOS images, development of methodologies for the roads extraction and the study of problems involved in the process, this paper present a method to road extraction with ALOS images through the use of mathematical morphology. The paper have the following specific objectives: Analyze the potential of use ALOS images for the roads extraction and evaluate the use of mathematical morphology in this case.

2. THE ALOS SATELLITE

The ALOS is a Japanese satellite that was launched by the Japanese Space Agency (JAXA) on January 24, 2006, becoming operational on October 20, 2006. This was launched by the rocket H-IIA from Tanegashima Space Center, Japan. His original name in Japanese language is "DAICHI.

The ALOS satellite carries onboard 3 sensors:

AVNIR-2: Advanced Visible and Near Infrared Radiometer - type 2;
PRISM: Panchromatic Remote-sensing Instrument for Stereo Mapping;
PALSAR: Phased Array L-band Synthetic Aperture Radar.

In this work it is worth highlighting the AVNIR-2 and PRISM. The AVNIR-2 is an optical sensor with 4 spectral bands, 3 bands of the visible and 1 near infrared band with a spatial resolution of 10 meters. The PRISM sensor operates in the visible light, with a panchromatic band and spatial resolution of 2.5 m. This is a set of 3 independent imaging telescopes that allow scenes nadir, leaning forward and leaning back. This system makes possible the acquisition of stereoscopic images along the path.

3. MATHEMATICAL MORPHOLOGY

The mathematical morphology has been widely used in digital image processing and focuses on the area that studies the geometric properties of objects in the images. This allows the extraction of image components that are useful in the representation and description of the shape of a region, such as borders and skeletons (Gonzales; Woods, 2000). The extraction of elements present in an image is accomplished with the help of a suitable structural element. The structural elements are matrices responsible for the removal or addition of labeled pixels in the image, which depend on their size and shape, usually defined by the User, according to the area to be applied.

In this paper the mathematical morphology adopted is binary, thus only binary morphological operators were used. The basic operations of morphology are erosion and dilation, at the first the pixels that do not conform to a given pattern are deleted from the image and at the second a small area related to a pixel is changed to a given pattern. These operations are the basis for most of the operations used in mathematical morphology, in other words, they are combinations of these such as opening, closing, skeletonization, among others.

The dilation is a morphological operation that combines two sets using the vector addition of elements of sets. Its symbol is $\oplus$, the result as the name suggests is a dilated image, like this the effect of the dilation on an image is the growth or expansion of the object. These objects refer to the pixels whose gray level is greater than zero in relation with the background. The dilation can also be understood as the union of translations of A by elements of B. The Dilation of a set A by B denoted by $A \oplus B$, is given as:

$$A \oplus B = (x \mid (B)\, x \cap A \neq \emptyset) \qquad (1)$$

where A represents the image being operated on and B is called structuring element and its composition defines the dilation, so the dilation expands an image.

Therefore, the dilation of A by B is the set of all x displacements such that $\hat{B}$ and A overlap in at least one nonzero element.

Unlike the dilation, the erosion reduces the object present in the image against the background. It is a morphological operation that combines two sets using vector subtraction of elements of sets, its symbol is $\ominus$. The erosion of A by the structuring element B, denoted by $A \ominus B$, is given as

$$A \ominus B = (x \mid (B)\, x \subseteq A) \qquad (2)$$

The erosion of A by B is the set of all points x such that B, when translated by x, be contained in A.

The result of successive erosions and dilations allow the elimination of specific details of the image, smaller than the structuring element without distortion of the features not deleted. The effect of re-application is no longer to modify the previously transformed result.

The opening operator is used to remove parts of objects or even objects smaller than the structuring element. Thus, the opening operator can eliminate noise due to the erosion operator that is applied initially. The opening of a set A by B, denoted by $A \circ B$ is given by equation 3.

$$A \circ B = (A \ominus B) \oplus B \qquad (3)$$

where A represents the image being operated on and B is called structuring element.

The closing operator tends to join "islands" which the distance between them is less than the structuring element and closing holes smaller than this element. Being the same set A and a structuring element B, the closing of A by B, denoted by $A \bullet B$, is given by equation 4.

$$A \bullet B = (A \oplus B) \ominus B \qquad (4)$$

Soon, these operated jointly applied enable the formation of the most compact and at the same time, eliminate regions very small or thin.

4. DEVELOPMENT

Inputs such as images, digital topographic mapping and software are needed to perform the work. The materials used and the methodology are presented as follows.

4.1 Materials

The ALOS images and the topographical mapping comprising the study area are shown in Figure 01. This area lies at Paraná (Brazil) state, specifically in the municipality district of Guaraqueçaba, Brazil, near the coastline.

