RESEARCH ON CHANGE DETECTION OF OUTDATED MAP ROAD FEATURE BASED ON UPDATED HIGH-RESOLUTION REMOTE SENSING IMAGE

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Commission VII, WG VII/5

KEY WORDS: Satellite remote sensing, Change detection, Image understanding, Feature detection, Updating, matching, High-resolution image

ABSTRACT:

This paper researched on change detection of outdated map road feature based on updated high-resolution satellite remote sensing (RS) image. The change of road feature was divided into two parts: one is disappear or partial change; the other is new added. To detect disappear or partial changed road, based on outdated map road feature, this paper put forward methods of **multi-scale template matching**, restricted by **buffer distance** and **knowledge judge logic**; To extract new added road, based on the study of LSB-Snake model, this paper put forward an **auto-initial-value LSB-Snake model**. Experiments were done using RS images of different resolution and road map of multiple scales, the experiment region including mountain, suburb and central urban. The experiments results indicate that, the average check-out-ratio reached 95%, the average correct-ratio reached 65%. The auto-initial-value LSB-Snake model is more automatically and more robust than the LSB-Snake model. The methods this paper put forward can detect the change of map road feature efficiently.

1. INTRODUCTION

As political and cultural center of China, Beijing is developing rapidly, the change ratio of land surface features reaches 5-10% every year, the change are so tremendous that maps are not usually consistent with the actual case of surface features. In order to keep the consistency, speeding up map updating rate are timely required. Change detection is an important process of map updating, Road is one of the most important feature in map, it's the most frequently changed feature, therefore the change detection of outdated road feature play an important role in map updating and become a frequently researched issue.

Nowadays, there are substantive researches on road change detection. The researches can be divided to two main directions by sense of data source: one is based on images of different temporal, the other is based on outdated road vector and updated image.

Some researches detect the change of linear features based on images of different temporal: Neil detect the change of linear features in aerial photographs, using edge-finding method, firstly extract the line feature, and then match the extracted feature, the failed matching result was the change to be detect(Neil C.R, 2001). The images of different acquire condition will affect the robustness of matching. Zhong put forward an algorithm to detect the change of road network, using ETM and SPOT image (Zhong J Q, 2007), it detect the edge in RS image firstly, then obtained the changed edge by the gradient, extract the changed linear feature by grouping and fitting to the edges, finally post processing the changed linear feature using a road model. The method can hardly effective while the changed road has been shaded by other objects such as buildings or trees. These change detection methods highly depends on the images of different temporal and not robust enough while roads encounter shades in image.

Some researches detect the road change based on outdated road map vector and updated image. If the road was sheltered by buildings or trees in image , the parted segments of road can be filled up under the lead of road vector, (Sui H G, 2002), the change detection method less depends on the updated image and more robust while encounter shades. This paper use this kind of method to detect outdated map road changes based on updated RS images. While this method hasn't any lead for detection of new added roads, they should be extracted by other methods. There have substantive research on linear feature extraction form RS images, such as the perspective group method (Trinder, J, 1998), the manual neural network method (Mayer, H., C,1998), the classification method, the active contour model (Snake model) method (Ivan Laptev, 2000; Gruen. A, 1997), the template matching method (Hu. X, 2000; Vosselman, 1997), etc. This paper based on the LSB-Snake model and template matching method, put forward a method of auto-initial-value LSB-Snake model to detect new added road in updated RS image.

2. METHOD

This paper mainly researches on change detection of outdated map road feature based on updated high-resolution satellite remote sensing (RS) image. The aim is to detect the changes of road accurately, quickly and automatically or semi-automatically. The change detection is divided into two types: one is the detection to disappeared or partial changed road, the other is the extraction to new added road. To detect disappeared or partial changed road, based on outdated map road feature, this paper put forward methods of **multi-scale template matching**, restricted by **knowledge judge logic** and **buffer distance**(figure .1). To extract new added road, this paper put forward a semi-automatic method, whose name is **auto-initial-value LSB-Snake model**, it bases on updated RS image and several manually input seed points, using the **buffer distance** and **multi-scale template matching** method restriction to create initial value for LSB-Snake model (fig 2).

