

AN APPROACH OF SEMIAUTOMATED ROAD EXTRACTION FROM AERIAL IMAGE BASED ON TEMPLATE MATCHING AND NEURAL NETWORK

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KEY WORDS: Road Extraction, Semiautomatic Extraction, Template Matching, Binary Template, Correlation Coefficient, Optimization, Artificial Neural Network, Hopfield Model.

ABSTRACT

In this paper, we propose a semiautomatic road extraction scheme that is based on template matching and optimization by Hopfield neural network. In the semiautomatic way, a road is extracted automatically after a series seed points have been given coarsely by the operator through a convenient interactive image-graphics interface. Attending to accuracy, robustness, speed and interactivity, we use a binary profile template as the local gray model to speed up the template matching and build a Hopfield neural network to select the 'best road way' from the candidates gotten from template matching. The template is generated by 'darkness-brightness-darkness' local road feature so it is mainly aim at extraction of 'light ribbon like road'. The Hopfield model is built according to the geometric and gray constraint of road on aerial image. Even there is serious noise, the algorithm extracts road well. The algorithm can extract the road of which width is from a few pixels to more than 100 pixels. This paper describes the principle and steps of the approach. Some experimental results and discussions about semiautomatic road extraction are also given.

1 INTRODUCTION

Automatic or semiautomatic extraction of roads from digital images has been a hot research subject for recent years because road is important geo-information. Unfortunately, there is not any practical system that can automatically and robustly extract road from different scales and complexity images. The reason is, from the viewpoint of image understanding, that the extraction is not only low level feature extraction, but also a recognition problem that needs to use 'high level knowledge', whereas how to handle and use knowledge of the scene is an unsolved problem. There are many embarrassments on overcoming noise or uncertainty and modeling the road feature from kinds of images. So, from the viewpoint of building a practical system, semiautomatic extraction has gotten special attention. In the other words, the so-called strategy of human-machine cooperation can conquer the 'bottleneck' of recognition and relieve the boring and laborious digitize work, and compare to fully manual operation, accurately position and delineate the road feature.

Some algorithms of semiautomatic road extraction have been proposed for recent years. Such as dynamic programming (Gruen A, Li H H, 1995) and active contour (snakes) (Trinder, 1995, Gruen A, Li H H, 1996), they are all optimization problems based on geometric and photometric constraint of road feature. In this paper, we present an algorithm of extraction based on the optimization by Hopfield neural network that faces to practical production of digital map from images. The next section provides an overview of our methods and then the steps of the algorithm and experimental results are given. Finally, the conclusions will be drawn.

2 OVERVIEW OF THE ALGORITHM

To realize a practical system of semiautomatic road extraction, we should take four factors into account. They are good accuracy, steady output, high speed and good interactivity. Steady output is to say the algorithm is not sensitive to noise and the slight variation of position of seed point. High speed means that operator needs not to wait for the extraction result after giving the seed points and good interactivity make it easy to use.

Most of semiautomatic extraction is based on optimization by radiometric and geometric constraint of the object (Gruen, Li H H, 1995). An object function that describes the constraints is often derived to model the object. The procedure of extraction is just to match the model with the image, once the match is successful, some parameters of the function is the result (eg. coefficients of spline). This is called top-down or model driven strategy. For example, the algorithm of graph searching realized by dynamic programming (Gruen A, Li H H, 1995) and active contour (snakes) which is a method of 'energy minimization' (Trinder J, Li H H, 1995, Gruen A, Li H H., 1996). According to former ways of interactivity, one gives start point and tracking direction (Quam L H, 1985). However, sometimes the result is unpredictable. By active contour, operator give some seed points as the global constraint of shape of the object, if the extraction fails, one has to do it again. It is not so good interactivity.

Our algorithm and interactive operation of the extraction are different with above-mentioned methods. We do not derive a uniform mathematical model of the road feature. Our approach is a step-by-step extraction. Firstly, a pair of seed point limits the searching scale in which some possible points are attained by correlation of local radiometric template. Then the segmented curve fitting eliminates the blunder points, finally a Hopfield neural network is built to optimize the result. By this approach, extraction algorithm is running in a pair of point. The interactive mode is 'what you see is what you get'. That is to say, the new extraction result appears while the operator gives the new seed point. During the procedure, one can expediently cancel the extraction in the 'segment', furthermore, the manual positioning operation could be inserted with no influence of entire extraction. At the end of entire extraction, all points of these segments will be fitted by spline. Figure 1 is the procedure of the algorithm.