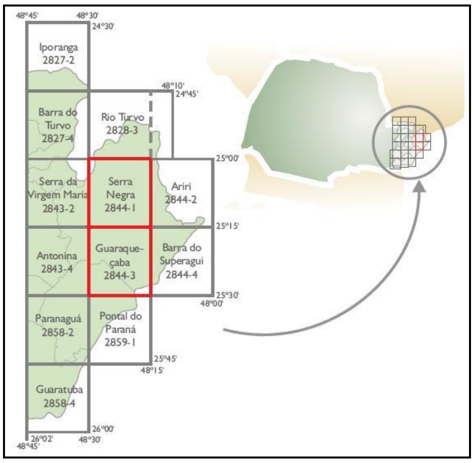

Figure 01: Area of study

The area is bounded between the coordinates UTM:

• Upper left:
Latitude -25° 11' 25.95"
Longitude -48° 22' 00.20"

• Bottom right:
Latitude: -25° 17' 05.17"
Longitude -48° 14' 37.92"

The ALOS images were acquired through the research program of the Brazilian Institute of Geography and Statistics (IBGE), which is responsible for distributing the ALOS images for federal government agencies, research institutions and other non-commercial users in Brazil. The software used is the ENVI 4.5 and MATLAB R2007b. The ENVI 4.5 allows the manipulation of ALOS images as well as the topographic mapping; the MATLAB is used for the development of routines that take the mathematical morphology.

4.2 Methodology

The roads extracted were not pavement and belonging to PR – 405. To obtain the field reality, topographic maps at 1:25.000 scales were used to identify the roads on the scene. From the step 01 to step 03, the processing was performed in the software ENVI 4.5.

STEP 01 - REGISTRATION: The registration is required for the integration of images acquired by different sensors, for example the AVNIR-2 and PRISM, integration of images obtained at different times, among other applications. For its implementation is necessary to choose control points. After collection of control points, which must be distributed across the entire image, is needed to define the interpolation process. In this work the bilinear interpolation method was chosen.

STEP 02 - FUSION: The images available are of different sensors, in this case AVNIR-2 and PRISM and with different spatial resolution, 10 meters and 2.5 meters respectively. Thus, for the analysis of mixed spatial databases, which may consist of images from different sensors with different spatial resolutions, it is necessary to perform the fusion process. Fusion was performed by principal components. After obtaining the principal components, the first component is removed and placed in the panchromatic image, in this case the PRISM image. After PRISM assume to be the first principal component is necessary to reverse transformation to return the multispectral bands.

STEP 03 - CLASSIFICATION: This step is performed the classification of the image obtained in the fusion process. The method used was the supervised classification, where the classes of information are pre-defined, and from its definition are acquired samples of each class. To perform the classification, classifiers are needed. The classifier used was the statistical Maximum Likelihood - ML. The classified image is used for verification of stretches of roads which are not possible to identify with the PRISM image.

From the step 04, all processes have been developed in MATLAB.

STEP 04 - EXTRACTION: An initial selection of stretches of road is done using algorithms of mathematical morphology and segmentation. For this process has generated a routine for the PRISM image binarization. Armed with binary image the morphological operators were applied to it. Operators of closing, erosion were applied. Several tests using different structuring elements were performed to find the best solution for the image used. At this stage, most other classes, such as vegetation, are eliminated. To eliminate other unwanted traces of features the connected components of the image were calculated and the smallest areas excluded. The product of this post-processing was a cleaner image of traces of unwanted features. However, at this moment the road obtained has not complete linear features, performing inconsistently.

STEP 05 - FILLING: Was developed a routine to complement the road obtained in extraction (step 04). This routine used other techniques of mathematical morphology and an algorithm for calculating the Euclidean distance. From a User-defined threshold, based on the calculated Euclidean distance, the road extracted was completed. At the end the images (PRISM binary code, classified, filled) were overlaid to verify the areas filled by the algorithm.

5. RESULTS

The methodology has been applied and the results were as follows. Initially the PRISM image panchromatic was binary code in MATLAB and the road cut into two parts. For this result was used a threshold equal to 90. This threshold is defined as object to be extracted in the image. After the application of morphological operators like dilation, was not possible to recover parts of roads that have been eliminated. The results are shown in figures 02 and 03.

