Road Extraction Using Stationary Wavelet Transform

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Abstract—In this paper, a novel road extraction method using Stationary Wavelet Transform is proposed. To detect road features from color aerial satellite imagery, Mexican hat Wavelet filters are used by applying the Stationary Wavelet Transform in a multiresolution, multi-scale, sense and forming the products of Wavelet coefficients at a different scales to locate and identify road features at a few scales. In addition, the shifting of road features locations is considered through multiple scales for robust road extraction in the asymmetry road feature profiles. From the experimental results, the proposed method leads to a useful technique to form the basis of road feature extraction. Also, the method is general and can be applied to other features in imagery.

Keywords—Road extraction, Multiresolution, Stationary Wavelet Transform, Multi-scale analysis.

I. INTRODUCTION

THE road extraction is an important part to identify linear or road features in an image. In recent years, the study of automatic or semiautomatic of road extraction methods from satellite image is becoming more and more important. In the past few years, many approaches have been developed to deal with road extraction [1]-[3]. Since road features can be seen as a linear feature, many researchers use filters that have small masks to detect lines in an image. However, the choice of the size of the masks is important because the optimal mask size varies with the image. In general, the smaller masks are sensitive to noise and suffer from excessive unwanted line fragments whereas the larger masks cannot resolve fine detail [4], [5]. A useful and convenient way to select only the salient lines is the magnitude of the second derivative of line profile in the point where the first derivative of line profile equal zero [6]. In fact, a line having the same contrast on both sides is not realistic. Therefore, line position can be misplaced from the true position. To overcome this drawback, this paper is emphasizing road detection based on a multiresolution approach using the Stationary Wavelet Transform.

When an image is examined for intensity variations, several scales generally are of interest. The detection of certain feature in an image is optimal at a certain scale. This scale depends on the characteristic scale contained in the object to be detected. Therefore, it is necessary to perform and combine information of road features at multiple scales. Since the Stationary Wavelet Transform (SWT) is clearly related to multi-scale analysis, the SWT could play an important role in multi-scale road detection [7]. Virtually, the fine scale of the SWT gives detailed information, whereas the coarse scale adds global information. To perform and combine information at multiple scales, it can improve the robustness of road detection.

In this paper, a road detection method using a multiresolution approach by forming the products of Wavelet coefficients at a few scales to locate and identify road features. In addition, a shifting road locations through multiple scales is also considered for robust road detection in the asymmetry line profile.

The paper is organized as follows. Section II provides the effect of asymmetry line profiles. In Section III, the methodology of proposed approach is provided. Section IV gives some experimental results to demonstrate the effectiveness of the proposed method compared with the performance of other existing methods applied on a number of test images. Finally, concluding remarks are given in Section V.

II. EFFECT OF ASYMMETRY LINE PROFILES

A line has an intrinsic length-scale, its width. Considering a symmetric line of width w and height h,

$$f(x)symmetric = \begin{cases} 0\,, |x| > w \\ h\,, |x| \leq w \end{cases} \qquad (1)$$

In the fact that a line has the same contrast on both sides is not realistic. Therefore, an asymmetric line must be considered,

$$f(x)asymetric = \begin{cases} 0\,, x > w \\ 1\,, |x| \leq w \\ a\,, |x| < -w \end{cases} \qquad (2)$$

The Mexican hat Wavelet filter corresponding to the second derivative of the Gaussain is used for line or road feature detection. Here, concentrating on how the detected line position can be misplaced from the true position. In other words, how the correlation height of an asymmetric line profile may shift with increasing value of a where a [0,1]. To show how the correlation height may shift when the value of a increases, the correlation between the Mexican hat wavelet filter and an asymmetric line profile are performed. In the discrete case, suppose that line is an impulse, zero on one side, a on the other. For no shift case, the correlation height between the Mexican hat wavelet filter and an asymmetric line profile is given as,

$$Cw = \sum_{i=-\left(\frac{w-1}{2}\right)}^{i=\left(\frac{w-1}{2}\right)} Gj(i) + \left(a * \sum_{i=\left(\frac{w+1}{2}\right)}^{i=\left(\frac{N-1}{2}\right)} Gj(i)\right) \qquad (3)$$

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where w is the width of line profile and Gj is the Mexican hat wavelet filter at scale j.

For m shifts case, it can be written the correlation height between the Mexican hat wavelet filter and an asymmetric line profile shown as,

$$Cw = \sum_{i=-\left(\frac{w-1}{2}\right)-m}^{i=\left(\frac{w-1}{2}\right)+m} Gj(i) + \left(a * \sum_{i=\left(\frac{w+1}{2}\right)-m}^{i=\left(\frac{N-1}{2}\right)} Gj(i)\right) \qquad (4)$$

where w is the width of line profile, m is a number of shift and Gj is the Mexican hat wavelet filter at scale j

To find the maximum correlation response of a line that can be shifted to the left and right up to two pixels, Fig. 2 shows the maximum correlation height response of a line, 1 pixel wide, at the different value of a from 0 to 0.9 in the Mexican hat wavelet filter at the second scale. The result shows that line is shifted away from the proper location.

III. METHODOLOGY

In Fig. 2, considering lines that shift up to two pixels between the Wavelet Transform of two scales b$_1$ and b$_2$, it can be gotten five products, b_1b_2, b_1b_{2R1}, b_1b_{2R2}, b_1b_{2L1} and b_1b_{2L2}, where b_{2R2} and b_{2L2} refer to shifts of b_2 to the right and left by two locations, respectively. The proposed approach, the product with shift method on the Wavelet Transform at scales one and two, b$_1$ and b$_2$ to identify the road location is formed [7].

