A Novel Recognition Method of Road Networks in Images from Remote Sensors based on Edge Feature Selection

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***Abstract* — In this paper we propose an ant colony algorithm to recognize road networks in remote sensor images using edge feature selection. The results of simulation comparison experiments indicate that the ant colony algorithm can select the feature subset with high relational degree to the road network recognition, which can: i) achieve dimensionality reduction on the feature effectively, ii) improve the global convergence of the algorithm and road-network recognition rate, and iii) be the reference for accuracy rate and instantaneity at the same time, iv) while recognizing the remote sensing image of a road network. The features of this method: i) extract key points of multi-data remote sensing image road network as the initial seed point and feature points for image registration, ii) it can improve the efficiency of change detection by combing the image registration and change detection. A strategy of energy minimization is applied in this method to extract the opacity of pixels, which can detect changes in road network density, including some imperceptible changes. The simulation indicates the effectiveness of this method.**

Keywords- image registration; remote sensing image; road network recognition; image processing; edge features

I. INTRODUCTION

The hard change detection of remote sensing image road network based on registration is one of the traditional research directions of change detection research of remote sensing image road network. Generally, this method shall include three procedures: pretreatment, change information acquisition and post-processing of change content. Where, the pretreatment shall include image registration, radiation correction, topographic correction and atmospheric correction etc. The image registration is the most important link in pretreatment. The hard change detection method of remote sensing image road network based on registration shall mainly research in two aspects: on one hand, how to maintain the spectral feature among various color channels in the multispectral images during the change detection process; on the other hand, how to reduce the influence of image registration on the hard change detection. This influence shall include two aspects: the first one is the precision, which is the influence of error in image registration on the hard change detection precision. The other one is the efficiency, which is the proportion of time spent in image registration in the overall hard-change detection time. In recent years, many hard-change detection methods based on registration have been proposed [1-5]. These methods can be divided into two classifications: detection methods based on supervision and detection methods based on non-supervision. A new non-supervision detection methods has been proposed in this Thesis; in which, a strategy of energy minimization has been adopted to extract the opacity of pixel, and the seed points shall be upgraded according to the Gaussian distribution in region of variation and region without variation.

II. FEATURE SELECTION OF REMOTE SENSING IMAGE ROAD NETWORK

A. Construction of Ant Colony Path for Feature Selection of Road Network Featutre of Remote Sensing Images

Ant colony optimization (ACO) is the collective intelligence algorithm. It simulates the information communication and mutual cooperation of ants in finding food, which has advantages of positive feedback, strong global searching ability and distributed computation. Although this algorithm was proposed very late, the development of which is extremely fast. It has been widely applied to solution TSP, workshop scheduling, network path (Qos) and knapsack problems etc.; and according to the simulation result, the ant colony algorithm has better effect [9].

As for the feature selection of remote sensing image road network, the feature is deemed as one node to be visited by the ant, and then the feature selection shall be deemed as the process of finding the optimal path while finding food. The node (feature) passed by the ant in finding food shall be connected as the foraging path (feature subset); groups cooperate through the pheromone remained on each feature node and finally find out the optimal foraging path (optimal feature subset); therefore, the feature optimal problem shall be transferred into path search problem firstly. See the feature selection forming process of road network featutre of remote sensing image in Fig.1.

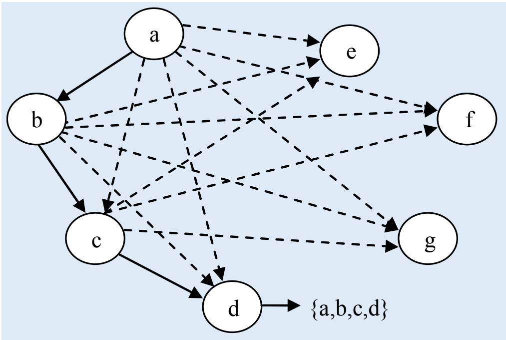

Figure 1. Path forming process of feature selection of remote sensing image road network.

B. Establishing of Fitness Function for Feature Seed Merit Evaluation

Objection selection of road network feature of remote sensing image includes two aspects: ①choose feature subset to enlarge image recognition rate; ②feature dimension shall be as small as possible, however, actually they contradict with each other. To balance them, feature selection algorithm fitness function of this research is defined as:

$$\max F = A + \lambda \frac{n}{N} \tag{1}$$

In the formula, F is objective function value; n is dimension of selection feature subset; N is total dimension of candidate feature set of remote sensing image road network; A adopts recognition rate of this feature; λ is weight balancing biggest recognition rate and feature dimension.

