EXTRACTION OF SIMPLE ROAD CROSSING

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Commission III , WG III/3

KEY WORDS: Road Crossing; Road Seeds; Segmentation of region crossings, Skeletonization.

ABSTRACT:

Road crossings of roads are important components of the road network. However, they generally are not explicit in the existing research on extraction of road network. This is due to the wide variety of road crossings may contain. Thus this paper presents a methodology for the extraction of simples road crossings considering the stages of pre-processing that performs a smoothing of the region of crossing, followed by binarization and skeletonization of the region of road crossing. Soon after the methodology proposes a model skeleton to perform a filtering of the spurious structures. Based on the model filtered performs the extraction of the edges of road crossings. The methodology was evaluated for four images with respect to the criterion of completeness and proved to be quite effective in content page 83.5% completeness of the average images.

1. INTRODUCTION

Currently, with the increasing need for rapid updates of mapping and surveying, the use of images has become an important tool in cartographic applications (Mena, 2003). Accordingly, the automatic extraction of objects in digital images, which is already a widely researched area in Computer Vision, wins also a great emphasis on the acquisition of information for GIS (Geographic Information Systems).

The extraction of cartographic features, for the acquisition and updating of GIS, is being carried out manually in most cases, which it is very costly and demand considerable time. To lessen the problem, the new digital photogrammetric systems have been developing technologies to capture and update spatial information in order to ensure a continuous decreasing of dependence on human operator (Dal Poz, 2003).

The work related to feature extraction for acquisition and updating of GIS, tend to be generally divided into problems of extraction of non-natural features (eg buildings and roads) and natural features (vegetation and water bodies).

Among the problems of extraction of non-natural features are the various problems for the extraction of roads. MENA (2003) presents a good overview on this topic. The theme of the extraction of road network in a digital image is still under scientific investigation. Among the many open problems in this area, is the extraction of road crossings.

The main problem in creating a methodology for detection and extraction of road crossings is related mainly to the large variety of road crossing that can be found in a road network. Thus, it is relatively difficult to develop a general model of road crossing.

From this perspective, most studies in the literature prioritize the extraction of roads seeds at the expense of reconstructing the road network topology, that depends on the detection and extraction of cross road (Zanin and Dal Poz, 2003).

So this paper proposes a methodology for the extraction of simple road crossings based on some tools widely used in the field of Computer Vision, like image smoothing, image thresholding, and skeletonization of images.

This work was divided into five sections. Section 2 is intended to briefly review the theory necessary for pre-processing of road crossing regions. The pre-processing is a necessary condition for the proposed methodology that is presented in section 03 and evaluated in section 04. Finally, section 05 presents the main conclusions.

2. PREPROCESSING OF THE REGION OF CROSSING

In this work, three stages will be treated as pre-processing. They are the following sequential operations: image smoothing; region segmentation of road crossing region; and skeletonization of the road crossing regions.

2.1 Image Smoothing

The process of smoothing of images is a widely used tool to mitigate the noise from different sources and processes that affect the subsequent image analysis. However, the simple smoothing, based mostly on Gaussian filters, leads to a dichotomy between the level of smoothing and displacement of the edges.

From the models created by PERONA and MALIK (1990), several authors have developed adaptations that sought a selective image smoothing. NORDSTRÖM (1990) developed a model resulting from the unification of nonlinear diffusion model with a term of regularization. The regularization term serves to keep the images generated on the time evolution close to the original image (Vale *et al.*, 2004).

The smoothing model based on anisotropic diffusion is based on a description of the image at multiple scales, whose formalism is the idea of filtering, or processing of space-scale that is based on theoretical representation of images, or signals at multiple scales.

The main idea of this approach is the convolution of the original image I_0 (x, y), generating a family of images I (x, y, t) by using a Gaussian filter G (x, y, t) (Perona and Malik, 1990).

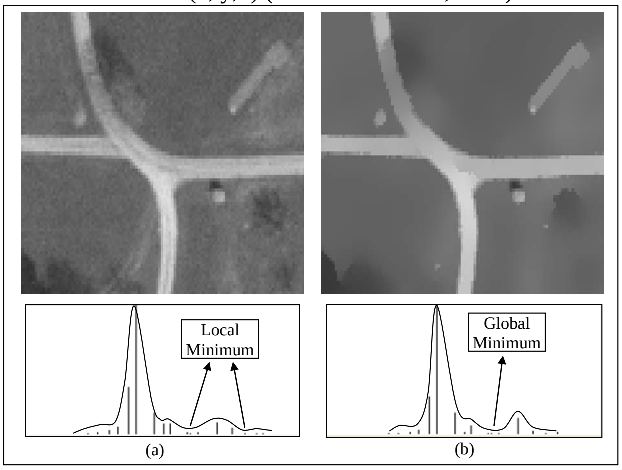

Figure 01 - (a) original image and its histogram, (b) Smoothed Image and its histogram.

