Road Detection on digitized maps

D. Borghys *,C. Perneel *,E. Nyssen ‡,and M. Acheroy *

*Royal Military Academy, Signal & Image Centre,
Renaissancelaan 30, B-1000 Brussels, Belgium
‡Vrije Universiteit Brussel, Elec. Eng. Dept.,
Pleinlaan 2, B-1050 Brussels, Belgium

Abstract

This article presents an overview of an approach to the automatic detection of roads on scanned topographic maps. In the presented method roads are described by a simple model and a combination of low-level image processing methods is used to detect candidate road segments. Higher level tools are used to reject false candidates and to connect the candidate road segments to form the overall road network. The presented work is part of a larger project[1] aiming at the automatic vectorisation of scanned topographic maps and in which other types of objects (e.g. buildings, forests, vegetation, rivers,...) are also extracted. Being able to automaticly vectorise maps is important for several reasons. Firstly, it is the first step of any map-updating, as most maps to be updated are paper versions. The second reason is the fact that automatic interpretation of satellite or aerial imagery can be greatly enhanced by using collateral information such as those that can be obtained from a map. A third reason is that maps can be used as a help for registering imagery from different kinds of sensors (e.g. SAR, visible and infrared images).

1 Introduction

For humanitarian or military missions it is often important to have an updated map of the region of operations available. Map updating can be achieved using satellite images or aerial photographs. However, the first step is to feed information of existing maps into the computer. Furthermore the availability of maps can aid the interpretation of satellite or aerial images [QS97, Sti95]. If digital maps of the region of interest are available the work has already been done. However, in many cases only paper maps exist. It is thus necessary to digitise them and to extract (vectorise) the relevant information (e.g. roads and rivers). The proposed paper focusses on the detection of roads on scanned maps. The presented work is part of a larger project aiming at the automatic vectorisation of scanned maps, in which also other types of information (e.g. vegetation, villages, text) are extracted. Many methods for detecting roads on aerial or satellite images are reported in the open literature. Detection of roads on images often relies on their homogeneity and their contrast with the surroundings. The low-level detector is then either a detector of parallel lines [Ste96, SEW96] or a detector of bar-patterns [Lac95]. In regions where the roads are partly occluded (e.g. by trees or by shadows of high structures), these low-level detectors will fail and higher level knowledge is needed to complete the road network [MS96, BSME97, SML95, ARJ94]. The detection of roads on maps is not influenced by occlusions. It does however present other problems. The first problem is the quality of the paper map and of the scanning device. The second problem is the complexity of the symbols used to represent roads. Roads that have a unique color are easily detected. In many cases however, the roads have the same color as the background but they have a border that can either consist of a solid line or dashed or dotted lines. The third problem is the fact that roads are often interrupted by text, grid-lines or contour-lines.

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2 Overview of the approach

For the detection of roads two complementary methods were used and results are fused to get the global result. The algorithm is based on a simple model of roads. Hence only a few parameters need to be defined (possible road colors, range of road width,...). These can be extracted from the legend of the map which is supposed to be known. Because of the limited set of easily identified parameters, the algorithm is expected to be easily adapted to different kinds of maps. In this article topographic maps of the Belgian national mapping agency were used. Figure 1 shows the global overview of the method. In figure 2 the Red, Green and Blue components of a part of the original image are shown. The detection of text is based on an adaptive region growing method combined with geometrical constraints while the detection of grid lines is based on detection of local maxima in the hough transformed image. The other parts of the approach are descibed in more detail in the following sections.