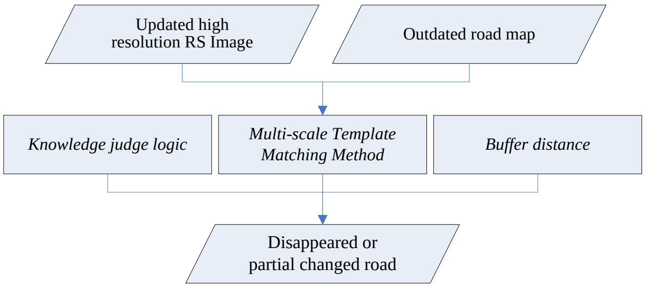


Figure 1. Flowchart of the change detection to disappeared of partial changed road

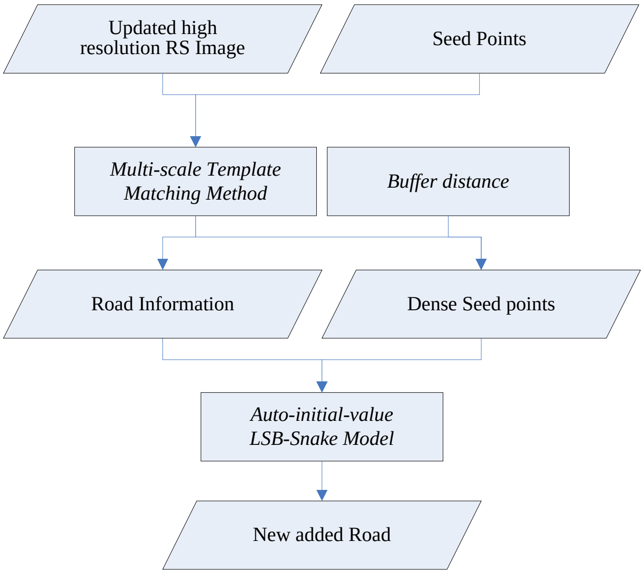


Figure 2. Flowchart of the change detection to new added road

Multi-scale template matching method, knowledge judge logic, buffer distance and auto-initial-value LSB-Snake model are the key technique of the paper.

The main effect of multi-scale template matching method is to judge whether the template match is succeed, if succeed, the road has not disappeared or partial changed, vice versa.

The knowledge judge logic method made the effective result of multi-scale template matching method more reliable, by the restriction of length and angle.

The buffer distance made the effective result of multi-scale template matching method more reasonable, by the buffer distance calculated.

Auto-initial-value LSB-Snake model is a method to detect or extract new added road. The method is based on LSB-Snake model in detection of new added road. The initial value of LSB-Snake model is obtained in advance, by means of multi-scale template matching method restricted by buffer distance, and dense seed points created in addition to initial seed points.

2.1 Multi-scale template matching

Road is a kind of typical linear-like feature, its character can be concluded as gray scale, geometry, topology, function and conjunction or context obligation etc. Among the 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 outdated road vector 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 compare with the background;
4) the judgement of whether a road has changed (disappeared or partial change) or not.
5)

The templates this paper designed are a series of ridge-like templates with multi-scale in width (Fig.3), 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, two series of templates are designed: the first series of multi-scale templates are bright ridge-like (fig.3), and the second series of multi-scale templates are dark ridge-like (fig.4). 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.

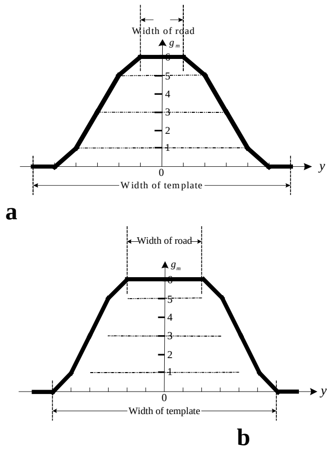
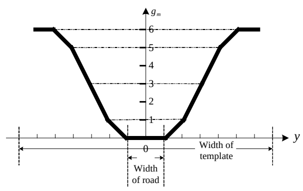
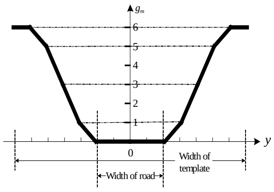


Figure. 3 bright ridge-like multi-scale template



a



b

Figure 4. dark ridge-like multi-scale template

Fig.5 is the overlap of outdated road vector and updated RS image, the white line represents road vector, the line between two vector vertexes is a vector segment, and a road vector is make up of several vector segments. The broken line represents the direction of template matching, the crosses represent the max matching point produced by multi-scale template matching method.