The parameter t is an increment of scale that generates image representations with smaller resolutions. Thus the set of generated images based on this parameter is called the space-scale.

The family of single parameters, i.e., the resolution of images derived at t can be seen as the solution of the equation of conduction, or diffusion of heat that is a partial differential equation of second order (Perona and Malik, 1990).

Figure 01 (a) shows the original image with its corresponding histogram, which impedes the determination of a threshold for segmentation. This is due to the existence of several local minima that hamper the determination of a global minimum. But the same does not occur in Figure 01 (b) that the image is smoothed. This image shows the histogram has a more stable behaviour for their local minima. So it is easier to determine a global minimum and therefore a threshold segmentation of the histogram. This is due to the smoothing process.

2.2 Segmentation of Region Crossing

According to [2], if an image is considered as a domain R, its segmentation is defined as sets R_i $(i = 1, \cdots, n)$, such that $R = \bigcup_{i=1}^{n} R_i$ and $R_i \cap R_j = \phi$, for all $i \neq j$, with ϕ representing an empty set.

Segmentation in image analysis is a critical task and the success of the next steps is conditioned on the segmentation.

Typically, the segmentation of regions is based on two basic characteristics of the spectral response of the image. Such features are discontinuity and similarity. Methods based on discontinuity, usually employed in panchromatic images, based on abrupt changes of the values in gray level image. Similarity-based methods are based on grouping of pixels that have some similarity in their spectral response, based on a tolerance parameter.

According to GONZALEZ and WOODS (2000), there are several segmentation techniques such as edge detection, thresholding, region growing, splitting and merging. Among these techniques, thresholding is receiving special attention in this work, given its importance for the methodology.

An object can be separated from the background by a thresholding operation. This requires a threshold T. Thus, both I(x, y) intensity in a grey scale pixel coordinates (x, y), one can define a threshold image L (x, y) as:

$$L(x,y) = \begin{cases} 255 & se \quad I(x,y) > T \\ 0 & se \quad I(x,y) \leq T \end{cases} \qquad (01)$$

According to [9], the threshold T can be viewed as a function of the form T:

$$T = T[x,y,p(x,y),I(x,y)] \qquad (02)$$

where p (x, y) denotes some local property at the pixel (x, y), for example, the average gray level of a neighborhood centered on (x, y). When T depends only on R (x, y), the threshold is called global, and when T depends on R (x, y) and p (x, y), the threshold is called dynamic.

The simplest technique of threshold determination is to partition the image histogram by a single threshold T. According to GONZALEZ and WOODS (2000), the success of this method depends entirely on the quality of the partitioning of the histogram.

2.3 Skeletonization of Region Crossing

According to PEDRINI and SCHWARTZ (2008), one of the basic problems for the development of efficient systems in the area of image analysis is the selection of characteristics needed to be extracted from the object of interest, i.e., after the segmentation of the image into regions or objects, the resulting pixel groups must be represented and described in formats suitable for the next processes.

In the literature, there are many models for the representation and description of objects. One feature that everyone should have is the robustness with respect to noise and geometrical transformations such as changes in scale, rotation and translation.

Algorithms for pattern recognition applications were firstly developed in 1960s, in particular for character recognition. However most of these applications had as main characteristic to reduce the large amount of information, even for segmented images, it was still a problem for subsequent processes.

During this period, there was the first skeletonization algorithms used to extract a set of points within an object to represent him. According to PLOTZE and BRUNO (2004), there is a discrepancy in the literature about the nomenclature used in the process of extracting the skeleton of an object. Some authors use different terms, such as centerline, thinning or skeletonization. In this work we opted for the term skeletonization.

The result of this process is called skeleton, which is essentially composed by a centerline of the object.

There are several other techniques in the literature to determine the skeleton of an object in an image. Such techniques take into consideration, for example, the Middle Axis Transform, Distance Transform, Voronoi Diagram and others.

In this article, we use the middle axis transform (MAT) algorithm for extraction of simple road crossing. An example of this process is shown in Figure 02.

