MODIFIED DOUBLE SNAKE ALGORITHM FOR ROAD FEATURE UPDATING OF DIGITAL MAPS USING QUICKBIRD IMAGERY

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ABSTRACT ... Road networks are important geospatial databases for various GIS (Geographic Information System) applications. Road digital maps may contain geometric spatial errors due to human and scanning errors, but manually updating roads information is time consuming. In this paper, we developed a new road features updating methodology using from multispectral high-resolution satellite image and pre-existing vector map. The approach is based on initial seed point generation using line segment matching and a modified double snake algorithm. Firstly, we conducted line segment matching between the road vector data and the edges of image obtained by Canny operator. Then, the translated road data was used to initialize the seed points of the double snake model in order to refine the updating of road features. The double snake algorithm is composed of two open snake models which are evolving jointly to keep a parallel between them. In the proposed algorithm, a new energy term was added which behaved as a constraint. It forced the snake nodes not to be out of potential road pixels in multispectral image. The experiment was accomplished using a QuickBird pan-sharpened multispectral image and 1:5,000 digital road maps of Daejeon. We showed the feasibility of the approach by presenting results in this urban area.

KEY WORDS: road features, QuickBird, double snake algorithm, seed point generation, updating

1. INTRODUCTION

The construction of road network databases is important for many Geographic Information System (GIS) applications such as urban analysis, navigation and city modelling. Verification of road networks is mostly conducted manually using aerial photos or satellite images. However, such work may contain geometric spatial errors due to digitizing mistakes and individual carelessness. Digital maps may be old since urban areas change so rapidly. The development of automatic road updating algorithms based on satellite imagery could be a useful solution to the above problems. Since high-resolution remote sensing satellites such as IKONOS-2, QuickBird, IRS and KOMPSAT have been launched, the spatial information for feature extraction and analysis can be provided more efficiently. The use of image processing techniques and pre-existing knowledge such as topographic digital maps, automatic linear feature updating and extraction methods have been discussed vigorously. Zhang produced the automated system for updating of road databases (C. Zhang, 2004). It is based on the 3D road features extraction technique of stereo aerial photography using various cues such as edges, DSM, shadows, land cover and geodatabase information. Various feature matching and detection algorithms to detect road changes and updates are proposed (Q. Zhang, 2003; G. Koutaki, 2004). An active contour model known as a snake algorithm is used to update road networks. Agouris extended the deformable contour models and proposed a new framework to differentiate change detection in road segments (P. Agouris, 2001). A geometric active contour model is applied to highway extraction from multiple frame aerial photographs (X. Niu, 2006). I. Laptev proposed a new road extraction algorithm from aerial imagery with a strategy based mainly on multi-scale detection, in combination with geometry-constrained edge extraction using snakes (I. Laptev, 2004). Most snake algorithms need manual seed points and are sensitive to an image's quality.

In this paper, an automatic road feature updating algorithm based on a modified double snake model is proposed. Using existing road networks of topographic digital maps, initial seed points in the snake model are generated automatically. To minimize effects of geometric noise, the double snake algorithm is modified using spectral information.

2. DOUBLE SNAKE MODEL

2.1 The original snakes

Snakes have been developed in the computer vision as object extraction tools. The goal is to find a contour that approximates the perimeters of an object (Kass. M., 1987). The snake is represented by a polyline which is defined by nodes. The geometric and radiometric relations of these nodes are expressed as energy functions. It is composed of internal and external force. Internal forces play a role in regulating the contour and external forces attract the contour to specific image features. The total energy functional is expressed as (1).

$$E_{snake} = \sum_i (\alpha E^i_{cont} + \beta E^i_{curv} + \gamma E^i_{image}) \qquad (1)$$

where $i = i^{th}$ node

α, β, γ =parameters to control the relative influence of the corresponding energy terms.

E_{cont} = the continuity term representing internal forces

A goal of the continuity term is to minimize the distance between the points and keep the points at equal distances. The equation is as follows.

$$E_{cont} = \bar{d} - |v_i - v_{i-1}| \quad (2)$$

where $\bar{d}$ = the average distance between all the points
v_i = the snake node.

E_{curv} is called the smoothness term of the internal force. It enforces smoothness and controls the curvature of the snake nodes. It is expressed as (3).

$$E_{curv} = |v_{i-1} - 2v_i + v_{i+1}|^2 \quad (3)$$

E_{image} is the edge attraction term of the external force. It attracts the snake points toward the target feature of the corresponding image.

$$E_{image} = -\|\nabla I\| \quad (4)$$

where ∇I = the intensity gradient of the image computed at each snake point.