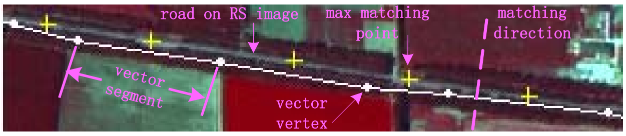


Figure.5 Multi-scale template matching

Take the outdated road vector as initial position, along the vertical direction of road segment, match every vector segment to RS image using multi-scale template. Compute the value of correlation coefficient, the formula is as follows.

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

In the formula, *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, the maximal value of correlation coefficient must corresponds the real place of the road.

After the multi-scale template matching, choose the max correlation coefficient as the unique matching result of a vector segment. If the unique result is larger than a given threshold, it's an effective result, each effective result must has an corresponding template, compute the sum length (called L_{same}) of the vector segments who are same in template width, choose the max L_{same} named $L_{sameMax}$, and the length of the road vector (called L_{total}), if the ratio of $L_{sameMax}$ to L_{total} is larger than a given threshold, this road hasn't disappeared or partial changed, vice versa.

The template width corresponded with the maximum length ($L_{sameMax}$) is considered as an efficient template, and its width of the road is considered as the width of road in image, the corresponding dark or bright attribute of the template is considered as the dark or bright attribute of the road in image.

2.2 Buffer distance

The buffer distance is here to check whether the effective matching result of multi-scale template should be accepted. The result of the multi-scale template matching might take the best matching at any place, regardless the distance between the place and the road vector, if the distance is too far, the result may not be the right place of road in RS image, and lead to wrong conclusion in judging whether the road has changed or not. The buffer is built along vertical direction of outdated road vector. If the road vector hasn't changed, it should have effective matching result inside of the buffer distance; if the effective matching result is outside of the buffer distance, we take this kind of matching result invalid. In fig 6, the bold dark line represent road vector, the distance between two broken lines is buffer distance.

Figure.6 Buffer distance

There are three factor affect the buffer distance: one is the accuracy of road vector map (σ_{map}), the second is the accuracy of correction accuracy of the RS image (σ_{image}), the third is the width of the road (σ_{width}). The formula to calculate the buffer distance is as follows:

$$BufferDis=\sqrt{\sigma_{map}^{2}+\sigma_{image}^{2}+\sigma_{width}^{2}}$$

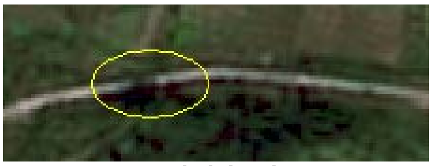
σ_{map} and σ_{image} are took as known value before change detection, σ_{width} has been calculated by multi-scale template matching method.

After buffer distance restriction, the effective matching result of multi-scale template is the result of change detection to road segment.

2.3 Knowledge Judge Logic

Inevitable, there exists the case that some parts of road in RS image are shaded by trees or buildings or other features. These shades will destroy the gray scale character of road, and lead to unsuccessful template matching result.

In fig .7a, the road is shaded by trees inside of the round area, in the fig.7b, the blue line represent road vector, white points are the vertex of road vector, there are six segments in all, the red cross is the result of multi-scale template matching, there are no matching point corresponded with the segment in the round area, for the shade of trees destroyed the gray scale character. How can this case be avoided?



a. shaded road

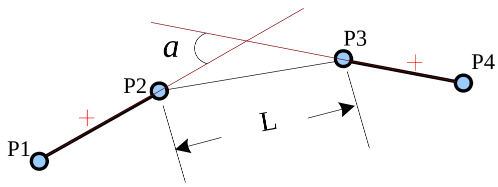
b. failure multi-scale template matching in shaded region

Figure.7 Shade or occlusion to road

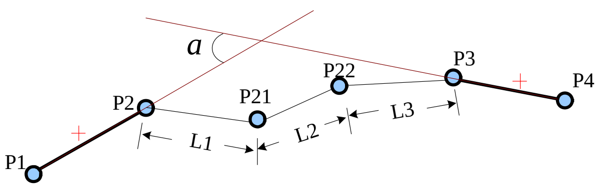
This paper put forward a method to solve the question named knowledge judge logic. The aim of it is to avoid the wrong matched result which is caused by shade or occlusion near the road in RS image.

