

# RESEARCH ON ROAD EXTRACTION SEMI-AUTOMATICALLY FROM HIGH RESOLUTION REMOTE SENSING IMAGES

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## ABSTRACT:

Nowadays, there have substantive research on road extraction automatically from RS images, restricted by low understanding level of images, the automatically extracting method is not robust, and a great many errors existed. The LSB-Snake model is an effective method to extract linear object semi-automatically, but needs manual input of road character for extraction, and not robust while the initial seed points are not dense enough. These hold down the working efficiency of LSB-Snake model. This paper put forward an **auto-initial-valued LSB-Snake model**, which use self-adapt template matching method to provide the road character to LSB-Snake model, and add seed points based on the initial points at the same time automatically. Experiments indicate: Given the same amount of initial seed points, our method is more **robust** than LSB-Snake model; Needn't manual input the road character, the auto-initial-value LSB-Snake model is more **automatic** than LSB-Snake model; The auto-initial-value LSB-Snake model can overcome the shade or shelter of land objects such as building and trees, and more powerful in **anti-jamming** than LSB-Snake model. The methods this paper put forward can extract road feature from remote sensing image efficiently.

## 1. INTRODUCTION

Linear features extraction from Remote Sensing (RS) images is a frequently researched issue, and road feature is one of the most important features in RS images. Nowadays, there have substantive research on linear feature extraction from RS images, such as the multi-scale space strategy method<sup>[1]</sup>, the perspective group method<sup>[2]</sup>, the manual neural network method<sup>[3]</sup>, the classification method, the active contour model (Snake model) method<sup>[4,5]</sup>, the template matching method<sup>[6,7,8]</sup>, etc. These extraction methods can be classified by semi-automatic and automatic. Many researchers are interested in the automatic extraction method, although it has been researched for about thirty years, no system presented put into application robustly without human interfere, and the semi-automatic extraction method such as template matching and Snake model are more applicable.

Road is a linear feature, and one of the most important feature in RS image, the extraction of road is important for urban layout, communication and surveying, etc.

Based on the template matching method, this paper put forward a method of self-adapt template matching, using the result of it as the initial value of LSB-Snake model, named "auto-initial-valued LSB-Snake model" to extract linear road feature from high resolution RS images semi-automatically.

## 2. AUTO-INITIAL-VALUED LSB-SNAKE MODEL

Road is a kind of typical linear-like feature, it's character can be concluded as gray scale, geometry, topology, function and conjunction or context obligation etc. among them, gray scale is the most important character, the gray scale of a road can be expressed as linear features of some the bright contrast between edge and the middle of road, the gray scale template of road's section is designed according to the gray scale character of road. We match the road in RS image using road section template.

This paper put forward a self-adapt template matching method to match the road in RS images by templates of series width, which is named as self-adapt template matching method, then takes the result of the template matching into LSB-Snake model as initial value to extract road from RS images, which is named as Auto-initial-valued LSB-Snake model. The flowchart of our method as follows.

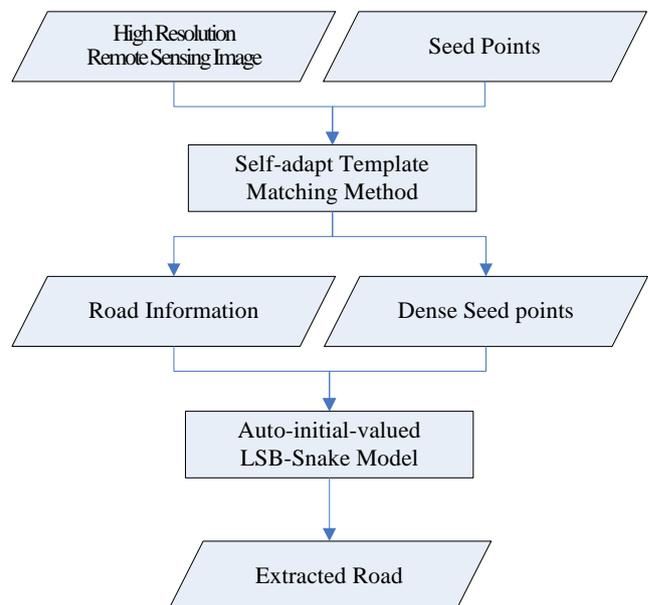


Fig. 1 Flowchart of Road Extraction Method

Self-adapt template matching method and auto-initial-valued LSB-Snake model are the key technique of the paper.