Use of the snake model is intended to minimize the above total energy function. We used the greedy algorithm in snake model for promoting computation efficiency (R. Peteri, 2004).

2.2 Double snake model

The double snake model is composed of two open snakes evolving jointly in order to keep a parallel between them (R. Peteri, 2004). The new energy term $E_{parallel}$ is added to maintain a local parallelism and width between two branches. The total energy function of the double snake model is defined as follows.

$$E_{snake} = \sum_i (\alpha E^i_{cont} + \beta E^i_{curv} + \gamma E^i_{image} + \delta E^i_{parallel}) \quad (5)$$

$$E_{parallel} = \frac{1}{2M+1} \sum_{j=i-M}^{j=i+M} (V_i - V_j) \quad (6)$$

Where, M =number of neighbourhood snake point
V_i =vector between the two branches.

Adding the parallelism condition, each snake point could approximate the target contour while maintaining the parallel option between two polylines.

3. ROAD FEATURE UPDATING METHOD

Our road databases updating methodology consists of pre-processing, seed point generation and road feature updating method. Details of the process are shown below.

3.1 Pre-processing

In this research, we use PCI Geomatics' PANSHARP technique, which was developed by Dr. Zhang to use high spatial resolution multispectral QuickBird imagery (Zhang. Y., 2002). Use of this technique showed significant output in both spatial and spectral resolution. Then, automatic registration of a fused image and topographic digital map is applied using the Boolean operator and modified ICP algorithm (D. Y. Han, 2007).

3.2 Initial seed points generation

In order to apply the snake algorithm, it is necessary to determine initial seed points. Initial seed points are extracted using a pre-existing digital road map. However, the digital road map contained many planar errors due to manual digitizing mistakes. So, a simple line segment matching technique between the image and road feature of the digital map was needed in order to correct global planar errors on the digital map. The PAN-sharpened NIR image was used to input data because it could distinguish between potential road features and other objects. The optimal shifting parameter between NIR edge information extracted by a Canny edge operator and existing road features is calculated by image correlation matching techniques. Then, shifted road polyline is sampled in order to initialize the snake nodes. The sampling rate can vary depending on the image resolution and the length of the corresponding polyline.

3.3 Road feature refinement based on modified double snake

After simple line segment matching, pre-existing road features still have specific digitizing errors and changes. To refine the road feature more exactly, we modified the double snake model. In this paper, two energy terms are added in comparing the original snakes. First, the parallelism energy term is simplified using unit vector. The constraint on parallelism is illustrated in Figure. 1.