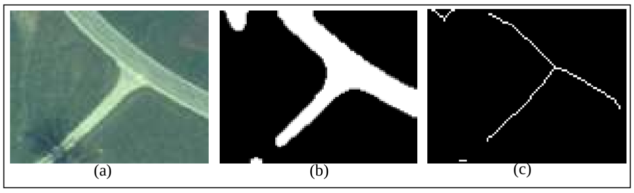

Figure 02 - (a) Original image of road crossing, (b) Segmented Crossing (binary), (c) Skeleton of the region of crossing.

3. METHODOLOGY FOR EXTRACTION OF ROAD CROSSINGS SIMPLE

The proposed methodology is divided into three stages: pre-processing based on sub-steps defined in section 2 (smoothing, binarization and skeletonization), modelling and filtering of the region of crossing, and extraction of the edges of the crossing.

3.1 Modelling of Road Crossing Region

For the binary image, as discussed in section 02, the methodology performs a skeletonization of the region of crossing through the middle axis transform. After skeletonization step, the methodology proposes a modelling process of the skeleton, which allows the filtering of spurious structures in the region of crossing.
Modelling is based on the result of the skeleton, which is a file with the coordinates of the pixels of the skeleton labelled according to their order of tangency. This order is created in the process of skeletonization.
The order of tangency allows a label for each skeleton point. Skeleton points belong to one of three following categories: Terminal Points, Crossing Points and Interiors Points. The Terminal Points and road Crossing Points are defined as points of interest.
The modelling process is based on the characteristics of the pixels that form the skeleton (label). To perform the modelling process it is firstly required a process of vectorization. The vectorization starts at one of the terminal point and searches all skeleton points, generating a structure defined as part of the skeleton. This part of the skeleton is formed by all the points connected, labelled according to the skeletonization process, and points of interest detailed in modelling.
An example of this modelling for figure 03 is presented below. That is, the representation of the skeleton after labelled is the following manner:

$$Skeleton\_Cross = [P_1; P_2; P_3]$$

$$P_1 = \{(C_1; T_1; T_2; T_3); (Interior\_Points\_P_1)\}$$

$$P_2 = \{(C_2; T_6; T_7; T_8); (Interior\_Points\_P_2)\}$$

$$P_3 = \{(T_4; T_5); (Interior\_Points\_P_3)\}$$

Where P represents a part, i.e. the set of points modelled, with the End Points (Ti) Crossing Points (Ci) and Interior Points, represented within each of their respective parts.

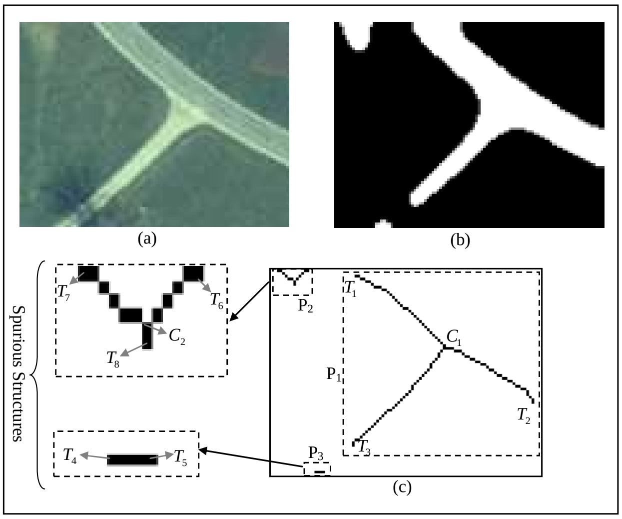

Figure 03 - (a) Original image, (b) Binary image, (c) Skeleton modelled and with their spurious structures.

3.2 Filtering of Region Crossing

At this stage of the methodology, skeletons generated and modelled as proposed in the previous section are essential for the filtering of structures defined as spurious.
These structures do not have the topological properties defined for a region of crossing road and its filtering is essential for the extraction process. This is important because the purpose of the methodology is to extract only the edges that are part of the crossing.
In order to perform the filtering of spurious elements from the skeletons detected in a road crossing region, two criteria were defined, as follows:
I - Elimination of parts of the skeleton that have the set of points of interest comprised solely of terminal points.
II - Skeletons formed by independent parties that have topological structures consistent with a region of the skeleton, i.e, having terminal points and crossing points between the points of interest, go through a test of area thresholding. So the structure that has a smaller area than a threshold, compared with the larger structure, is eliminated.
An example of application of both above criteria can be seen in figure 03, in which a region of crossing (Figure 03(a)) and its binary image (Figure 03 (b)) are presented. The skeletonization result is presented in figure 03(c). This same figure also shown that the region of crossing is modelled by three parts p1, p2 and p3, where the parts p2 and p3 are spurious structures.

