A ROAD NETWORK EXTRACTION METHODOLOGY APPLIED IN REMOTE SENSING IMAGES OF LOW AND MEDIAN SPATIAL RESOLUTION

Guilherme P. Cardim[1], Samara C. Azevedo[1], Erivaldo A. Silva[1], Maurício A. Dias[1], Ignacio Bravo[2] and Alfredo Gardel[2]
[1]Universidade Estadual Paulista – UNESP – Brazil | [2]Universidad de Alcalá – UAH – Spain
{gpcardim, samaracalcado88, silva.erivaldo}@gmail.com; madias@fct.unesp.br ; {ignacio.bravo, aldredo.gardel}@uah.es;

PECORA 20 – OBSERVING A CHANGING EARTH – SIOUX FALLS, SD – NOVEMBER 13-16, 2017
FAPESP 2013/25257-4 | 2014/24392-8 | 2016/04553-2

INTRODUCTION

The remote sensing data have been widely used for cartographic studies. Remote sensing is the name given to the cartographic studies using data that are collected without a physical contact with the object measured. The most common remote sensing data, used in cartographic research, is the digital image, which can be used for several purposes, such as urban cadastral studies and road maps updating. Considering the need to have updated road mapping, it is possible to find several researches aiming to automatic extract road networks from remote sensing images. There are several concepts used to develop new extraction methodologies, such as convolutional neural networks, partial differential equations and mathematical morphology (MM). Among them, the MM theory is widely used due to its ability to maintain the geometry structure of the target after a processing step. Despite the high number of methodologies proposed, there is no ideal solution for all situations. Furthermore, the recent great availability of high-resolution remote sensing images has made studies of road extraction using low-resolution images, for large areas, become scarce. In this sense, this paper proposes a novel method for road network extraction from low-resolution remote sensing images. The proposed method is based on mathematical morphology, Otsu segmentation and a geometric step analyzing the target structure. The results were statistical evaluated to confirm the method's ability to extract road networks.

STUDY AREA

To verify and evaluate the methodology we used the panchromatic layer of a remote sensing image, acquired in July 2017, by CBERS satellite, which has spatial resolution of 5m per pixel. The images are from Alta Paulista region, a region of the São Paulo state in Brazil, as presented by Figure 1. This area was chosen due to the recent renovation and extensions carried out by the governments on the roads. Considering the highways as the study focus, the image was split in six subsamples. Figure 2 shows two subsamples selected to be presented in this paper.

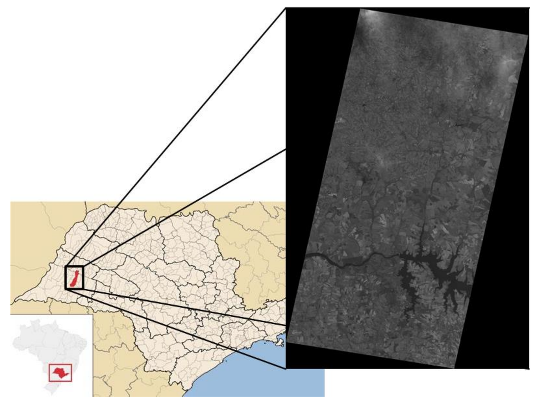

Figure 1. Selected image for study.

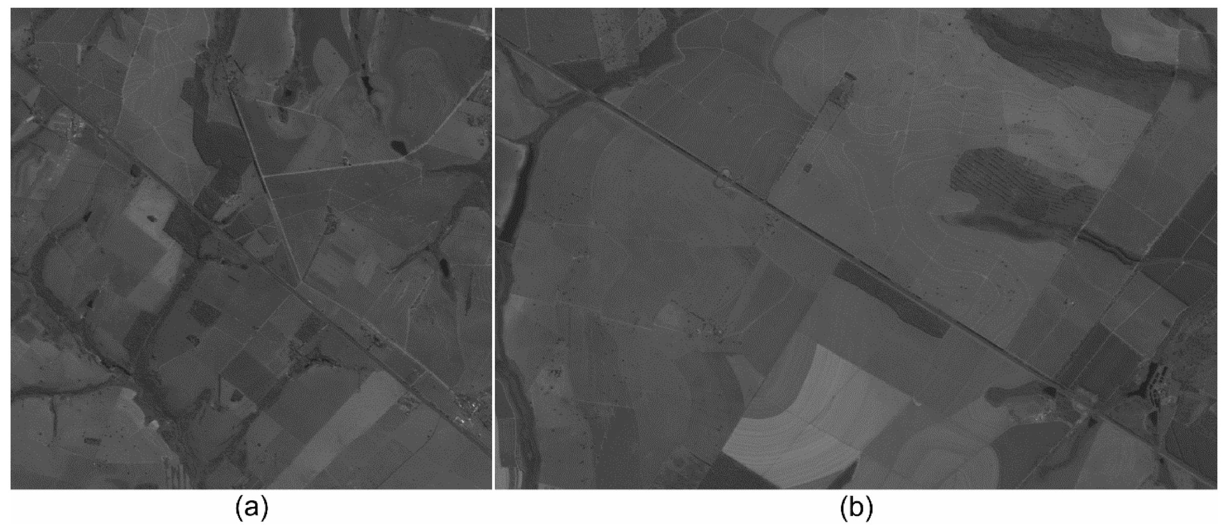

Figure 2. Subsamples used as examples.