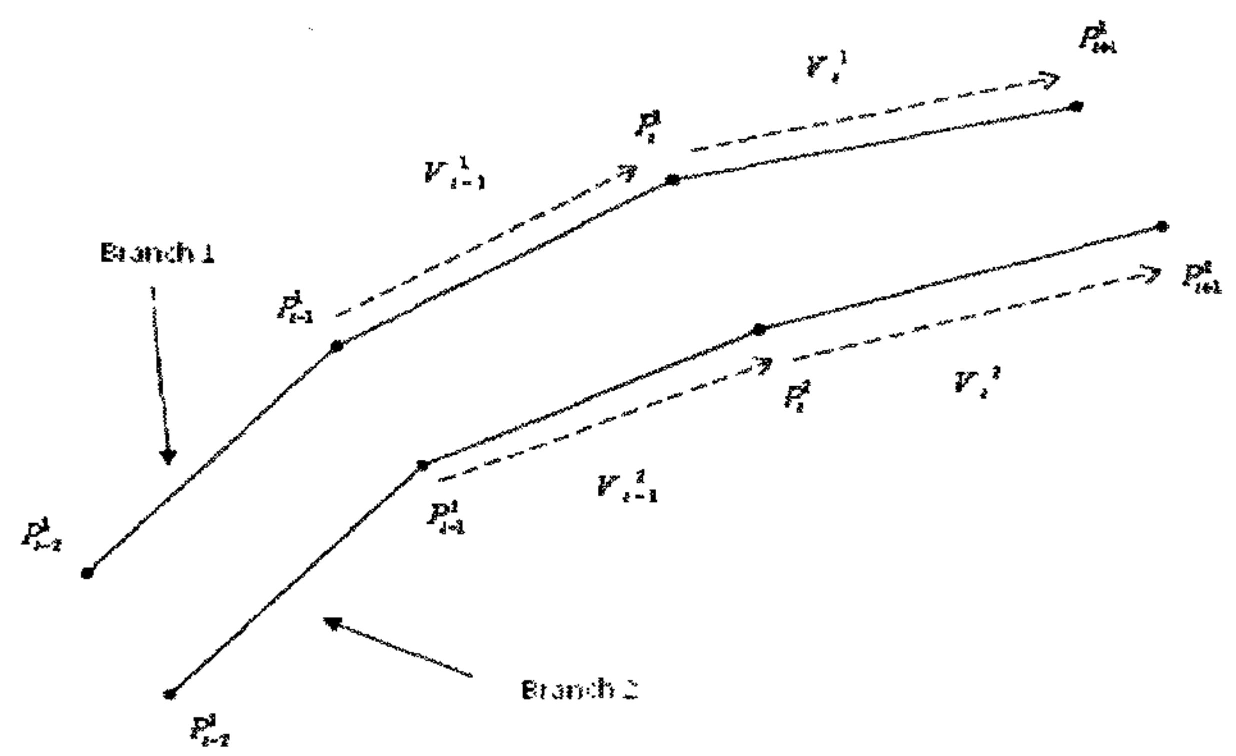

Figure 1. The local parallel term of a unit vector between two branches in the modified snake model

The original double snake used to vector between the two branches such as equation (6), influencing the node's direction and width. However, the original double snake model was less suited to the greedy algorithm in computation efficiency and Keeping the width among the nodes might lead to approximate the contour toward another object's edges around road edge. Therefore, we only used the new parallelism energy term, using unit vector $\overrightarrow{P^1_{i-1}P^i_i}$ to maintain only the relative vector's direction. Then, to preserve local width among the branches, we appended the new spectral information term to a double snake model. The spectral information term is based on the NDVI of the PAN-sharpened satellite image because road area has specific values with comparing another area in spectral characteristics in NIR band. The spectral information based energy term was able to attract snake points toward not another edge in image, but potential road edge. New terms were calculated according to similarity between the potential road pixel and the neighbour pixel in snake point. It has a similar role with comparing pre-existing external forces, but it could make up the external forces in the weak intensity gradient area. The modified energy function is defined as (7)-(9).

$$E_{snake} = \sum_i (\alpha E^i_{cont} + \beta E^i_{curv} + \gamma E^i_{image} + \delta E^i_{parallel} + \varepsilon E^i_{spec}) \quad (7)$$

$$E_{parallel} = \frac{1}{2M+1} \sum_{j=i-M}^{j=i+M} (V_i^1 - V_i^2) \quad (8)$$

$$E_{spec} = \left| \overline{R} - s_i \right|^2 \quad (9)$$

Where, $E_{parallel}$ = new parallelism energy term

E_{spec} = spectral information term

V_i^j = i^{th} unit vector of j^{th} branch

$\overline{R}$ =mean NDVI value of the potential road pixel

s_i =NDVI value of snake point.

4. EXPERIMENTAL RESULT

In order to estimate the performance of the proposed road updating method, a 1:5,000 digital map and QuickBird high-resolution satellite image datasets were selected. QuickBird images were acquired on 25 May 2006. The site was located in Daejeon, Korea, which included various land-cover types such as those in Figure 2.

