AUTOMATIC EXTRACTION OF CLOSED CONTOURS IN THE PORTUGUESE CADASTRAL MAPS

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Abstract: The automatic extraction of closed contours is the most important and difficult problem in the automatic recognition of the Portuguese cadastral maps. Many difficulties such as gaps on contour, elements connected on contour, crossing of lines and the association of each entity to its contour have to be solved. In literature there are very few studies about the recognition of cadastral maps and the maps already studied are different than ours. Therefore our research mainly focused on appropriate computer vision algorithms that yield acceptable results.

In this paper we present a sequence of algorithms to solve various problems in the contour extraction. The algorithms are completely different and each one tries to solve one specific problem of the analysis. The methods used were the Block-Fill algorithm, the Lohmann's algorithm, the Seed-Segment algorithm and the Rosin-West's vectorization algorithm.

The architecture of our system is presented and the results are shown at the end of the paper.

1 INTRODUCTION

The automatic digitalisation of the Portuguese cadastral maps has many problems and difficulties that represent interesting challenges in the image recognition field. One of those problems and certainly the most difficult is the automatic extraction of the closed contours. These difficulties are due to the quality of images to recognise and the way the maps were drew.

These cadastral maps are composed by many different patterns such as crosses, circles, arcs, dashed lines, solid lines and characters. Each pattern has a semantic, for instance a circle represents a cadastral entity, which is inside of a closed solid line that represent the parcel's contour and defines the contour perimeter. Perhaps a parcel has inside some dashed lines and some characters that represent the sub-parcel's contour and the sub-parcel's type or sub-parcel's number.

The automatic extraction of the closed contours in this type of maps has many difficulties namely gaps in contour, elements connected on contour and also the crossing of lines on contour (see figure 1). Furthermore, it is necessary to associate each parcel using the circle position with its closed contour.

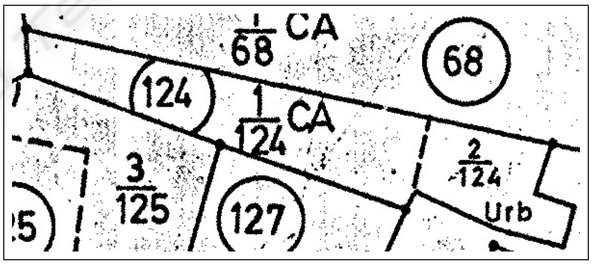

Figure 1: Examples of some problems in the contour extraction such as gaps in contour, elements connected on contour, the crossing of lines and also it is needed to associate a circle with a contour.

In the literature, there is not any algorithm which could solve all of these problems, but only simple methods that can individually solve one problem. Therefore, we use one algorithm to solve each problem, instead of trying to design a complex method to fix all of them.

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2 RELATED WORK

The image recognition problem can be seen on two different perspectives, considering the pattern recognition at pixel level or using segments from the vectorisation process. Those approaches can recognise the graphical primitives in image but each one has specific problems. Song et al. (Jiqiang Song and Cai, 2002b) discussed the recognition from binary images using each one of these approaches, and they suggested to use both, since neither of them is perfect enough to handle all the difficulties.

The image recognition at pixel level should be analysed in a hierarchic point of view, recognising the features of the drawings from the simplest to the most complex primitive. Song et al. (Song et al., 2002) considered that an engineering drawing can be seen as a collection of lines, arcs, curves, simbols and strings. In each recognition process the elements detected are erased or segmented to simplify the next detections.

Dori and Wenyin (Dori and Wenyin, 1999) have developed a vectorisation system for the mechanical drawings, firstly doing a description of the image by segments and detecting higher shapes as circles or arcs later. But as our maps have elements connected on contour, a vectorisation and followed by the recognition of shapes would introduce many errors. Therefore our choice was to analyse the image at pixel level since it is less complex even though slower (Tombre et al., 1999).

Song et al. (Jiqiang Song and Cai, 2002a) studied the vectorisation of engineering drawings at pixel level and Dosch et al. (Dosch et al., 2000) studied a system for the recognition of architectural drawings.

The French cadastral map is a completely different sheet because it is older and has others types of problems, Shahbazkia (Shahbazkia, 1998) studied the recognition of the French cadastral maps. Also Viglino et al. (Jean-Marc Viglino, 2003) are studying the contour extraction in the French cadastral map. The knoweledge on the Portuguese cadastral maps (analysis domain) is available and we can use it to simplify the contour extraction.