The block diagram of proposed algorithm is illustrated in Fig. 1. In order to avoid the misrepresentation in each subimage and make the size of each subband same as original, the Stationary Wavelet Transform, Mexican hat filters, is applied levels one and two to original image in both vertical (V1-V2) and horizontal (H1-H2) directions, separately. Then, the different scales are merged by using the product with shift method and labeled the results as Wcv and Wch, followed by thresholding to get the binary images (Wh and Wv). Then, we form the product with the Wavelet coefficients at the first scale to get the directional line images in both vertical and horizontal images (Mv and Mh). Finally, the modulus sum, M(x,y), of Mv and Mh is used for the final result.

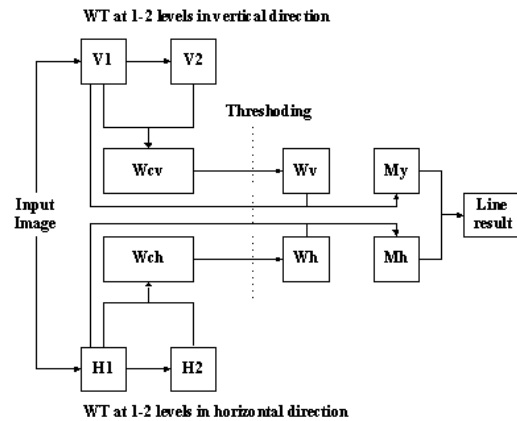$$M(x, y) = \sqrt{[Wh * b1h]^2 + [Wv * b1v]^2} \qquad (5)$$

Fig. 1 Block diagram of the line detection algorithm

IV. EXPERIMENTS

The main purpose of the experiments is to test the performance of the proposed approach using the combination o f Wavelet coefficients at a few scales by comparing with the results using only one resolution or scale. The two satellite color images, road1 and road2, are used. Firstly, both two color images, RGB model, are transformed to YIQ model where Y is the luminance, corresponding to roughly with intensity, are applied with the Wavelet filters at the first scale and compared the results with the multiple scales. In addition, a binary circle image is also tested. From these results, Fig. 3, it can be seen that the combination of the wavelet coefficients at a few scales provided the better performance results when comparing with single scale.

V. CONCLUSION

In this work, a road feature extraction method using Wavelet filters is presented. In addition, the shifting line location is considered through multiple scales for robust road detection in the asymmetry line profile. It is found that the proposed approach leads to a useful method to form the basis of road feature extraction approach. Also, the method is general and can be applied to other features in imagery.
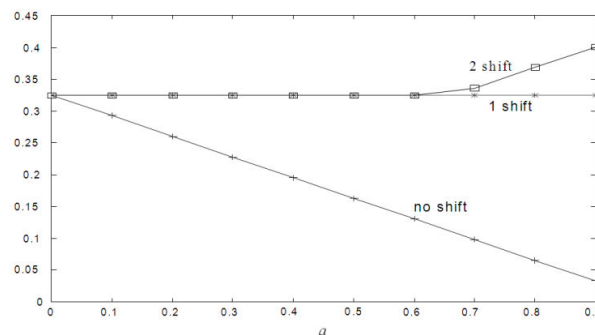

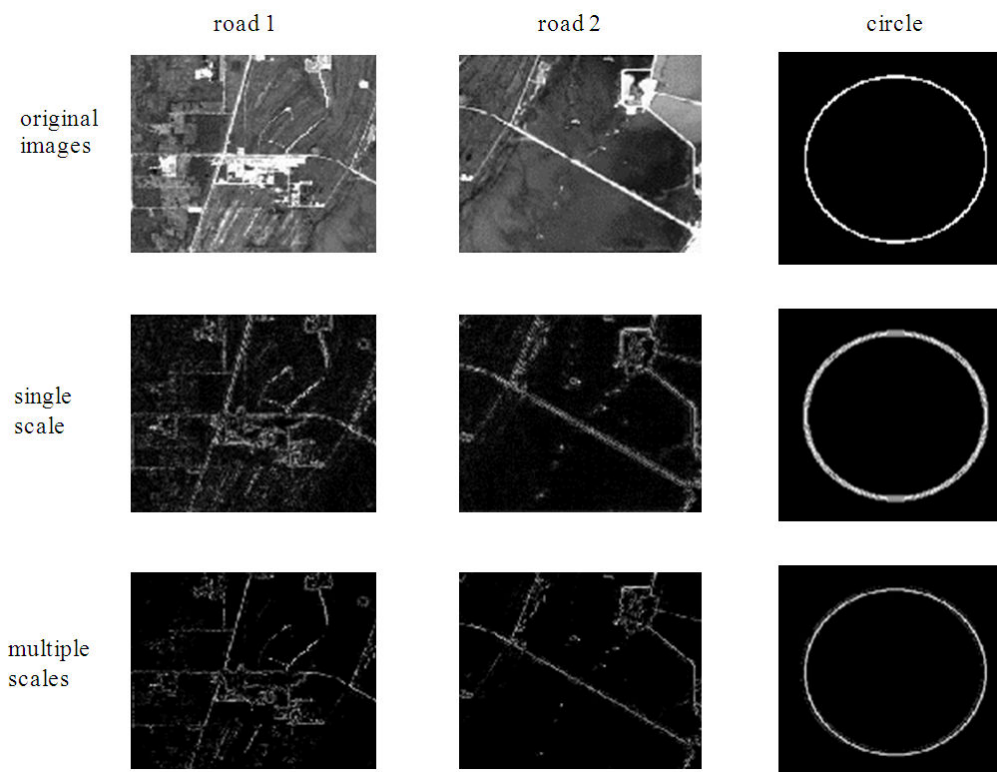Fig. 2 Maximum correlation response of road 1 pixel wide at the second scale when a increasing

Fig. 3 Experiment results of line detection using single scale and multiple scales

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