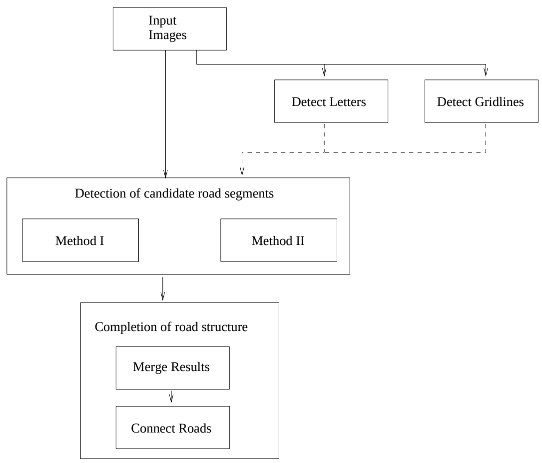

Figure 1: Overview of the approach

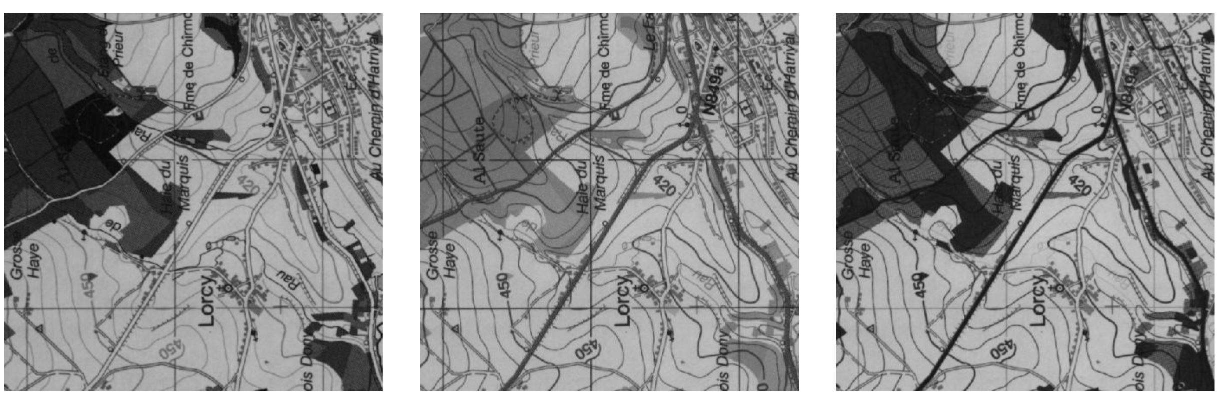

Figure 2: R,G and B components of map image

3 Detection of Candidate Road Segments

For the detection of candidate road segments two complementary methods were used. They are described below.

3.1 Method I

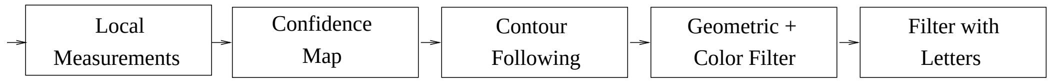

Figure 3: Overview of Method I

The method consists of five steps (see fig 3). In the first step local measurements are calculated that are used as indicators of the possible presence of a road. The basic hypothesis is that the variance along a short line in the direction of a road is very low and in the direction perpendicular to the road, on the contrary very high. At each pixel of the image the variance within a short line segment pointing from the current pixel to the right is calculated. Then the line is gradually rotated around the pixel and for each orientation the variance is calculated again. Figure 4 illustrates this for a rotation step of 45 deg.

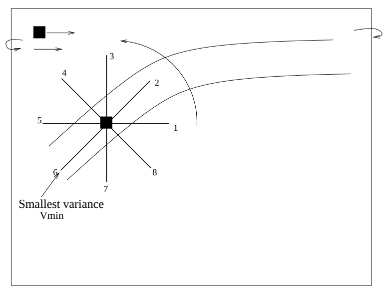

Figure 4: Search for "road direction"

Once the direction of lowest variance (V_{min}) is determined, some other local statistical measurements are calculated:

- the variance (V_{perp}) of a line segment perpendicular to this direction
- the position (edge points) and value of largest grey level gradient along this line at both sides (V_{grad1} and V_{grad2}) of the current pixel
- the distance between these edge points at both sides of the current pixel (road width)
- the total grey value difference along this line ($V_{TotDiff1}$ and $V_{TotDiff2}$) (contrast)

In the second step, for each pixel for which the road width and the distance to the road centre is within a specified range the other measurements are combined to give a heuristic confidence that the pixel belongs to the road:

$$Conf = \frac{| V_{perp} V_{TotDiff1} V_{TotDiff2} V_{grad1} V_{grad1} |}{1 + | V_{min} |} \tag{1}$$

The confidence image is shown in figure 5a. Candidate road pixels are chosen by applying a threshold to this confidence. The third step of the algorithm then follows the selected pixels to identify possible road segments. In the fourth step these segments are filtered by imposing geometrical constraints as well as constraints about the uniformity of color within the road (figure 5b). Because the presence of text on the image introduces false detections of road segments, the road segments that are too close to the text are eliminated. Figure 5c shows the final results of this part of the algorithm.