C. Ant colony Algorithm Design of Feature Selection

(1) Transition Probability

Probability of ants transited from feature i to feature j is:

$$p_{ij}^k(t) = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum \tau_{is}^{\alpha}(t)\eta_{is}^{\beta}(t)} & j,s \notin tabu_k \\ 0 & otherwise \end{cases} \tag{2}$$

In the formula, η_{ij} is heuristic factor, and the bigger η_{ij} is, probability of ants transited to feature j is bigger; $\tau_{ij}(t)$ is information factor from feature *i* to feature j at moment t and *tabuk* is taboo table of ant k.

(2) Partial Elaborated Search Process

In ant feature search, introduce partial elaborated search link to prevent reservation of redundant or irrelevant features to recognition result in feature subsets.

Suppose after ants search *i*th important feature *fm* (feature set at this time is denoted as *Sm*), they search (i+1)th important feature *fn*, after k sub-important features, then elaborated search shall be conducted in feature set $U(U \neq \varnothing)$ consisting of k features:

Mark any subset of U as ui, mark Si=Sm∪ui∪{fn} , search optimal subset uj satisfying:

$$F(S_j) = \min_i \left(S_i, \forall i\right) \tag{3}$$

Modify present feature set into *Sj*, make ants forget partial sub-important features, which are irrelevant or redundant features.

(3) Update Rule of ant Pheromone

When all ant groups finish linear solution structure, then compute recognition result of classifier corresponding to every solution, thus obtaining fitness value of every ant, then conduct global update of pheromone according to formula (5).

$$\begin{cases} \tau_{ij}(n+1) = \rho \cdot \tau_{ij}(n+1) + \sum_k \Delta\tau_{ij}^k \\ \Delta\tau_{ij}^k = \dfrac{Q}{F(s_k)} \end{cases} \tag{4}$$

In the formula, *F(sk)* is fitness value of feature subset s; ρ is residual factor of pheromone; n is iteration number; k is ant number; Q is increasing concentration of pheromone.

(4) End Condition of Ant Colony Algorithm

If optimal fitness function of ant group after several continuous iteration does not change, it denotes search end of ant colony algorithm.

(5) Selection Procedure of Road Network Feature of Remote Sensing Image

Step 1: collect remote sensing image road network, and conduct pretreatment on it.

Step 2: extract color and textural features of remote sensing image road network, combine them into feature vector.

Step 3: normalize all eigenvalues in [0 1] via normalization formula.

Step 4: initialization of ant colony parameters including ant number M, biggest iteration number *Tmax*, and parameters such as α, β, ρ, etc.

Step 5: iteration number T=1

Step 6: generate randomly initial ant position (nodal point), compute transition probability of every ant according to formula (3), then construct a feasible solution at next nodal point; when ant colony finishes a search, update present optimal solution and pheromone.

Step 7: increase of T=T+1 on iteration number

Step 8: if it satisfies the condition, then iteration is finished, denoting optimal solution is found at this time, namely feature subset of optimal remote sensing image road network; otherwise, turn to (5) to continually conduct feature optimization of remote sensing image road network.