### 2.1 LSB-Snake Model

Snake<sup>[9]</sup> model is a spline curve of least energy, it has three elements: inner force, outer force and image force. The inner force restricts its shape, the outer force lead its action, and the image force push it to notable image character. The energy function of Snake  $E_{snake}$  is defined as follows:

$$E_{snake}(v) = \frac{1}{2} \int_{\Omega} [E_{int} + E_{image} + E_{con}] ds$$

LSB-Snake<sup>[10]</sup> is an efficient model to extract liner-like features, it describes Snake curve using B-spline with parameters, and iterative to minimum energy by using the algorithm of least square estimation, allocate the place of node points by the complexity of B-spline.

Before the extraction of road by LSB-Snake model, it need manual input the width and dark or bright character of the road to be extracted, Manual input may not be accuracy and hold down the extract efficiency. Besides this, the LSB-Snake model is not robust while the initial seed points are not dense enough.

In our method, we obtain each road's **width** and **dark or bright attribute** by self-adapt template matching and take it as initial value of LSB-Snake, this value is accurate and trusty, so the manual input is avoided. And, comparing with LSB-Snake model in extraction of road, the method this paper put forward can use not only the initial seed points, but also the **new added seed points** created by self-adapt template matching method, this makes the extracting result of roads more robust.

### 2.2 Self-adapt Template Matching

Self-adapt template matching method can obtain the dark or bright attribute and the width of a road, at the same time, it creates some new added seed points for LSB-Snake model.

The character of a road in remote sensing image can be described by gray scale, geometry, topology, function and conjunction or context obligation etc. Among these characters, gray scale is the most important one, the gray scale of road can be expressed as linear feature with gray difference between the sides and the middle, so the ribbon-like (for ideal road) or ridge-like (for general road) template can be applied to match the road. This paper takes the initial seed points as initial place, to match the updated RS image by multi-scale template matching method. The results are:

- 1) The maximum template matching point;
- 2) the width of the road in image;
- 3) whether the road in image is bright or dark comparing with the background;

The templates this paper designed are a series of ridge-like templates with multi-scale in width (Fig.2), they are one-dimensional templates.  $g_m$  axis represents template gray scale,  $y$  axis represents the template width, the middle part with even  $g_m$  value represents the width of road. The difference of the width of template and the width of road is a constant. A series of templates were designed, they are differ in width of road, the width are respectively 3, 5, 7, ..., 25(pixel) ..., etc. In figure 3a, the width of template is 13, the width of road is 3; in figure 3b, the width of template is 15, the width of road is 5. The template

with 3 pixel of road width will get max matching result with a narrow road in image, and the template with 25 pixel of road width will get max matching result with a broad road in image. While the width of a road in image is unknown, it can be obtained by multi-scale template matching method.

The road in image may be either bright or dark strip comparing to the background, so two series of templates are designed: the first series of multi-scale templates are bright ridge-like (fig.2), and the second series of multi-scale templates are dark ridge-like (fig.3). The former match bright road more efficient, and the latter match dark road more efficient. Whether the road is bright or dark could be judged by this means.

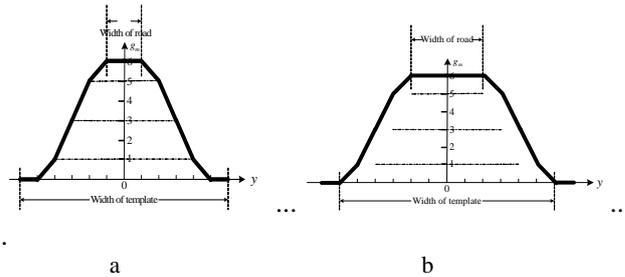


Fig. 2 bright ridge-like multi-scale template

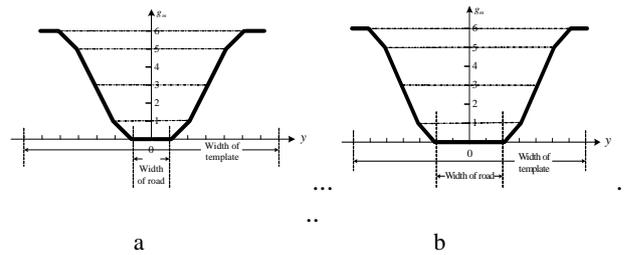


Fig. 3 dark ridge-like multi-scale template

After manually input several initial points, dividing the distance between each two points by several segments, using templates of different widths to match each segment with the RS images along the vertical direction respectively, compute the value of correlation coefficient, the formula is as follows.