3 STEPS OF THE ALGORITHM

3.1 Input Road Width and Seed Point

The road width should be input through interface, such as dialog input or manual measurement. When the width is wider (larger than 10 pixels), operator can give two points near two sides of the road, then the algorithm automatically finds the real edges and calculates the width.

3.2 Image Segment Resampling

A rectangle area between a pair of seed point is resampled from the whole image. The range of the area is related to the road width and the distance between the two points (see Figure 2).

3.3 Template Matching

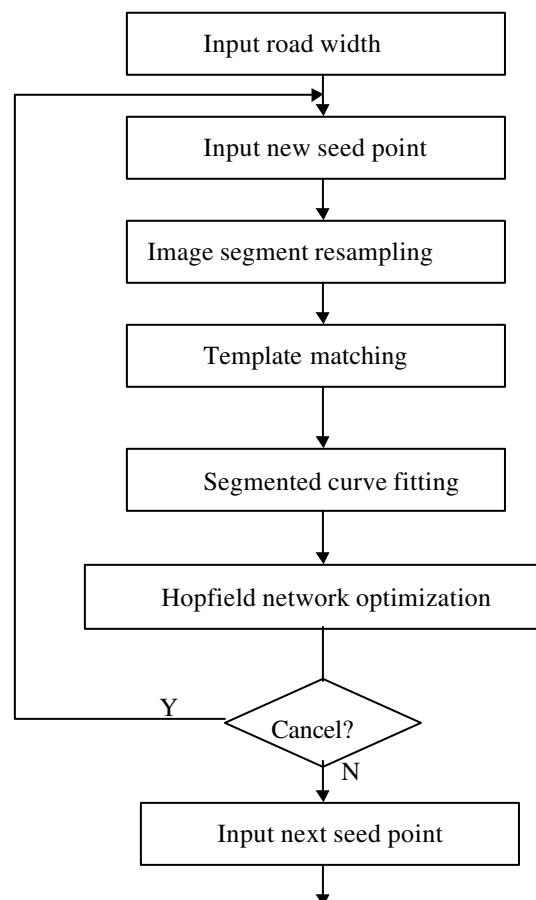


Figure 1. Procedure of semiautomatic road extraction

The local gray feature that is defined by road 'profile' forms the template. Compare to normal gray level and rectangle shape template, this particular template is a single pixel width and binary (0-1-0) template. Within the image segment, the template moves along the vertical direction of the road (vertical to segment axis) to calculate the correlation coefficient with the image, see Figure2. The calculation gets several peak values that are stored in a structure list. According to the definition of correlation coefficient, suppose the correlation coefficient between the signal p and q is c , $q_1 = aq + b$, then the new value of correlation coefficient between p and q_1 is $c_1 = c$.

The correlation of binary template could not only save the time by transferring the correlation to a partial adding calculation, but also remove the influence of local different contrast between the road and the environment (linear distortion of the binary template function). Furthermore, the pixel by pixel moving correlation could take the fast algorithm. The algorithm extremely speeds up the time consuming correlation computation.

For the wide road (the width is larger than 10 pixels) on the image, the template matching proceeds at a multi-layer image structure, like (Heipke C, Steger C. A., 1995). The results of matching are transferred from lower resolution layer to higher resolution layer. However, this has been proved as a more effective and reliable strategy. The layer count is dominated by the road width. This multi-resolution correlation lead to the matching for wide road extraction that is as fast as that of few pixels width road.

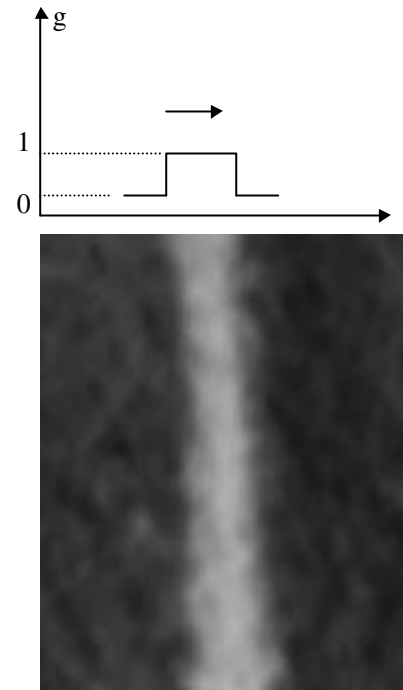


Figure 2. Binary template correlation

3.4 Segmented Curve Fitting

After above processing, most of the max-correlation points are the right centerline point, the errors only occur in the column direction of the segment. According to the geometric constraint, road is a continuous and smoothly changed shape. The local wiggles and burrs are regard as errors. So a segmented curve fitting by least square could be used to remove these blunders. Here a quadratic curve defined by the equation: $y = a_0 + a_1x + a_2x^2$ is to iterate the processing of fitting with eliminating the errors that are larger than a restriction until all final errors are less than a given restriction value. The length of segmented curve is settled by the road width since most of the wider roads in the image have less curvature and variation of curvature.