3 PROCESSING METHODS

The main stages of the cadastral maps recognition are the detection of circles, the parcel's number recognition and the contour extraction. Since any parcels have a contour associated, so the contour extraction algorithm has as input the circle position to allow the association with the contour.

The deformation of the image introduces noise and degradation, and it is going to yield dirt and gaps in the drawings. The cadastral maps have symbols, dashes and circles over the contours as well. This superposition difficults the extraction very much since it is necessary to segment the two elements first.

It is important to deeply look for each problem of the contour extraction to choose the algorithms that can solve them. The main difficulties of this analysis are the discontinuities, the elements connected and the crossing of contour lines. The application of the line following algorithm (Spinello and Guitton, 2004) with waiting lists is very complex in the last situation due to the variety of paths to follow. Furthermore the line following algorithm does not solve the problem of elements connected on contour, the association of each parcel to the contour and neither the discontinuities on it.

In the literature there is not any general method solving all these problems, however for each problem there is some possible solution. We chose that each method had to solve one specific problem since we think this improves the robustness of the application and makes it simpler. Each algorithm has different features and properties and all of them enable us to solve most of the difficulties.

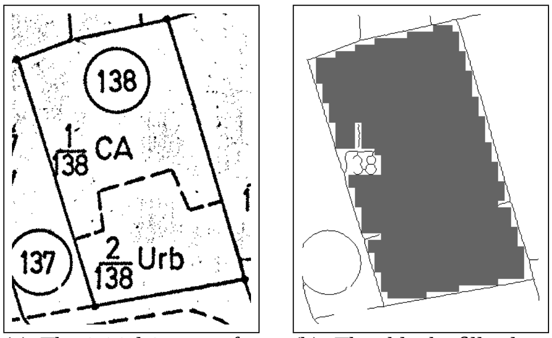
3.1 Block-Fill Algorithm

From the beginning, we tried to find out an off-the-shelf method (Tombre et al., 1998) to implement the contour extraction. Our first idea was to use the classical snakes algorithm (Kass et al., 1987) but as it needs some control points and it did not always converge due to the lack of grey value in image, we did not use it.

As the method can start the analysis from the circle position, the flood fill algorithm sounded better. As some contours have gaps, we implemented an algorithm based on the flood fill but using blocks. The input image is pre-processed by a thinning (Tombre and Tabbone, 2000) to detect the central contour points since it is necessary to have the same segment between two neighbors contours.

The block fill algorithm starts the detection at the circle position and fills the parcel with blocks of size NxN. This algorithm is iterative, in the first iteration the stack has only the circle position, in the second the first block's 4-neighbors if the blocks have not any black pixel inside, the algorithm continues the filling looking for the neighbor blocks (see figure 2).

The detection of the contour points is done considering the blocks that touch on the contour. Each block has neighbor blocks outside of the contour and they were tested in every directions to detect every contour points. The goal is to detect as many points as possible, however as there are parts of the contour where it is impossible to detect all the points, it is necessary to use a method of line following to detect the contour points that are between the two parts already



(a) The initial image of a closed contour.

(b) The block fill algorithm in the thinned image.

Figure 2: Example of the block fill algorithm application.

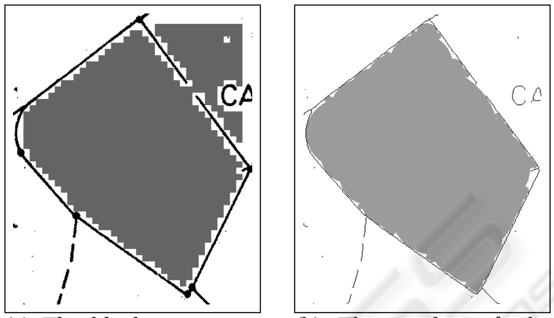
detected. The line following algorithm is applicable since we used a thinning of the contours and without the non connected elements resulting in the contour lines with one pixel width.

The block fill is the kernel of the contour extraction and the next algorithms were implemented to solve some problems of this algorithm.

3.2 Lohmann's Algorithm

The first problem of the block fill algorithm is that some blocks go out of the contour due to the large discontinuities. For instance, a large discontinuity can appear when two small discontinuities are close, after segmenting the bigger from the smaller elements (component labeling algorithm) the element between the two discontinuities is erased. The goal of the Lohmann's algorithm (Lohman, 1995) is to segment the inner contour that is open and has large discontinuities.