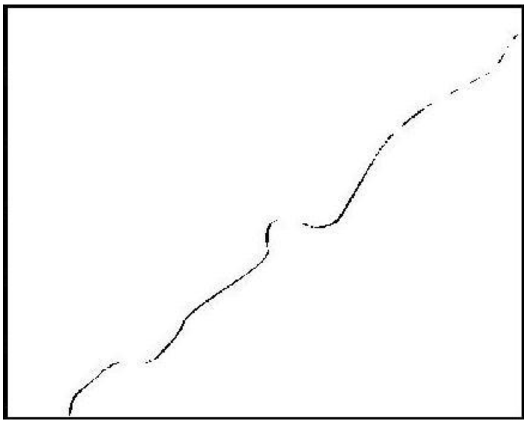

Figure 02: Road segmented – stretch 01

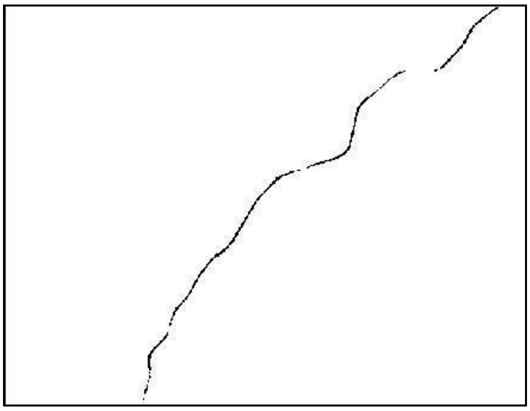

Figure 03: Road segmented – stretch 02

This is due to the spectral similarity between some parts of the road and vegetation present in the scene. Thus, to segment the image in order to eliminate the vegetation, parts of the road were also eliminated.

Thus, the road must be completed. The process of filling by calculating the Euclidean distance can be seen in Figure 04 e 05. It is observed that the areas highlighted in both figures have not been the appropriate completion.

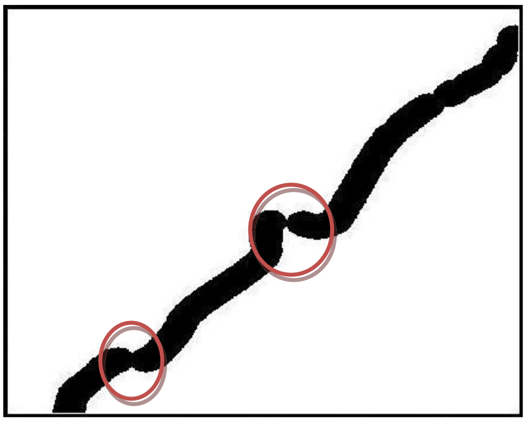

Figure 04: Euclidian distance – stretch 01

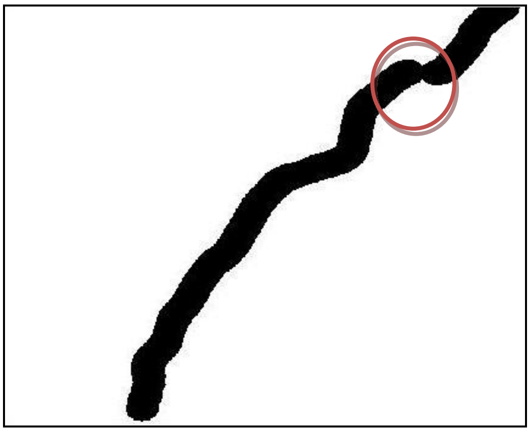

Figure 05: Euclidian distance – stretch 02

This fact is due both to the curvature of the road, and the amount of road lost in the segmentation process. The morphological closing operator was applied to correct such failures. The Figure 06 and 07 present the results. The same areas were highlighted in both figures to verify the result.

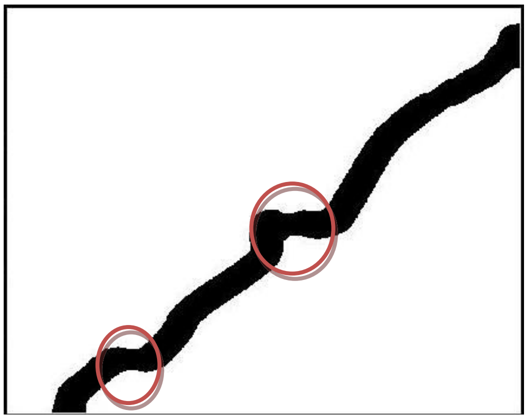

Figure 06: Closing – stretch 01

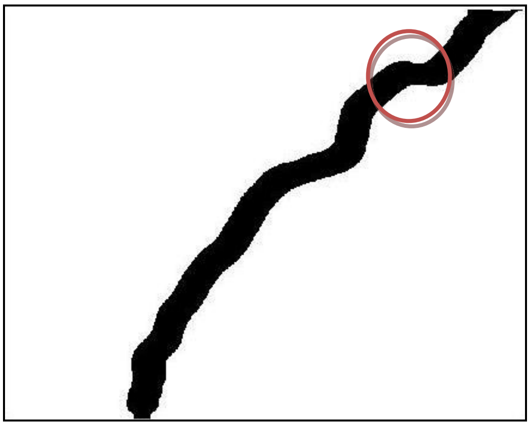

Figure 07: Closing – stretch 02

After applying the closuring operator, was possible to define the linear feature complete, in this case the complete road. However, the road was still showing a dilated form, requiring the operator's application of erosion operator to obtain a road consistently. The result can be seen in Figures 08 and 09.