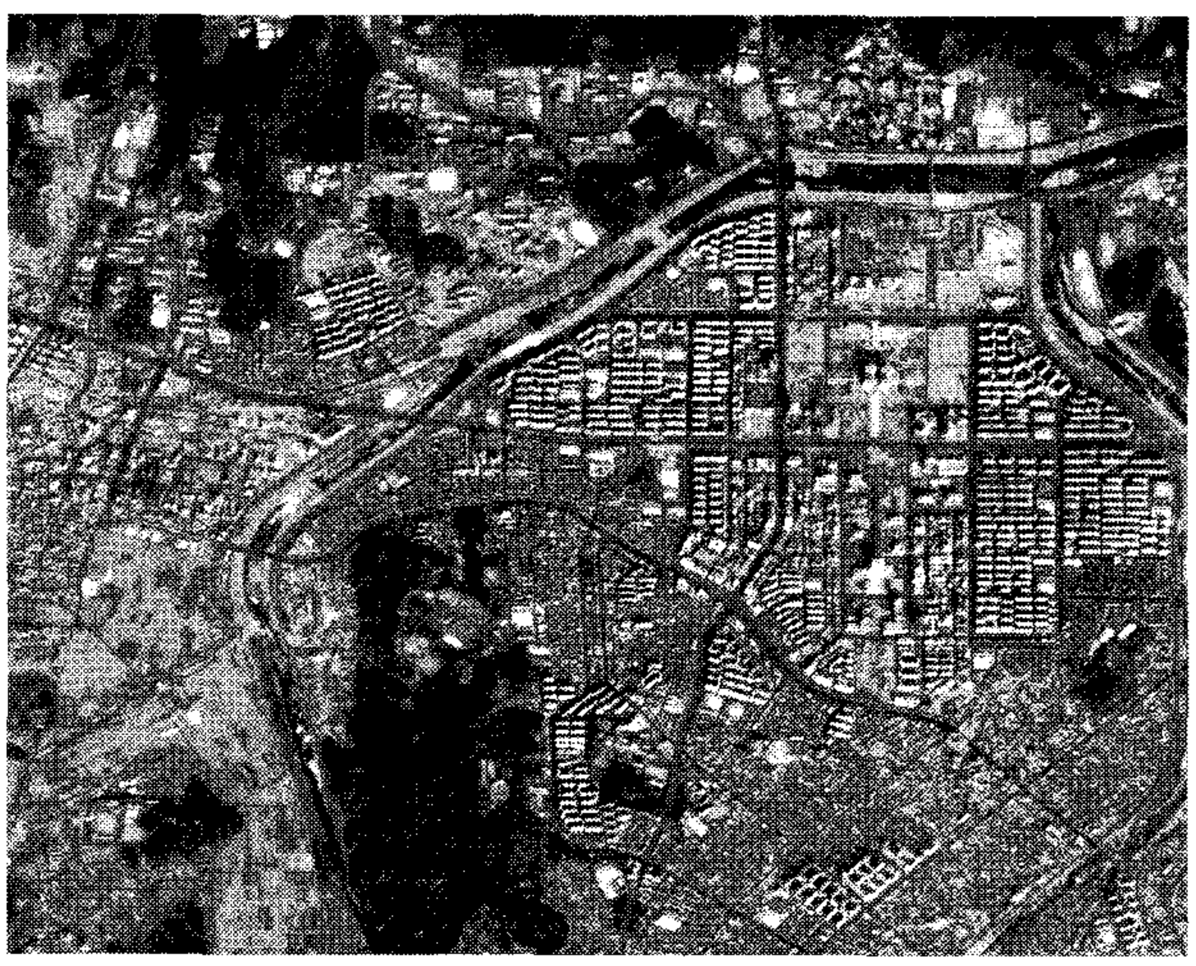

Figure 2. Test area

In applying the modified double snake model, we used the Luminance image of RGB color image to enhance the edge information. Figures 3 and 4 are the digital road map and the updated road networks overlapped with the original images.