Before applying the Lohmann's algorithm, it is necessary to have the distance transform (di Baja, 1994) of the thinned contour image. As the block fill algorithm, this also has as input a point inside of the contour. This algorithm is iterative and starts pushing the input point into the stack. Following, the point of the stack's head is popped and from this position is found out the maximum circle radius that touchs the contour points. The algorithm then detects the local maximums over the maximum circle radius and store them into the stack. Once a circle is accepted as being inside of the contour, if there is not any end point in the circle radius, then the points inside of the circle are painted with the black color in the distance transform image to enable the convergence of the algorithm. This process repeats until the maximum circle radius has a discontinuous point of the contour (a point with only one neighbor), so the gap length is calculated and if the circle is outside of the contour or the gap length is bigger than a threshold value, then is not considered, otherwise the expansion continues and the maximum locals of the circles are pushed into the stack.



(a) The blocks goes outside using the block fill algorithm.

(b) The circles of the Lohmann's algorithm do not go outside.

Figure 3: Example of the Lohmann's algorithm behavior with big discontinuities.

This process continues until the stack is empty. At the end, the contour is filled with circles of different sizes (see figure 3) allowing to segment the inner contour.

After getting the list of circles that segment the contour, we can only consider the blocks from the block fill algorithm that are inside of at least one of these circles. Therefore we can use the block fill algorithm to detect only the points inside of the contour even having big discontinuities.

3.3 Seed-Segment Algorithm

Another problem happens when the symbols are connected on the contour. A consequence of this fact is that the parcel's contour is empty or incomplete after the application of the block fill algorithm. One possible solution is first segment the symbols from the contour using a straight line detection algorithm such as the hough transform algorithm (Jiqiang Song and Cai, 2002c) but after some tests this algorithm did not solve our problems since there are some curves in images.

A seed segment is a small rectangle with any orientation that is characteristic of a straight line and it is found considering some conditions. The seed segment algorithm (Song et al., 2000) starts looking for seed segments in the image. This method detects the straight lines in the image doing the line tracking from the seed segment orientation.

Knowing some contour straight lines, it is easy to segment the symbols from the solid line. The figure 4 shows an element connected to the contour, but after the application of the line tracking, it is possible to de-

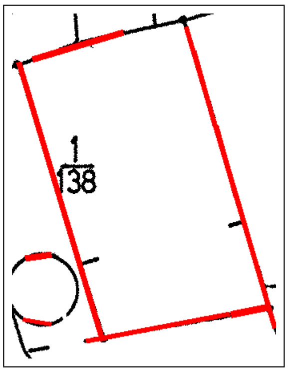


Figure 4: Segmentation of the characters and the dashes from the contour.

tect some straight lines of the contour and segment the elements from the contour. Finally, having the plain contour we can apply the block fill algorithm again to extract the contour points.

3.4 Rosin-West Algorithm

The contour extraction is implemented using the block fill algorithm. After of the contour points are obtained they are verified to assess if the contour has big discontinuities or if the list of contour points is too small. The Lohmann's algorithm is used in the first case while the seed segment algorithm is used in the second one. After of the identification of the algorithm to use, a window over the map is used with center in the circle position. This is important to locally process each parcel since the two methods are slow and the first one needs to calculate the distance transform image and we do not need it to all the map.

After the application of the previous algorithms, it is necessary to vectorize the contour. The contour points are drew in an image and vectorized using the Rosin-West algorithm (Rosin and West, 1989). At the end of this process, the segments are obtained and they can be post-processed by the next algorithm.

3.5 Segment Following Algorithm

The contour segments obtained from the vectorization can have symbols or dashes connected on contour and discontinuities. The dashes connected on contour can be found considering that three segments have a common point, the segment that represent the dash is smaller than a threshold value and its orientation is the most different of the three collinear segments.

If the contour has a discontinuity that is smaller than a threshold value then we can close the contour adding the necessary segment. This can be very useful for small discontinuities since it happens frequently.

The problem of the symbols connected is more difficult to solve, it can be detected since there is a sequence of small continuous segments with different orientations (there is not a stable sequence of orientations). These small segments were removed and the contour is verified to see if it has only small discontinuities by removing the segments, otherwise this is a problematic situation. The dashes and symbols connected to the contour are added to the list of the parcel's objects.