$$\rho(c, r) = \frac{\sum_{i=1}^m \sum_{j=1}^n g_{i,j} \cdot g'_{i+r,j+c} - \frac{1}{m \cdot n} (\sum_{i=1}^m \sum_{j=1}^n g_{i,j}) (\sum_{i=1}^m \sum_{j=1}^n g'_{i+r,j+c})}{\sqrt{[\sum_{i=1}^m \sum_{j=1}^n g_{i,j}^2 - \frac{1}{m \cdot n} (\sum_{i=1}^m \sum_{j=1}^n g_{i,j})^2] [\sum_{i=1}^m \sum_{j=1}^n g'^2_{i+r,j+c} - \frac{1}{m \cdot n} (\sum_{i=1}^m \sum_{j=1}^n g'_{i+r,j+c})^2]}}$$

Where,  $m$  and  $n$  represent the row and column of image block respectively,  $r$  and  $c$  represent the searching scope,  $g$  and  $g'$  represent the grayscale of template and image respectively.

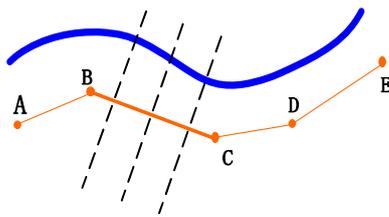


Fig4 Template matching

In fig 4, the A、B、C、D and E are initial seed points, the bold line above represents a road in RS image, the broken lines represent the direction of template matching.

Choose the maximum correlation result as the only matching result of the segment. If the only matching result is larger than a given threshold, it's an efficient matching result. Take several maximum efficient matching results as adopted matching results.

At the matching place of adopted matching results add seed points automatically, these seed points accompany with the initial seed points, composed the seed points of LSB-Snake model.

After processing above, on the one hand, we compute the sum of the number of corresponding templates of the efficient matching results, take the template of maximum sum as the width of the road; on the other hand, compute the frequency of "bright ridge" and "dark ridge" template responding to the adapted matching result respectively, educe the road's attribute of dark or bright by the higher frequency.

### 3. EXPERIMENTS

A program is developed to realize the method above using Visual C++ language<sup>[11]</sup>, a series of experiments is presented to extract roads from IKONOS and QuickBird image, to compare the result of road extraction by our method and LSB-Snake model.

Fig. 5 uses IKONOS image, in this experiment, there almost doesn't interfered land object around the road. Input several a few seed points as fig. 5a, the round points are inputted manually, and the extraction result of LSB-Snake model is presented, the extraction result of auto-initial-value LSB-Snake model as fig. 5b, the rectangle points are added by self-adapt template matching method.

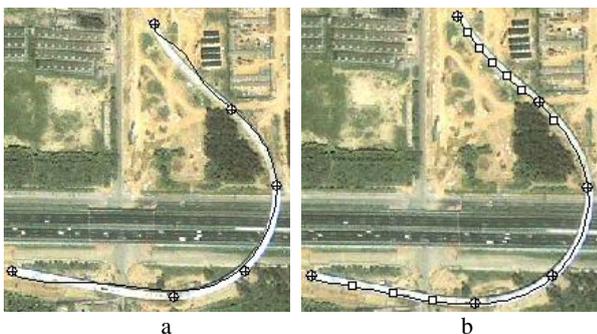


Fig. 5 Comparing of Road Extraction Results

From this experiment we can see that, if the initial seed points are not dense enough, the result of road extraction by LSB-Snake model is incorrect, while the auto-initial-valued LSB-Snake model can extract road correctly, it's more robust and automatic than LSB-Snake model.

Fig. 6 uses QuickBird image, in this experiment, there exist heavy shade or shelter around of the road by trees and houses, fig. 6a is the result of road extraction by LSB-Snake model, fig. 6b is the result of road extraction by auto-initial-valued LSB-Snake model.