As we know, road's curvature usually changes slowly, look at fig .7a, the P1P2 segment and P3P4 segment are succeeded matched road, the P2P3 segment are failed matched road segment by means of multi-scale template matching method. If the P2P3 vector segment satisfies the condition as followed, we shall consider the segment as successful matched. The condition is:

1) The distance (L) between the former and the latter road vector segment are less than some given thresholds, if there are many segments failed matching, L is the sum of L1, L2 and L3, as Fig.7b.
2) The angle (*a*) between the former and the latter road vector segment which were succeeded in template matching are less than a given thresholds.



a



b

Figure.7 Knowledge judge logic

After processing above, compute the sum length of successfully matched road vector segments, and the ratio of it to the total length of the road, if the ratio is less than a given threshold, the road has disappeared or partially changed, or it's unchanged. By means of knowledge judge logic, the ability of anti-shade is strengthened.

2.4 Auto-initial-value LSB-Snake Model

This paper put forward a semi-automatically change detection method to extract new added road. After selected a few seed points manually in RS image, we use auto-initial-value LSB-Snake model to extract roads.

Snake model (Michael Kass, 1987) 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:

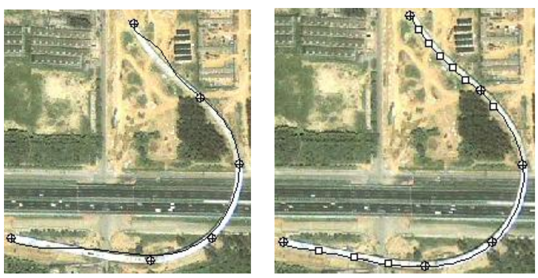
$$E_{snake}(v) = \frac{1}{2}\int_{\Omega}[E_{\text{int}} + E_{image} + E_{con}]ds$$

LSB-Snake (Gruen. A, 1997) 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 multi-scale template matching method as initial value of LSB-Snake, this value is accurate and trusty, the manual input is avoided. And, Comparing with LSB-Snake model in extraction of road, this method can use not only the initial seed points, but also the new added seed points created by multi-scale template matching method with buffer distance restriction, this makes the extracting result of roads more robust.

In fig .9a, the dark point is the initial seed points manually input, the dark line is road extraction result of LSB-Snake model, figure .9b is the extraction result of auto-initial-value LSB-Snake model, the rectangular points are the new added seed points of multi-scale template matching. the extraction result of fig .9b is more robust than fig .9a.



a b

Figure.9 compare of LSB-Snake and auto-initial-value LSB-Snake model

3. EXPERIMENTS

Based on the research above, a series of experiments are taken to testify if the change detection method is effective. The updated RS image in the experiments including SPOT5, IKONOS and QuickBird, the scale of outdated map road including 1:50000, 1:10000 and 1:2000 respectively. We use multi-scale template matching method, knowledge judge logic and buffer distance restriction to detect disappeared of partial changed roads; and auto-initial-value LSB-Snake model to detect or extract new added roads.

In the change detection to disappear of partial changed roads, two index mark are used to evaluate the result, one is **check-out-ratio**, the other is **correct-ratio**. Given the total num of roads are N_{total} (Fig.10), the actual num of disappeared of partial changed roads are N_{actual}, the detected num of disappeared of partial changed roads are N_{detect}, the num of road N_{detect} which included N_{actual} are N_{check}, the value of ($N_{check} \times 100/ N_{actual}$ %) is the check-out-ratio. The check-out-ratio is an important index mark to evaluate the efficiency of change detection method.
The correct-ratio is:

$$(\underline{N_{total} - N_{detect} - (N_{actual} - N_{check})} + \underline{N_{check}}) \times 100/ N_{total}\,\%$$

The first underline part means: the roads which are actually unchanged and in experiment result of change detection they are unchanged; the second underline part means: the roads which are actually changed and in experiment result of change detection they are changed. The sum of them is the num of right-judged road including changed and unchanged.