3.3 Extraction of Simple Crossing

This work is intended only to extract the crossings classified as simple. This classification is done based on the number of crossing points that remain after the process of modelling and filtering of skeletons.

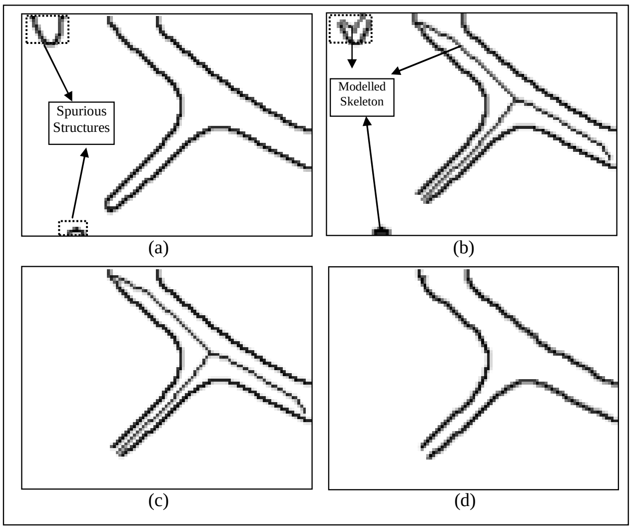

Figure 04 - (a) Edges extracted from the binary image, (b) Edges with their skeletons modelled, (c) Result of filtering the skeletons with their edges, (d) Edges selected based on the skeleton filtered.

Thus, the extraction is performed in the following sequence:
I - Construction of an edge image by the differentiation of the binary image of the region of crossing. At this stage an edge detector is applied to the binary image explaining all the edges of the region of crossing. An example of binarization of image of figure 03 (b) is shown in Figure 04 (a).
II - Vectorization of the image edges, obtaining a region with its characteristics organized according to the coordinates of the pixels that make up the region.
III - Selection of edges that actually make up the region of crossing.

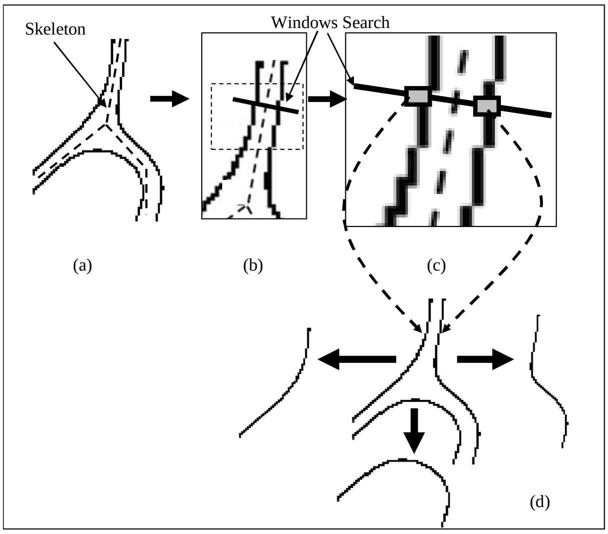

Figure 05 - a) Edges with skeleton b) Search windows unidimensional c) Seek edge pixel based on one-dimensional search window, d) Edges of the selected region of crossing.

At this stage of the methodology is verified the importance of the skeleton, because it is based on the skeleton and its modeling that there is a selection of the edges that really are part of the crossing.
An example can be seen in Figure 04. In figure 04 (a), all detected edges are displayed. In figure 04 (b) the edges are displayed with their skeleton modeled.

Based on the filtering of the skeletons, the only remaining structures are which in fact belong to crossing. These structures extracted as can be seen in Figure 04 (c). Finally using the skeletons filtered to select only the edges that really represent the crossing without the spurious structures. These are shown in Figure 04 (d).
The extraction process, ie the delineation of borders that actually are part of the crossing is performed based on a one-dimensional search window that is perpendicular to the skeleton modelled and filtered, as shown in Figure 05 (a - c).
Based on this search window, the method looks for pixels of the respective edges of the region of crossing, selecting all the features that make up the crossing, as shown in Figure 05 (d).

4. AVALIATION OF THE PROPOSED METHODOLOGY

To evaluate the methodology proposed in this work, we used four images with considered degree of difficulty, as shown in Figure 06 below.