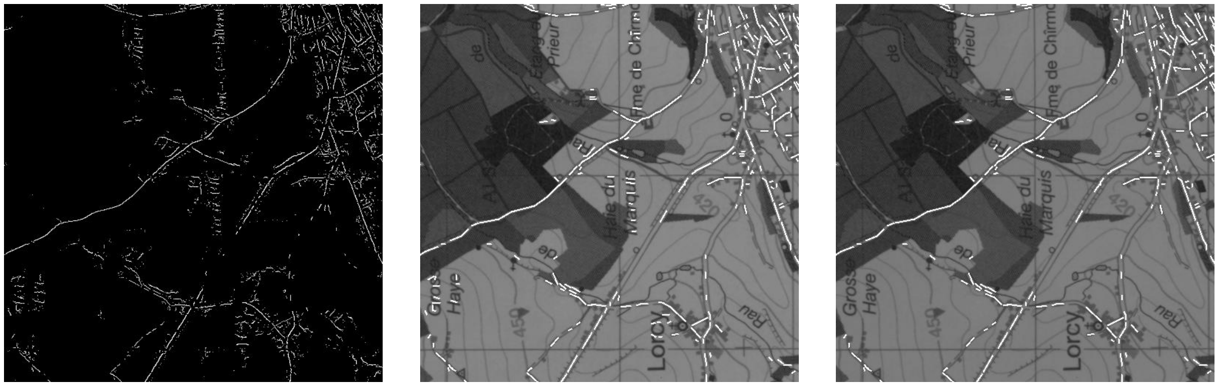

Figure 5: a. Confidence Image b. Results after geometric filter c. Final Results of Method I

3.2 Method II

As the set of possible colors that the roads within a map can have is limited, it is always possible to find a color transform such that roads are bright and colors that are far from the typical colors of roads are dark.

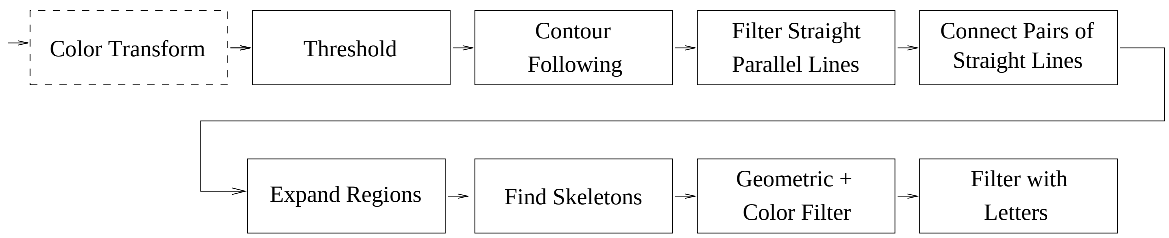

Figure 6: Overview of Method II

The second method (fig 6) starts by applying a threshold on this transformed image. On the maps we investigated roads were colored either red, purple, orange, yellow or white. Therefore the threshold (fig 7a) could be applied directly on the red component image on which all of these colors appear bright. The next step is to determine the borders of the road parts that were segmented by the threshold. This is implemented by means of a contour following algorithm of the segmented regions. At each point of these contours the direction of the best linear segment is determined by sliding a window over the contour points and at each position calculating the linear correlation coefficient of all of the contour points that lie within that window. At each point the direction which corresponds to the highest linear correlation coefficient and straightness is stored. Then pairs of linear parts that are sufficiently long and almost parallel are detected (fig 7b). These are supposed to be the borders of road segments. In the next step the color characteristics of each segment are determined and a multi-spectral region growing is applied to expand these road segments (fig 7c). To find the actual road positions, the morphological skeleton of these new regions is determined (fig 7d). Geometrical constraints are applied to reduce the number of false candidates (fig 7e). Figure (fig 7f) show the final results of the second part of the algorithm after rejection of false alarms produced by the presence of text.