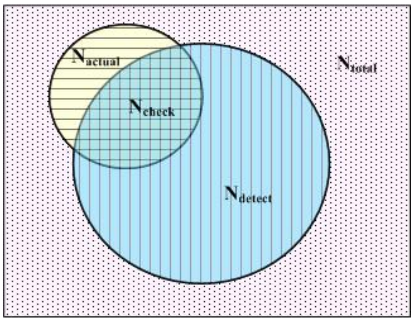


Figure.10 sketch map of index mark

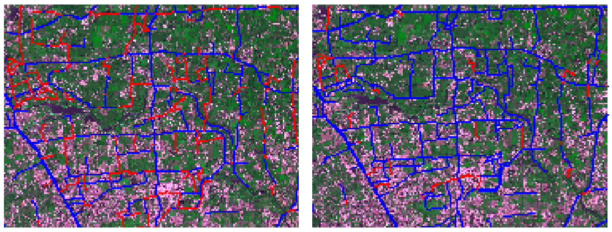
The extraction of new added road is semi-automatic, the extraction precision depended on the precision of LSB-Snake model, and it can reach pixel level. There is no other index mark to the experiments of new added road extraction.

3.1 SPOT5 image and 1:50000 map road vector

1) Change detection to disappeared of partial changed roads
The SPOT5 image is a fusion image of band 1, band 2 and band3, the resolution is 2.5 meter. Fig.11a is the change detection result of our method, the blue line is unchanged road, the red line is changed road judged by the methods this paper put forward. Fig.11b is the actual changed road. There are 533 road vector total, the actual disappear of partial changed road is 57, our method detected 219 disappeared of partial changed

2) Change detection to new added roads

road, among them 52 are right. The check-out-ratio is 91.23%, the correct-ratio is 67.7%.



a b

Figure.11 Change detection result of SPOT5 and 1:50000 map road vector

2) Change detection to new added roads

a. b

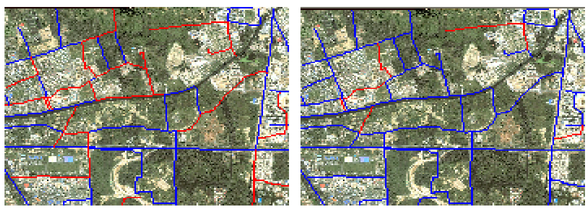
Fig.12a is the extraction result of LSB-Snake model, fig.12b is the extraction result of auto-initial-value LSB-Snake.
Figure.12 compare of LSB-Snake and auto-initial-value LSB-Snake model

If the initial seed points are not dense enough, the result of road extraction by LSB-Snake model is incorrect, while the auto-initial-value LSB-Snake model can extract road correctly, it's more robust and automatic than LSB-Snake model.

3.2 IKONOS and 1:10000 map road vector

1) Change detection to disappeared of partial changed roads

The IKONOS image is a fusion image of band 1, band 2 and band3, the resolution is 1.0 meter. Fig.13a is the change detection result of our method, figure .13b is the actual changed road. There are 87 road vector total, the actual disappeared of partial changed road is 8, our method detected 41 disappeared of partial changed road, among them 8 are right. The check-out-ratio is 100.00%, the correct-ratio is 62.07%.



a b

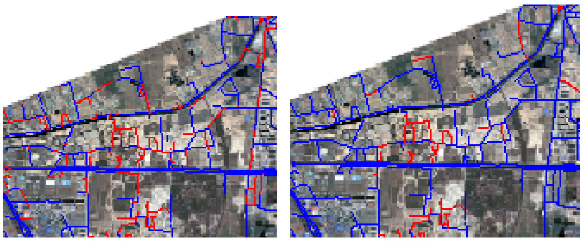
Figure.13 Change detection result of IKONOS and 1:10000 map road vector

The result of experiment in IKONOS image is Figure.8.