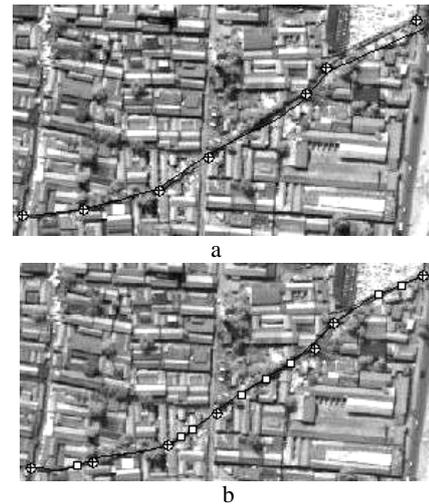


Fig. 6 Comparing of Road Extraction Results

From this experiment we can see that, if the shade or shelter is heavy, the extraction result would be incorrect as fig 6a indicates, while the auto-initial-valued LSB-Snake model can overcome the shelter and extracts road correctly, more powerful in anti-jamming than LSB-Snake model.

### 4. CONCLUSIONS

Based on the research of LSB-Snake model, this paper put forward an auto-initial-value LSB-Snake model using self-adapt template matching method to extract road feature in high resolution remote sensing image semi-automatically. IKONOS and QuickBird image are taken for experiments, manually input the same amount of initial seed points, comparing the extraction result of the LSB-Snake model and auto-initial-valued LSB-Snake model. Experiments indicate:

The auto-initial-valued LSB-Snake model can add seed points automatically by self-adapt template matching. Given the same amount of initial seed points, our method is more robust than LSB-Snake model.

Needn't manual input of the parameter, such as the width of road, dark or bright, the auto-initial-valued LSB-Snake model is more automatic than LSB-Snake model.

The auto-initial-valued LSB-Snake model can overcome the shade or shelter of land objects such as building and trees, and more powerful in anti-jamming than LSB-Snake model.

While, because the condition of the road in High resolution remote sensing image is complex, our method of road extraction

may be doesn't work while the shelter or shade is very heavy. Further research will take not only the gray scale character into account, but also the geometry, topology, function and conjunction or context obligation into the extraction of road to obtain more robust result.

#### REFERENCES:

1. Bajcsy R, Tavakoli M., 1976, computer recognition of road from satellite pictures. IEEE Trans on systems, Man and Cybernetics, Vol.6,No.9,pp.623-637.
2. Trinder, J. and Y. Wang. Automatic road extraction from aerial images. Digital Signal Processing, 1998, 8 :pp.215-224.
3. Mayer, H., C. Steger. Scale-space events and their link to abstraction for road extraction, ISPRS Journal of Photogrammetry and Remote Sensing,1998,53:pp.62-75.
4. Ivan Laptev, Helmut Mayer, Tony Lindeberg, Wolfgang Eckstein etc. Automatic extraction of roads from aerial images based on scale-space and snakes. Technical report CVAP240,ISRN KTH/NA/P-00/06-SE,March 2000.
5. Gruen, A., H.H Li. Semi-automatic linear feature extraction by dynamic programming and LSB-Snakes, Photogrammetric Engineering and Remote Sensing,1997, 63(8):pp.985-995.
6. Hu, X., Z. Zhang, J. Zhang. An approach of semi-automated road extraction from aerial image based on template matching and neural network. International Archives of Photogrammetry and Remote Sensing, 2000,XXXIII(B3/3):pp.994-999.
7. Gruen, A., P. Agouris, H.H Li. Linear feature extraction with dynamic programming and globally enforced least squares matching. Automatic Extraction of Man-made
8. Vosselman, G., J. Knecht. Road tracing by profile matching and Kalman filtering. Automatic Extraction of Man-made Objects from Aerial and Space Images (A. Gruen, O. Kuebler and P. Agouris, editors), Birkhauser, Basel,1997:pp.265-274.
9. Objects from Aerial and Space Images(A. Gruen, O. Kuebler and P. Agouris, editors ), Birkhauser, Basel, 1995, pp.83-94.
10. Michael Kass, Andrew Witkin and Demetri Terzopoulos. Snakes: active Contour models. In: Brady I M, Rosenfield A eds. Proceedings of the 1st International Conference on Computer Vision. London: IEEE Computer Society Press,1987.259-268.
11. Gruen,A.,P.Agouris,H.H Li.Linear feature extraction with dynamic programming and globally enforced least squares matching. Automatic Extraction of Man-made Objects from Aerial and Space Images(A.Gruen, O.Kuebler and P.Agouris, editors), Birkhauser, Basel,1995,pp.83-94.
12. David J. Kruglinski. Programming Visual C++6.0. Beijing Hope Electronic Press. 2003.

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