At the end, if the contour is closed and every segments are used to follow the contour then the contour is valid.

4 RESULTS AND DISCUSSION

We developed our algorithms using a set of 5 cadastral maps with A0 size and digitalised, a map has in average 10 000x8 000 pixels. A map is a huge sheet and has a great quantity of information, so we can see a huge diversity of shapes, symbols, characters and contours in a single map. In each one, there are problems for the contour extraction but we have verified that all of these drawbacks are contained in the cases studied by the three algorithms. We consider the 5 cadastral maps studied representative of the diversity of the Portuguese cadastral maps.

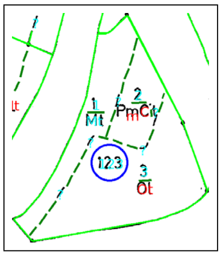


Figure 5: Example of a large contour without problems in the extraction.

Our sheets have many types of contours but in most cases they are large contours and there are not any elements connected to the contour (see figure 5). The gaps on contour frequently happen but these discontinuities are small and the block fill algorithm is sufficient to handle the problem. The big gaps are less frequent since they are originated by two close discontinuities, and this is solved by the Lohmann's algorithm. The problem of the open contours with small and big discontinuities are completely solved since these contours are obtained without many problems.

In most cases the dashes connected on contour are detected and this problem is considered solved too. However, some dashes connected on contour are also connected to characters and that difficults considerably the problem. Thus, the simpler cases are solved while the difficult problems are very specific and we do not consider their solution yet, since we are looking for general algorithms at this level of recognition.

The problem of the characters connected on contour is a more difficult problem. The seed segment algorithm detects the straight lines but it does not detect all the straight lines on the contour, so if a character is connected on a curve or on a straight line that was not detected, then the character is not erased. The contour in figure 6 is composed by straight lines and in this case is possible to segment the characters from the contour. The contour post-process do not remove all the characters connected on contour, since the method previously described only remove the cases where the character only has one segment collinear with the contour. In the figures 7 and 8 we can see some difficult problems of the contour extraction since in the first case there is more than one segment collinear between the contour and the character and in the second case is the same situation and the element in on a curve. In the other cases the problem is more difficult to detect and we do not consider it yet. As this problem happens less than 5% in each map, we think that it is not too problematic and do not influence considerably the results.

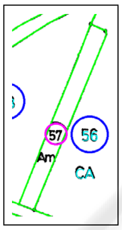


Figure 6: Example of a thinned contour with some elements connected.

The implementation of the algorithms were made in different levels of abstraction. We started considering few contours and at the end we considered the results of all the contours in 5 maps. The tunning of the algorithms and the identification of all the problems is very important to improve the system. Since the contour is extracted at a low level, so it is important to consider only the main drawbacks and distinct the particular from the general problems, avoiding introduce more complexity into the main goal.

The results of the contour extraction are considered good since the recognition rate is higher than 70% in each map. Furthermore, the process of contour extraction is fast, spending only 2 minutes on an Intel Pentium IV at 3.0MHz, in average for each sheet.

The general classification of the system is good and we consider that it is already a valid prototype, since the system complexity level and the recognition rate is balanced. We think that the ideas and concepts developed are correct and the next steps should be the optimization of the algorithms and the resolution of some difficult problems. The algorithms works well in different types of maps namely urban or rural cadastral maps.

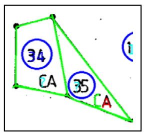


Figure 7: Example of characters connected to the contour.

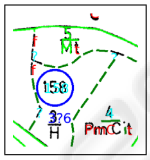


Figure 8: Example of characters connected to a curved contour.

5 CONCLUSIONS

Once the problems are complex and very different in each map, the analysis should be made with simple methods. The approach should be general and not particular, so one method should solve only one problem. Because it is not possible to extract all the contours from the maps, we should design the algorithms to extract most of them. Thus, first the problems need to be completely identified to choose the algorithms features and to obtain a higher recognition rate.

The results are good and the system can extract more that 70% of the contours in each maps. The algorithms studied are sufficient to solve all the problems of the contour extraction of the Portuguese cadastral maps. The recognition rate could be improved solving particular problems but doing this we will increase the system complexity and the improvement of the results are not a true consequence again. This happens because the system should be balanced between its complexity and the recognition rate. Using the methods presented here we can conclude that the problem of the contour extraction is globally solved.

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