4 Completion of the Road Structure

The results of both methods used to detect candidate road segments are complementary. Before connecting the resulting road segments the two sets of results are merged. This is done by replacing each pair of overlapping segments with a similar orientation by the best segment. Then the

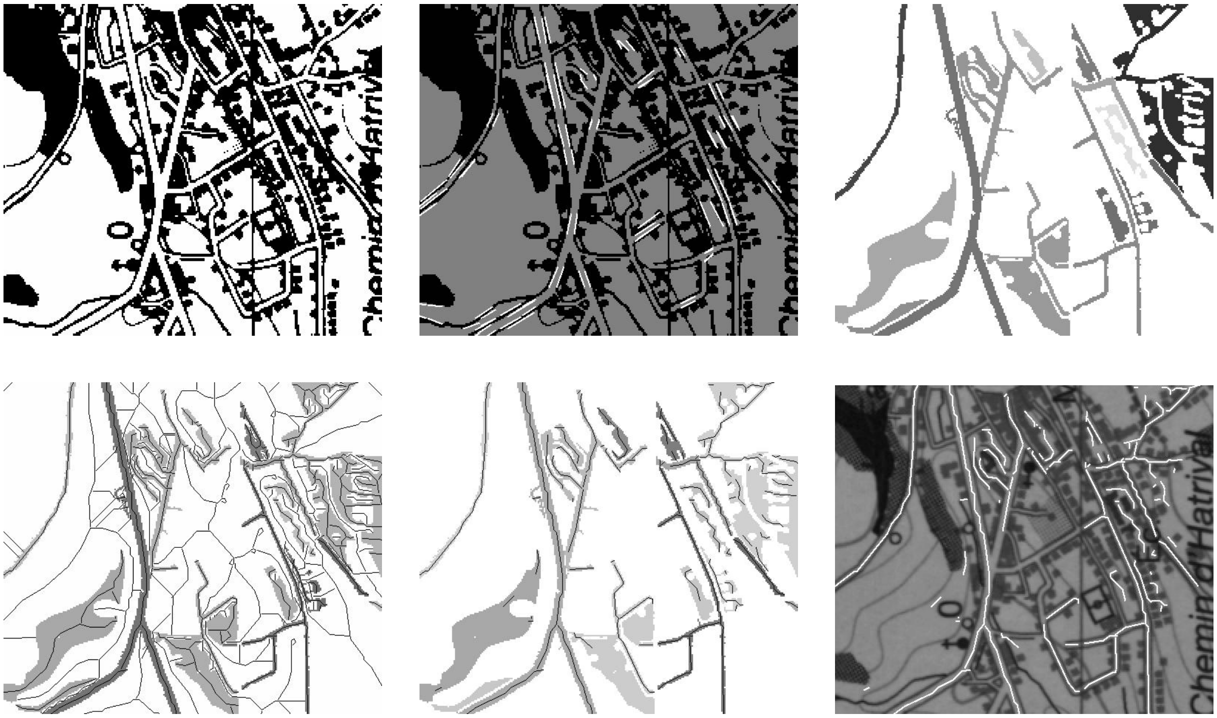

Figure 7: a. Threshold image b. Parallel line segments c. Results of region growing d. Skeletons e. Filtered Skeletons f. Final results of Method II

borders of each segment are searched and for each segment possible connections are determined. Connections are only considered at a given angle with the direction of the initial segment and within a given distance. A tree search algorithm (the A^* Algorithm see [Ric83, HNR68]) is used to find the optimal path connecting the segment to a given possible connection candidate. The tree search takes into account the position of detected borders and attributes a cost to each path. This cost is a function of the distance as well as of some color measurements along the path. For the part of the cost based on color measurements, grid-lines and text in the path are discarded. For each segment only the connection with the lowest cost is kept providing this cost is below a given threshold. The presence of borders is checked to reduce the number of false targets. The final stage of the algorithm eliminates road segments that are not connected to the global road structure. The final results of the road detection are shown in figure 8.

5 Conclusions

An approach to the automatic detection of roads on scanned topographic maps was presented. The method consists of two independent parts each based on a simple model of a road. The first method is based on the homogeneity of the road color and the contrast between the roads and their surroundings. The second method uses knowledge about the possible colors of roads and determines the presence of borders to detect them. The performance of both parts of the algorithm is hindered by the presence of grid-lines and text on the maps. Both need to be detected and taken into account in the algorithm. Because only a limited set of easily identified parameters needs to be determined, the method is expected to be easily adapted to different kinds of maps. This has not yet been verified. Although most of the road structure is correctly detected some false alarms still persist. Especially in a village false alarms are generated between rows of buildings. In order to eliminate these false targets the buildings need to be detected. This is a topic for further work.

Figure 8: Final Results

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