3.3 QuickBird and 1:2000 map road vector

1) Change detection to disappeared of partial changed roads

The QuickBird image is a fusion image of band 1, band 2 and band3, the resolution is 0.61 meter. Fig.14a is the change detection result of our method, figure .14b is the actual changed road. There are 402 road vector total, the actual disappeared of partial changed road is 60, our method detected 177 disappeared of partial changed road, among them 55 are right. The check-out-ratio is 91.67%, the correct-ratio is 68.41%.

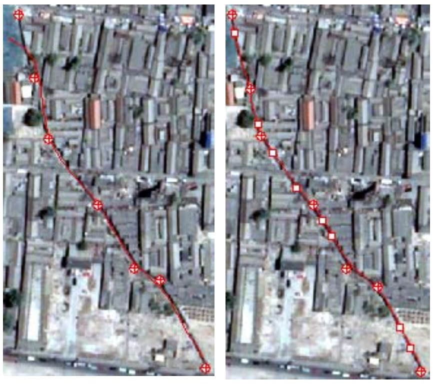


a b

Figure.14 Change detection result of QuickBird and 1:2000 map road vector

2) Change detection to new added roads

Fig.15a is the extraction result of LSB-Snake model, figure .15b is the extraction result of auto-initial-value LSB-Snake.



a. b

Figure.15 compare of LSB-Snake and auto-initial-value LSB-Snake model

If the shade or occlusion are strong, the extraction result would be fig. 15a, while the auto-initial-value LSB-Snake model can avoid the shades and extracts road correctly, more robust than LSB-Snake model in some degree.

Besides the experiments above, we had done many other experiments, including mountain region, suburb region and central urban region. In addition, road side line feature was detected in 1:2000 road side line vector map, where the template was redesigned correspondingly.

The result of change detection indicates: in the change detection to disappear of partial changed roads, the check-out-ratio reached 95%, the correct-ratio reached 65%.

1) The efficiency of change detection in suburb region is higher than mountain regions and central urban region. For road in mountain regions often illegible, this lead to unsuccessful template matching, road in central urban region usually be shaded by tall building or lined trees.

2) On check-out-ratio, the change detection result of IKONOS was the best of all RS images. The resolution of SPOT5 was relatively low, it's insensitive to small partial change; the resolution of QuickBird was relatively high, the roads were wide, there might be no unique ridge-like gray scale character for a road, and there exist too much disturbance, such as cars, lined trees, buildings, etc, these factors usually lead to wrong template matching result.

In the extraction to new added roads, comparing the LSB-Snake model and auto-initial-value LSB-Snake model:

1) The latter need less initial seed points than the former, and need no manually input of the character of the road to be extracted, due to the application of multi-scale template matching.

2) While, at the strong occlusion place, where the gray scale characters of road don't distinct, both methods are inefficiency, wholly manual extraction is needed.

4. CONCLUSIONS

This paper detected the change of the outdated road feature based on updated RS image. The change of road was divided into two parts: first, disappear or partial changed road; and second, the newly added road.

Different methods were put forward: multi-scale template matching method, knowledge judge logic, and buffer distance restriction are applied to detect disappear or partial change of road automatically. The multi-scale template matching method and buffer distance restriction provided initial value for auto-initial-value LSB-Snake model, are applied to detect the new added road semi-automatically.

Experiments were done, the RS image including SPOT5, IKONOS and QuickBird, the scale of road vector map including 1:50000, 1:10000 and 1:2000, the region including mountain region, suburb region and central urban region. The experiments results indicate that, the average check-out-ratio reached 95%, the average correct-ratio reached 65%. The auto-initial-value LSB-Snake model is more automatically and more robust than the LSB-Snake model.

As a result, the methods this paper put forward are efficient in change detection to road vector map based on RS image. While, due to the strong shelter or occlusion of land surface feature, such as trees and buildings to road in RS image, the result of change detection is influenced, further research are needed on taking knowledge into account, such as DSM, road joint relation etc, to improve the checking-out-ratio and correct-ratio in road change detection. Although the issue this paper discussed is change detection automatically and semi-automatically, the dominant effect of human being can't be ignored, human intervene are necessary in the threshold setting of algorithms, an issue of searching for an optimum combination point between human and computer task is an issue worthy of research in the future.

ACKNOWLEDGEMENT

This research is funded by the Beijing New Century Hundred, Thousand and Ten Thousand Talent Project.

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