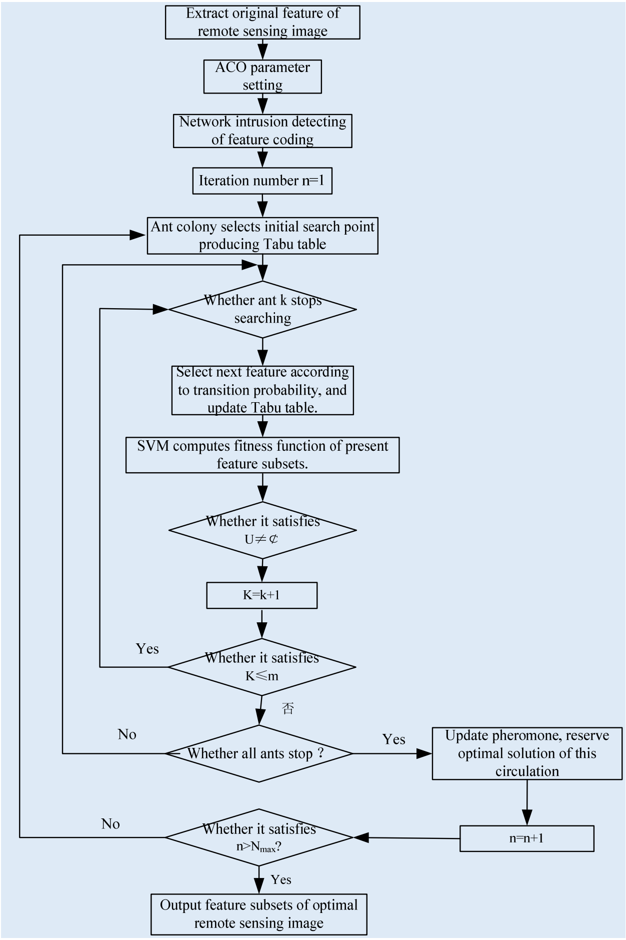

Figure 2. Selection procedure of road network feature of remote sensing image.

III. CLASSIFIER CONSTRUCTION OF REMOTE SENSING IMAGE ROAD NETWORK

At present, many algorithms are used for classification, such as algorithms of neural network, support vector machine, bayesian network and K neighboring, etc, and other algorithms are very complex except K neighboring with merits of simpleness, easy-to-realize, etc; this research adopts K neighboring algorithm to conduct classifier construction of remote sensing image road network . Find K neighbors of remote sensing image road network to be recognized, adopt similarity formula to judge category of remote sensing image road network, analyze merits of recognition result; if preset recognition rate satisfies the requirements, then optimal K value is determined, or adjust K value until requirements are satisfied. Adopt Euclidean distance to measure similarities among samples, namely:

$$d(x_i, x_j) = \sqrt{\sum_{r=1}^{n} \left(\alpha_r(x_i) - \alpha_r(x_i)\right)^2} \qquad (5)$$

(1) Mean recognition rate is relatively low in case of adopting single color or textural feature to conduct road network recognition of remote sensing image, reason of which mainly lies in inaccurate description of single feature on category information of remote sensing image road network.

(2) It is not ideal to make all features be recognition result of remote sensing image road network on recognition features, and it is because a complex non-linear relation exists between feature number and recognition result, thus higher feature dimensions cannot guarantee better recognition effect of remote sensing image road network, and recognition efficiency is low, and result shows many redundant or useless features exist in twenty four road network features of remote sensing image; if they participate into construction of classifier, it increases computing complexity and affects recognition result.

(3) Feature numbers of selected sub-features adopting ant colony algorithm are all less than original feature, and they can maintain recognition rate of remote sensing image road network higher than original feature sets, indicating features with bigger contribution on recognition result are reserved in the process of feature search of ant colony algorithm, and some bad features are deleted and optimization is conducted on feature combination.

IV. EXPERIMENT RESULT AND ANALYSIS

An experiment is given here to check effectiveness of change detection method based on random walk proposed in this Thesis. Input image is shown as Fig. 3, adopting key points obtained via method in 2.1 section as initial seed point of region of non-variation. According to strategy of energy minimization, we can get partition result of first iteration (shown in Fig. 4(a)), and we can find big difference exists between them comparing Ground Truth in Fig. 4(e). Correspondingly, value of energy function obtained from first iteration is also higher (shown in Fig. 4(f)). Upon update of seed point, we obtain partition results of second, third, fourth iteration (shown in Fig. 4 (b), (c) and (d)), and energy obtained from these three iterations is less than that of first iteration, among which, energy of fourth iteration is the smallest. Herein, we choose partition result of minimum energy of four iterations (shown in Fig. 4 (d)) as last change detection result.