3.5 Optimization by Hopfield Network

The segmented curve fitting could remove most of blunders. But sometimes the segmentation causes the discontinuous among the segments. In the case of heavy shadows and other noises, some max-correlation in a short segment might be wrong. We need a global optimal computation to select an optimal solution that accords with the radiometric and geometric constraint of the road.

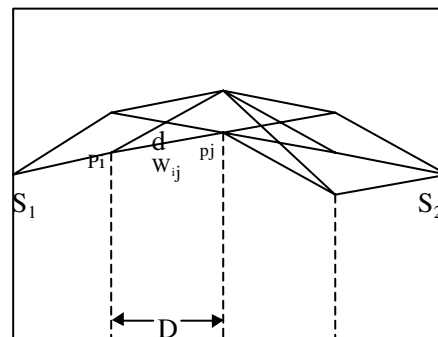


Figure 3. Hopfield Model

Artificial neural network (ANN) is a promising and widely used method in the field of pattern recognition. If the initial state of the network is the noise-polluted pattern and the minimal value of network energy defined a known pattern, the network that is built with the weights, I/O characteristic

and the thresholds of the unit would convergent to a steady state of representation of the pattern. The knowledge of the recognized object is stored as the weights, I/O characteristic, thresholds and the initial states of the units. Here a Hopfield neural network is constructed as an optimization way for the extraction of the 'continuous, smooth and light ribbon' from aerial image (see figure 3, S_1 and S_2 are seed points). In the net, adjacent peak correlation values are connected each other. The original value of the unit is correlation coefficient, the weight W_{ij} is a function of the distance of the unit (d), difference of the gray at the center of the template matching and average of correlation coefficient of the two unit (v). According to the road feature, the less d and d_g are and the greater v is, the greater W_{ij} is, as follow:

$$W_{ij} = C_d D/d + C_e v + C_g d_g \quad (1)$$

Here C_d , C_e and C_g are weight coefficient of the items, we set their value 0.45, 0.25 and 0.3. D is matching interval. The I/O characteristic of the unit is defined by a sigmoid function:

$$f_i = 1 / (1 + \exp(-(3 + \sum W_{ij} - I))) \quad (2)$$

I is the threshold of the unit, it is direct ratio of the distance between the unit and the fitted curve. The experimental result shows that the convergence of the net (the states of all units don't change) is right output even there is heavy noise. For example, there are not active output units where the road is shadowed by trees. The performance of Hopfield neural network assures the convergence and our I/O function of the unit guarantees fast convergence.

4 EXPERIMENTAL RESULTS

We have integrated the algorithm into a digital photogrammetric workstation – VirtuosoTM. Using the system, many