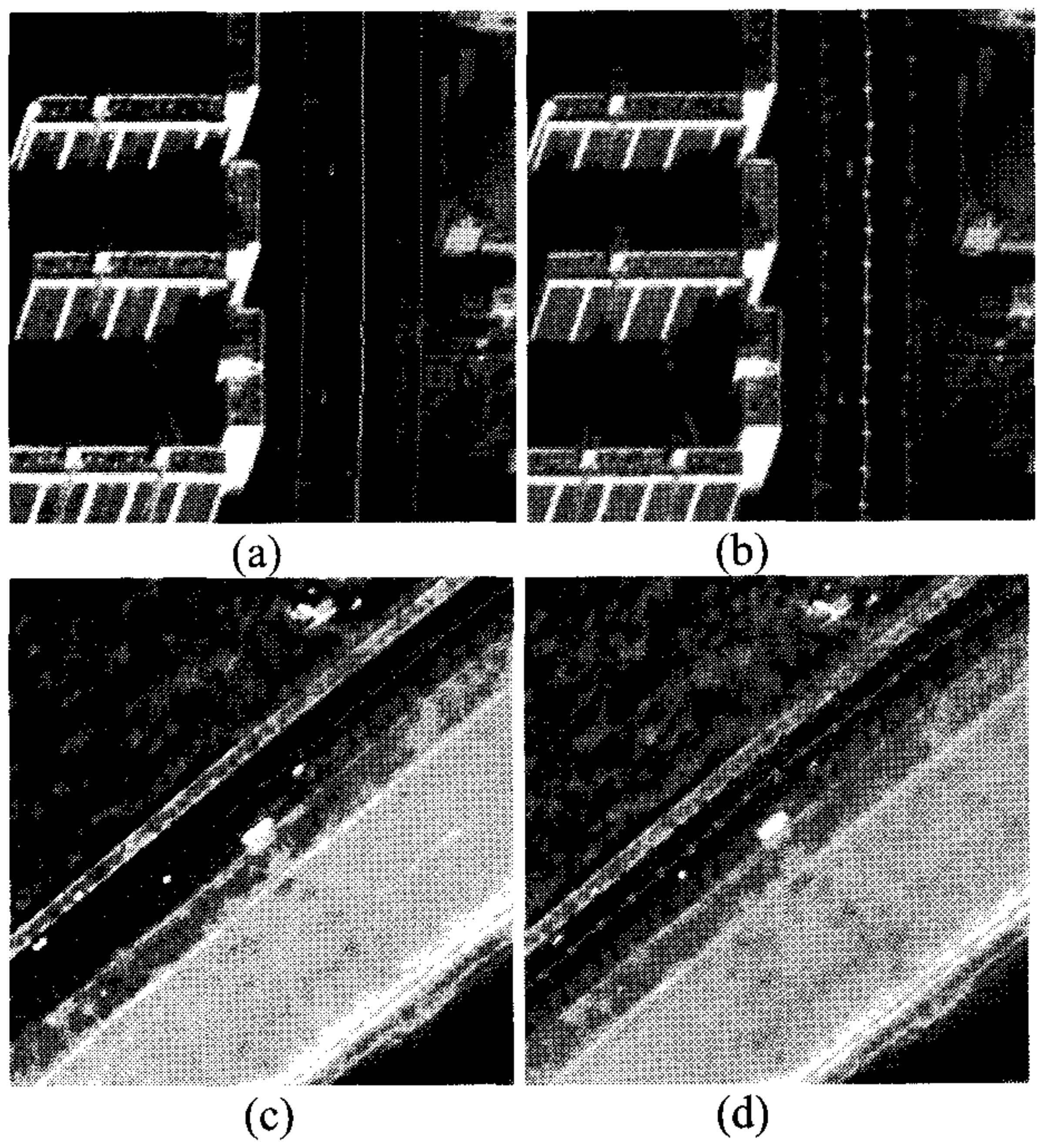

Figure 3. Results of road feature updating

(a), (c): initial road feature and (b), (d): updated road feature

These results indicate that the updated road networks are well matched in the satellite image. Visually, the results are very close to the roads on the original image. Many initial road networks had a road width error and digitizing error due to street edges, but our algorithm detect and revise road error and change. However, some nodes in the results (Figure 4) showed an incorrect position because of shadows and geometric noises, such as from trees or cars. This will need to be corrected in the future.

5. CONCLUSION

In this paper, we developed a road features updating method using vector maps from multispectral high-resolution satellite images. Initial seed points for snake model were generated using line segment matching. And then, the modified double snake algorithm was applied to refine the road networks update. The accuracy of the updated road network was estimated visually. From the visual evaluation, our output was close to the road edge on the high resolution image. In the future, experiments about the various sites will be undertaken. The optimal parameter selection and some incorrect nodes also need to be corrected in future.

References

C. Zhang, 2004, Towards an operational system for automated updating of road databases by integration of imagery and geodata, ISPRS Journal of Photogrammetry & Remote Sensing, 58, pp. 166-186.

D. Y. Han, H. J. Kim, and Y. I. Kim, 2003, Automatic registration of QuickBird Image and digital map, Conference on KSRS, 2007.

G. Koutaki, K. Uchimura, and Z. Hu, 2004, Road updating from high resolution aerial imagery using road intersection model, ISPRS conference, Pitsanulok, Thailand.

I. Laptev, H. Mayer, T. Lindeberg, W. Eckstein, and C. Steger, A. Baumgartner, Automatic extraction of roads from aerial images based on scale space and snakes, Machine Vision and Applications, 12, pp. 23-31.

Kass, M., Witkin A,and Terzopoulos D, 1987, Snakes: active contour models, International Journal of Computer Vision, 1(4), pp.321-331.

P. Agouris and S. Gyftakis, 2001, Differential snakes for change detection in road segments, PE&RS, 67(12), pp. 1391-1399.

Q. Zhang and Couloigner, I., 2003, Automatic road change detection and GIS updating from high spatial remotely-sensed imagery, 2003 Asia GIS Conference.

R. Peteri and T.Ranchin, 2003, Multiresolution snakes for urban road extraction from Ikonos and Quickbird images, in 23nd EARSeL Annual Symposium "Remote Sensing in Transition", Ghent, Belgium, 2-5 June.