Figure 3. Input image

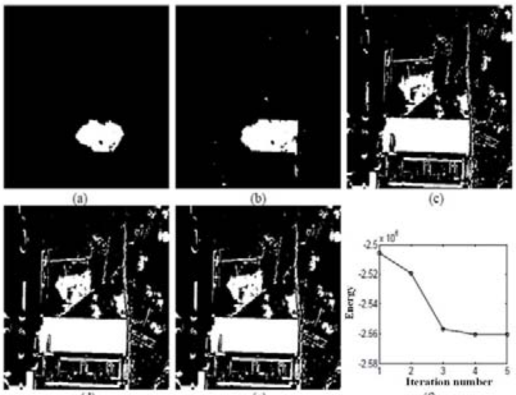

Figure 4. Change detection result of change detection method in the process of energy minimization of iteration based on random walk.
(a) Result of first iteration; (b)Result of second iteration; (c)Result of third iteration; (d)Result of fourth iteration; (e)Standard data; (f)Change situation of energy E(α,k,θ, x) of four iterations.

Next compare algorithm of this Thesis with several traditional methods: change detection method based on EM, change detection method based on mean value of PCA+k and change detection method based on principle component analysis of quaternion. Change detection method based on EM automatically gets best decision threshold value via minimizing change detection error, thus achieving change detection; change detection method based on mean value of PCA+k firstly adopts principle component analysis method to generate feature vector space from $h \times h$ non-overlapping blocks of difference imaging, then map $h \times h$ non-overlapping blocks on feature vector space, thus getting feature vector, finally adopt k mean value clustering method to cluster feature vectors into two categories, namely variable type and invariable type. Clustering result obtained is used to denote change detection result of this method.

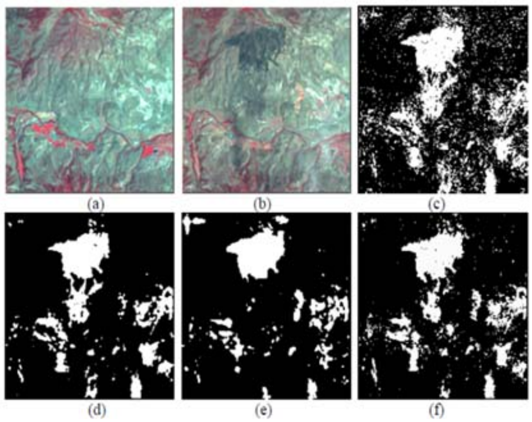

Figure 5. Change detection results of different methods.
(a)Input image X1; (b)Input image X2; (c)Change detection result based on EM; (d)Change detection result of pca+k mean value method; (e)Change detection result based on change detection method of principle component analysis based on quaternion; (f)Change detection result of change detection method based on random walk.

It can be found from Fig. 5 that detection rate of change detection methods based on EM method and random walk is relatively high, but they are likely to produce high false alarm rate, and they are both sensitive to noise, while anti-noise performance of change detection methods based on PCA+k mean value method and principle component analysis of quaternion is better than previous two methods, but these two methods are likely to generate high missing report rate, and they tend to ignore some regions of weak variation. For instance, for multi-date remote sensing image road network in first group, change caused by forest fire is very significant, and this change is distributed in many areas of figure. Fig. 5(c) is change detection result of change detection method based on EM method, we can find that from the figure this method also detects many noise points besides detecting areas of significant change, and false alarm rate of it is relatively high.

Change detection result of change detection method based on PCA+k mean value method is shown in Fig. 5(d), we can find that false detection of this result is relatively few, and anti-noise performance of this method is better compared with change detection method based on EM method, but its missing report rate is higher. Change detection result of change detection method based on principle component analysis of quaternion (shown in Fig. 5(e)) is similar to that of change detection method based on PCA+k mean value method, but missing detection is likely to appear. Change detection result of change detection method based on random walk is shown in Fig. 5(f), and change detection result of this method is close to that of change detection method based on EM method, and this method can merge image registration into change detection compared with other three methods, while other three methods need to conduct registering on input image in advance.

V. CONCLUSION

To enhance recognition rate of remote sensing image road network, this Thesis proposes a feature selection method of remote sensing image road network based on ant colony algorithm; emulation experiment result shows this algorithm can search optimal feature subsets of remote sensing image road network fast and accurately and eliminate adverse influence of useless and redundant features, and it increases minute recognition efficiency and recognition rate of remote sensing image road network. This method extracts multi-date key points of remote sensing image road network as initial seed point of random walk and feature point of image registration, and improves efficiency of change detection by combining image registration and change detection. This method applies a strategy of energy minimization to extract opaqueness of pixel.

ACKNOWLEDGMENTS

Study on the Response of Regional Soil Organic Carbon Sequestration to Rapid Urbanization(31200366).

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