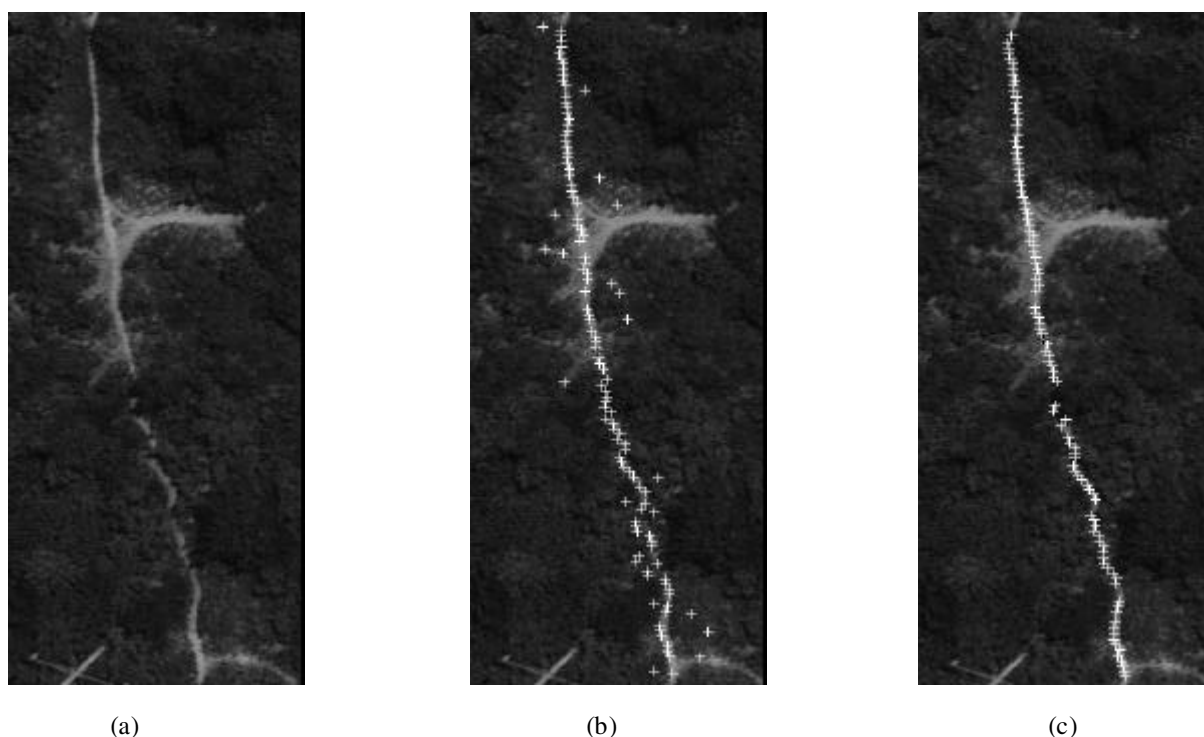


Figure 4. Experimental result of one road extraction

experiments have been done for practical mapping from images.

Figure 4 shows a road extraction. There are two seed points at the end of the road segment. The crosses in (b) are the max-correlation points. Some of them are errors. Part (c) shows the result after segmented curve fitting and optimization by Hopfield neural network. The result indicates the effect of the algorithm.

Figure 5 is a semiautomatic extraction result of a road network in an aerial image of which scale is 1:25000, all extracted central lines of road are fitted by cubic spline. Part (b) is a snapped vector window of the result.

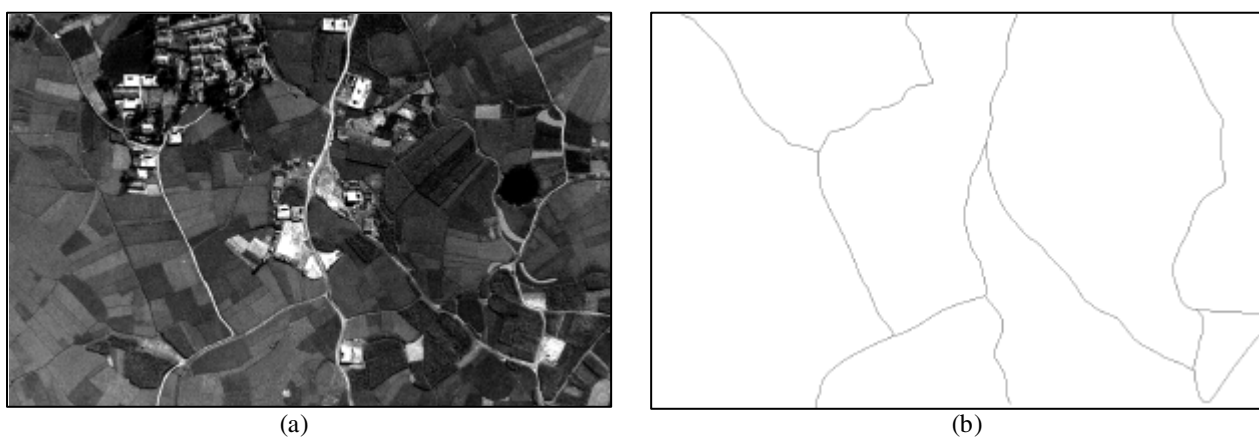


Figure 5. Extraction result of a road network

5 CONCLUSIONS

The practice indicates that our algorithm and human-machine cooperation has good accuracy, steady output, high speed and good interactivity and is much more effective than traditional manual digitizing. Our algorithm uses some experiential parameters or thresholds, such as the resampling range (searching range of template correlation), error restriction of curve fitting and weight coefficient of weight function of the Hopfield network. Face to practical production of digital mapping, it is good as long as it accomplishes the task.

However, our model of road extraction is based on a 'light ribbon like' feature, there are still problems in extraction in downtown area and color image. The template might be more complex and the optimization should integrate more factors, such as texture and color information. That is the farther work.

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