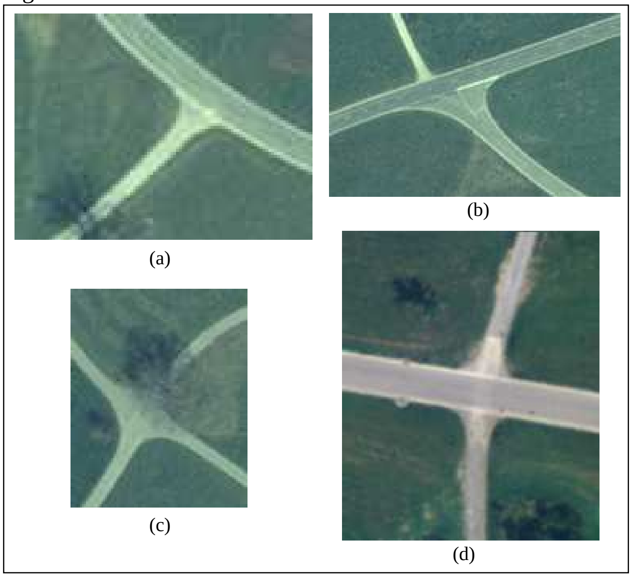

Figure 06 - Test Images, (a) Test image 01, (b) Image Testing 2002, (c) Test Image 03, (d) Test Image 04.

The results, i.e. the crossing found were superimposed on the original image allowing a visual evaluation. However, it was used also one of the evaluation criteria widely used in the extraction of roads that is the completeness. The completeness is defined as the ratio between the number of components extracted and the total number of elements of the crossing. Thus the completeness is defined by equation 03.

$$completeness = \frac{Number\_elements\_extracted}{Total\_number\_elements\_reference} \qquad (03)$$

The numbers of elements extracted and the number of elements of references are developed based on the number of pixels used to represent the features extracted and reference as shown in equation 04. The numbers of elements of references are given manually.

$$\textit{Number of elements extracted and/or reference} = \sum_{i=0}^{n-1} f_i \qquad (04)$$

Where f_i denotes each of the pixels used to represent the feature. The results for the test image, in the criterion of completeness, which is a numerical evaluation are presented in the following table.

Table 01 - Results of tests image for completeness

Image	Completeness
Test Image 01	82%
Test Image 02	94%
Test Image 03	97%
Test Image 04	61%

A visual presentation of results can be verified in figure 07, below, where the crossings extracted was superimposed in white on the panchromatic image.

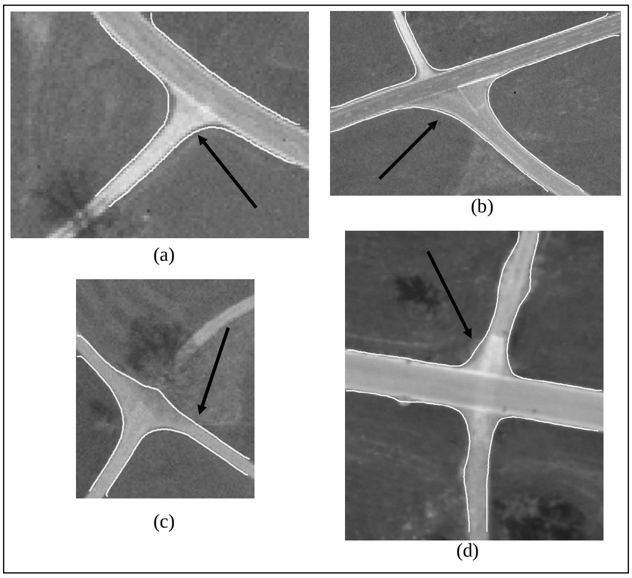

Figure 07 - Results superimposed on the images tests, (a) Test image 01, (b) Image Testing 02, (c) Test Image 03, (d) Test Image 04.

5. CONCLUSION

The results showed that the proposed methodology is promising for the extraction of simple road crossings. The efficiency of this methodology is evidenced by the average of the completeness the test image, which in these cases reached 83.5%.
Some details can be seen on the results presented in Figure 07. A result that deserves mention is the failure of extraction crossing in Figure 07 (c), which is due the failure in the modelling of the skeleton generated in the region of crossing.
Finally, this methodology can be considered reliable and robust. Thus it can be incorporated in the extraction methodology of the road network, indicating the importance of smoothing, skeletonization and the modeling can offer these methodologies.

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7. ACKNOWLEDGEMENTS

The authors wish to thank the State University of São Paulo (UNESP), the State University of Mato Grosso (UNEMAT) to support the development of this research. They also thank the Foundation of Research of State Mato Grosso (FAPEMAT) which funded much of this research.