X. Niu, 2006, A geometric active contour model for highway extraction, ASPRS 2006 Annual Conference, Reno, Nevada, May 1-5.

Zhang. Y., 2002, A new automatic approach for effectively fusing Landsat 7 images and IKONOS images, IEEE/IGARSS 2002, Toronto, Canada, June 24-28.

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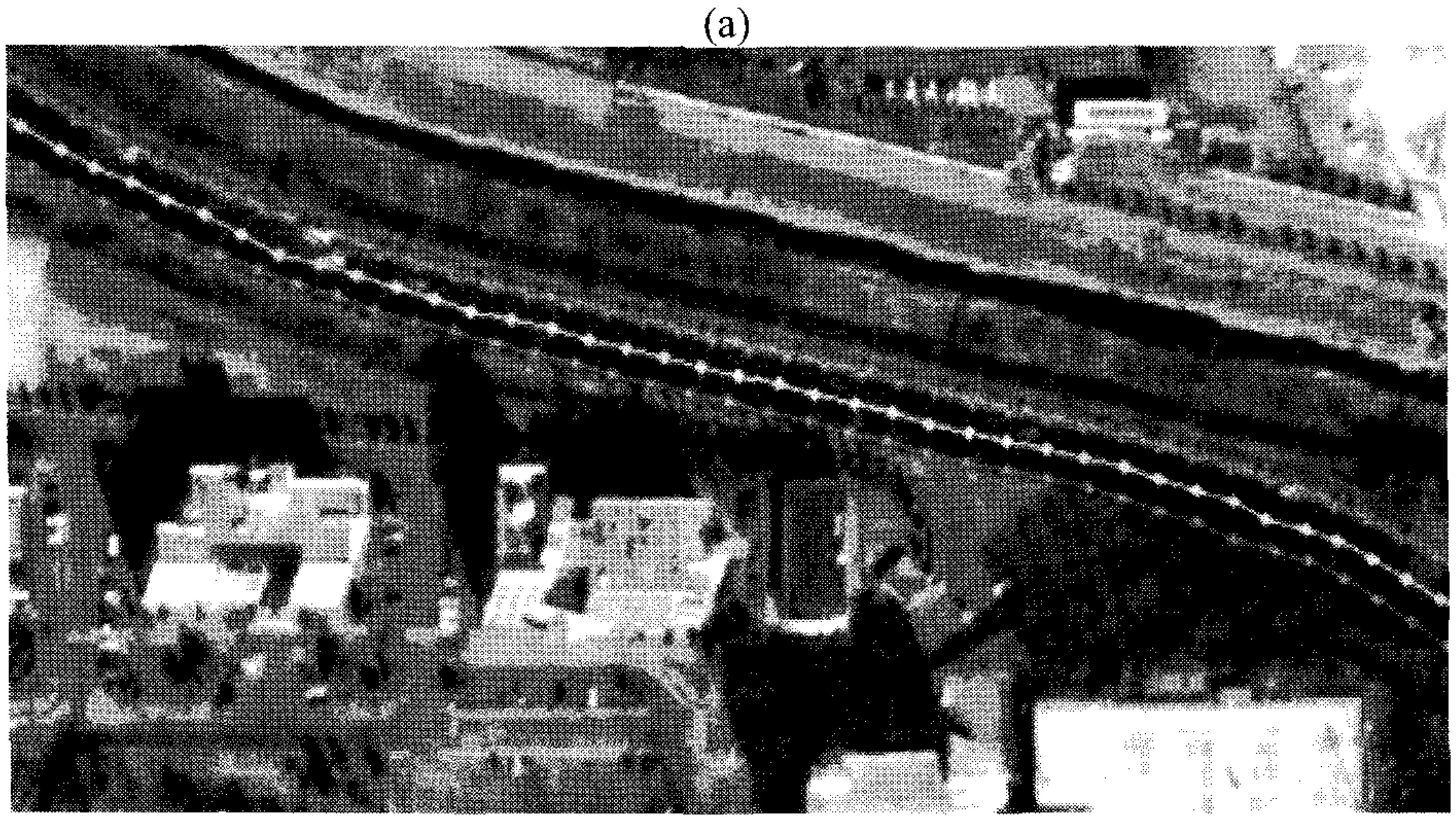
(a)



(b)

Figure 4. Results of road feature updating
(a): initial road feature and (b): updated road feature