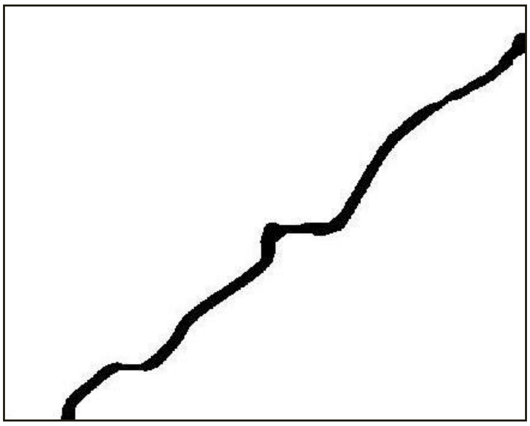

Figure 08: Erosion – stretch 01

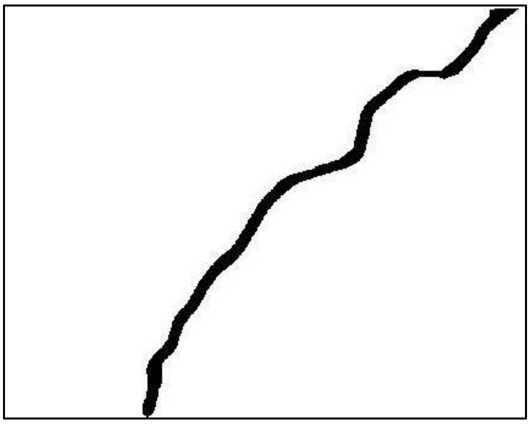

Figure 09: Erosion - stretch 02

At the end of the process the roads were overlaid with the classified image in order to check the area filled by the algorithm.

Figure 10: Overlay – stretch 01

6. CONCLUSIONS

The roads extracted still need to be refinement, because the edges have not yet obtained homogeneity along the stretch. Further tests must still be performed, since the methods and techniques used to extract features vary by area of study and type of image being used. The results are satisfactory as it was possible to fill the roads with the use of mathematical morphology and the result is close to the classification made. The extraction using mathematical morphology showed good performance, and only need the panchromatic band for its realization.

6.1 References

Baumgartner, A., Steger, C., Mayer, H., Eckstein, W.and Ebner, H., 1999. *Automatic Road Extraction Based on Multi-Scale, Grouping, and Context*. Photogrammetric Engineering and Remote Sensing, v. 65(7), p. 777–785.

Cleynenbreugel, J. et. al. *Delineating Road Structures on Satellite Imagery by a GIS-Guided Technique*. IAPRS - International Archives of Photogrammetry and Remote Sensing, v. 56(6), p. 893 – 898. 1990.

Clode, S.; Kootsookos, P; Rottensteiner, F. *The automatic extraction of roads from LIDAR data***.** IAPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Istambul, v. 35, p. 231 – 237. 2004.

Dal Poz, et. al. *Extração automática de feições rodoviárias em imagens digitais*. Revista Controle e Automação. v. 18, n. 01, jan./fev./mar. 2007.

Gonzales, R. C., Woods, R. E. *Processamento de imagens digitais*. Traduzido. Editora Edgard Blücher Ltda. 2000. 509p.

Instituto Brasileiro de Geografia e Estatística (IBGE). *IBGE como sub-nó de distribuição de imagens do satélite ALOS*. Rio de Janeiro, 2007. No prelo.

Maillard, P.; Cavayas, F. *Automatic map-guided extraction of roads from SPOT imagery for cartographic database updating*. IAPRS - International Archives of Photogrammetry and Remote Sensing, v. 10, p. 1775-1787. 1989.

Mohammadzadeh, A.; Tavakoli, A.; Zoej, M. *Automatic linear feature extraction of Iranian roads from high resolution multi-spectral satellite imagery*. IAPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, v. 35, p. 764- 767. 2004.

Wang, L.; Qin, Q.; Du, S.; Chen, D.; Tao, J. *Road Extraction from Remote Sensing Image Based on Multi-resolution Analysis*. In: International Symposium on Remote Sensing of Environment (ISRSE) – Global Monitoring for Sustainability and Security, 31st, 2005, Saint Petersburg. Proceedings… Saint Petersburg: ISRSE, 2005.

Wessel, B.; Wiedemann, C. *Analysis of automatic road extraction results from airborne SAR imagery*. IAPRS - International Archives of Photogrammetry and Remote Sensing, Munich, v. 34(3), 2003.

Zhang C.; Murai, S.; Baltsavias, E. *Road Network Detection by Mathematical Morphology*. IAPRS - International Archives of Photogrammetry and Remote Sensing, Paris, p. 185-200, 1999.

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