METHODOLOGY

The methodology proposed is based on digital image processing focusing on the mathematical morphology theory. The methodology is organized in four stages: preprocessing, segmentation, post-processing and a skeletonization. Figure 3 presents the road extraction methodology proposed.

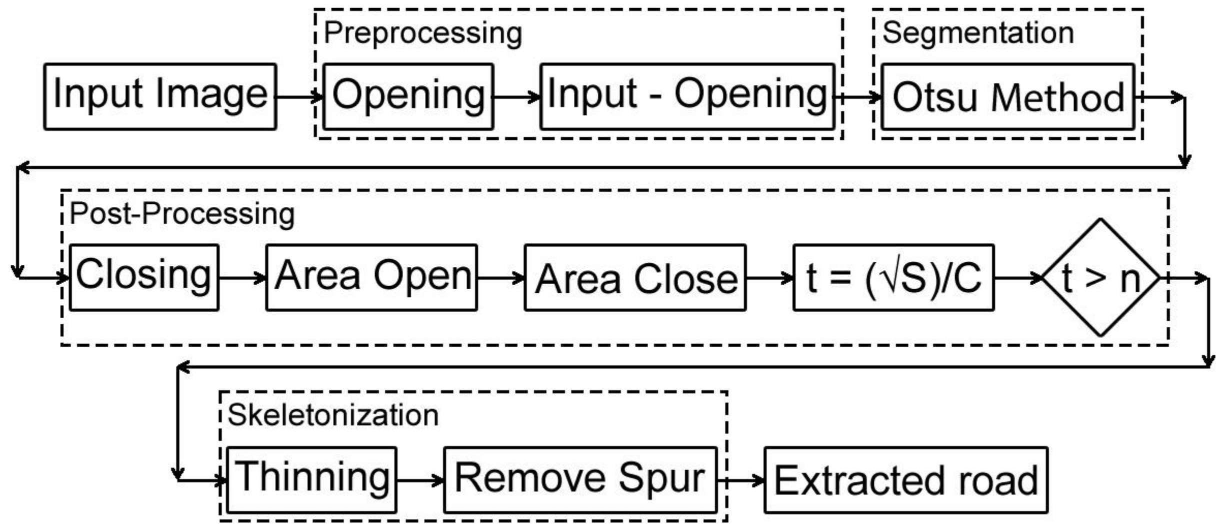

Figure 3. Flowchart of the proposed methodology.

Preprocessing Stage
A morphological opening function is applied, using a disk with eight pixels of radius, to remove the interest roads from the original image, which is recovered and highlighted subtracting the opening result from the original image.
Segmentation Stage
The Otsu method is performed composing the segmentation stage due to the capability to segment a gray image automatically defining a threshold. It uses statistical to determine the two classes with highest interclass variance possible.
Post-processing Stage
The third stage aims to reduce noises and improve the segmentation results. Firstly, a morphological closing operator is performed to group targets separated during the segmentation process. After, the salt and pepper noises are removed applying, respectively, the morphological area open and area closing functions. Furthermore, a step based on road geometry is performed calculating the ratio between the area and the perimeter of each target in the image, as defined by Equation 1, where:

$$t = \frac{\sqrt{S}}{C} \quad (1)$$

t - Target's ratio index;
S - Target's area;
C - Target's perimeter.

Skeletonization Stage
To acquire the main road axis, the morphological thinning algorithm is performed. However, it creates some undesirable spur segments. To remove it, we apply the morphological spur filter, resulting in the extraction of the road main axis.

RESULTS

This section presents the results obtained with the methodology proposed. Figure 4 shows the extraction result after the geometric analysis step, while Figure 5 presents the final result, after obtained the road main axis, over the original image, to enable a visual analysis of the road extraction result. The visual analysis is directly related to the visual ability of the user. In this way, a mathematical analysis must be performed. Following a statistical analysis from the literature, the completeness and correctness metrics were calculated using a reference image, which is considered as ideal result. Table 1 presents the results of the statistical analysis performed in the dataset used for tests.

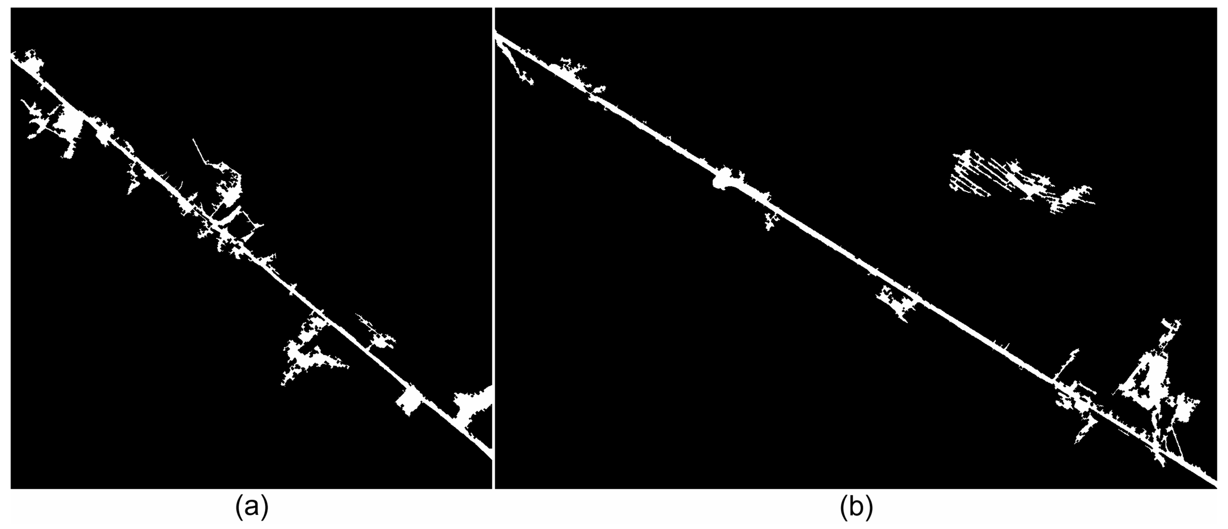

Figure 4. Result after the geometric step.

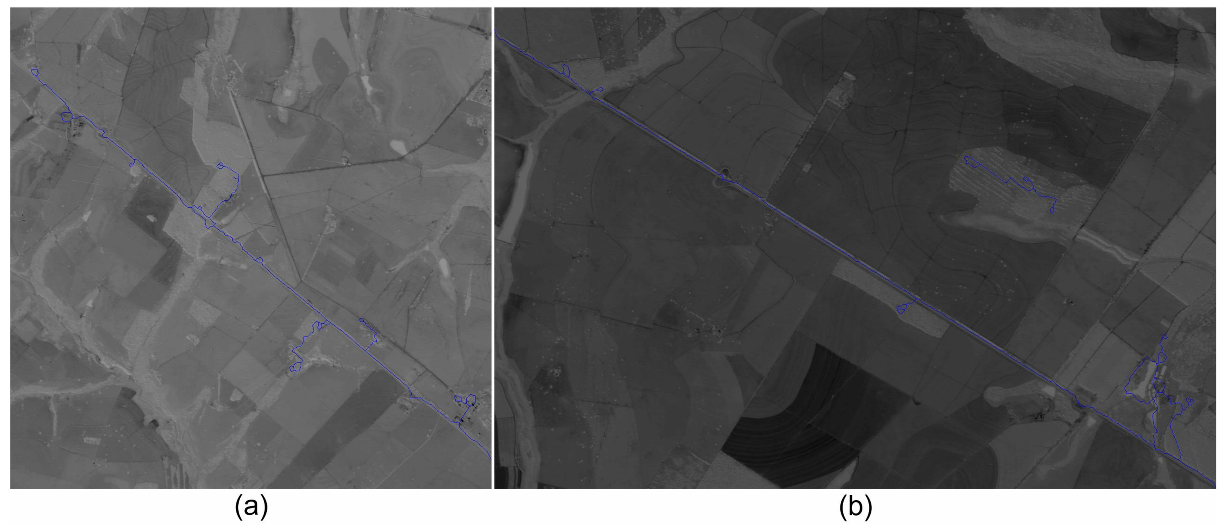

Figure 5. Road main axis extracted over the original image.

Table 1. Statistical Analysis

Dataset	Completeness	Correctness
Image (a)	0.9092	0.5171
Image (b)	0.9440	0.5261
Average	0.8233	0.4883

DISCUSSION / CONCLUSION

Intending to obtain the road main axis from low spatial resolution remote sensing images and considering the importance of road mapping for urban planning, a road extraction methodology was proposed. It was tested using a panchromatic layer from CBERS satellite imagery. The interest roads extracted is visually properly located in the road's course indicating the correct detection of the road centerline. However, it still having a few segments of lines that do not correspond to the interest road, producing errors of false positive type. In this way, the results were statistically evaluated to verify and quantity mathematically the errors generated during the extraction process. The statistical evaluation confirms that the extraction methodology achieved the goal of detect the road main axis with completeness values over 90%. Nevertheless, it also proved the existence of a high number of segments not corresponding to the interest road achieving correctness values around 50%. Despite the low number of false negatives, the methodology has to be improved to achieve a lower number of false positive errors and better correctness values. For future works, we intend to improve the post-processing including some steps based on the targets geometry to differentiate the segments that still not corresponding to the interest road. Furthermore, a bigger dataset has being planned to verify the efficiency of the proposed methodology using others characteristics.

ACKNOWLEDGMENTS

The authors would like to thank FAPESP (Proc. nº 2013/25257-4; 2014/24392-8 and 2016/04553-2) for the financial support given to the development of this work.