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Somkait Udomhunsakul
Samuel Peter Kozaitis
U. Sritheeravirojana

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S. Udomhunsakul[a], S. P. Kozaitis[b], and U. Sritheeravirojana[a]
[a]King Mongkut's Institute of Technology Ladkrabang
Faculty of Engineering, Information Engineering Dept., Bangkok 10520, Thailand
[b]Florida Institute of Technology, ECE Dept.
150 W.University Blvd. Melbourne, FL 32901 USA.

ABSTRACT

In this work, we proposed a method to detect roads in aerial imagery. In our approach, we applied the wavelet transform in a multiresolution sense by forming the products of wavelet coefficients at the different scales to locate and identify roads. After detecting possible road pixels, we used a graph searching algorithm to identify roads. We found that our approach leads to an effective method to form the basis of a road extraction approach.

Keywords: wavelet transform, road detection, multiresolution, graph searching

1. INTRODUCTION

Linear feature extraction from aerial or satellite images has been an active and important area in the field of computer vision over the past two decades. There are various kinds of features that can be extracted from aerial imagery, such as roads, forests, buildings, lakes, rivers, etc. Automatic road extraction from aerial imagery has received considerable attention because it is very useful in many applications, especially in geographical information systems (GIS), remote sensing and photogrammetry.

In the part twenty years, many researchers have studied and developed to deal with the detection of roads in aerial or satellite images. For instance, Fischler presented two types of detectors-type (1), few false alarms, and type (2), few false detection, where their results are combined and applying F* algorithm. The shortest path of road seed candidates is linked by using a dynamic programming algorithm.[1] An optimal convolution filter, constructed by Petrou, is used to identify roads and threshold line segments where smaller than a prespecified size are removed for road detection.[2] Tupin presented two local line detectors and a method to combine the information from these detectors to get road segments. They identified the real roads by using a Markov random field (MRF) on a set of segments.[3]

When an image is examined for intensity variations, several scales generally are of interest. Virtually, real images may contain roads of widely varying width. In addition, 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. Optimal processing of an image thus requires the representation of an image at different scales. In order to detect roads in an image, it is necessary to perform and combine information of road detection at multiple scales. Since the WT is clearly related to multi-scale analysis, the WT could play an important role in multi-scale road detection. Practically, the fine scale of the WT 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 our approach, we develop a road detection method for use with aerial imagery using a multiresolution approach by forming the products of wavelet coefficients on different scales to locate and identify roads. After detecting possible road pixels, we used a graph searching algorithm to identify roads.

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2.WAVELET TRANSFORM

The wavelet transform has become a powerful and remarkable tool, which is used for handling fundamental problems in science and engineering. It is an alternative way to represent a signal when compared to the Fourier transform. Instead of transforming a pure time description into a pure frequency description, it is carried out to represent a signal in the term of time frequency. Wavelets are obtained from a single prototype wavelet, called mother wavelet $w_{jk}(t)$, by dilations (scaling) and translation (shifts). The parameter a corresponds to the scale while b is the shift parameter.[4,5]

$$w_{jk}(t) = \frac{1}{\sqrt{a}} w\left(\frac{t-b}{a}\right) \tag{1}$$

The analysis function of forward transform continuous wavelet transform is defined by the integral where b_{jk} are the wavelet coefficients, j and k are real number refer to the scale and shift of the mother wavelet $w_{jk}(t)$.

$$b_{jk} = \int_0^{\alpha} f(t) w_{jk}(t) dt \tag{2}$$

In the discrete case, we take the discrete values of the scale parameter a and the shift parameter b in a different way. The basis function is shrunk by a factor of two, dyadic sampling, at each increasing scale where we take parameter a to be the form of 2^{-j} and b to be the form of $k2^{-j}$. So, we can written in discrete case as,[6]

$$W_{jk}(t) = 2^{j/2}\, w_{jk}(2^{j} t - k) \tag{3}$$

3.WAVELET ROAD DETECTION

We used the Mexican hat wavelet that corresponds to the second derivative of the Gaussain. In our approach, we found the relationship between road width and scale to determine what scale we need for a maximum response for a road profile for different pixels widths. The maximum convolution height response of roads in each scale is used to determine what scales we use for each road profile.

As we mentioned before, real images may contain roads of widely varying width. Therefore, it is necessary to perform and combine information of road detection at multiple scales. The multiple scales do we use to detect a road depended on the threshold dependent where we threshold the results at different scales. For example, we set the threshold at T=70% and 50% of the max convolution for different width roads at a particular scale. We found which scales are greater than the threshold shown in table 1. The number of scales to be used to from the product is based on table 2. For instance, when a user specifies the threshold at 70% and the range of road widths to be detected is from 2 to 6 pixels wide, according to table 2, the algorithm will form the product of scale 1 to 2, 1 to 3, and scale 2 to 3. Then, summing the results to get the road pixel image.

Road width	T=70%	T=50%	Possible scales to use (max at scale 4)
1	scale 1	-	scale 1
2	scale 1,2	-	scale 1 to 2
3	scale 1,2	scale 1,2,3	scale 1 to 2 or 1 to 3
4	scale 2	scale 1,2,3	scale 1 to 3
5	scale 2,3	-	scale 2 to 3
6	scale 2,3	scale 2,3,4	scale 2 to 3 or 2 to 4
7	scale 2,3	scale 2,3,4	scale 2 to 3 or 2 to 4
8	scale 3,4	scale 2,3,4	scale 2 to 3 or 2 to 4
9	scale 3,4	-	scale 3 to 4
10	scale 3,4	-	scale 3 to 4
11	scale 3,4	scale 3,4,5	scale 3 to 4
12	scale 3,4	scale 3,4,5	scale 3 to 4
13	scale 3,4	scale 3,4,5	scale 3 to 4
14	scale 3,4	scale 3,4,5	scale 3 to 4
15	scale 3,4	scale 3,4,5	scale 3 to 4
16	scale 4,5	scale 3,4,5	scale 3 to 4
17	scale 4,5	scale 4,5	scale 4

Table 1 Scales to be used for each road profiles

Road size	scales to be used for threshold at 70%	scales to be used for threshold at 50%
1-2	1to2	-
1-4	1to2, 1to3	1to3
2-6	1to2, 1to3, 2to3	1to3, 2to4
2-8	1to2, 1to3, 2to3, 3to4	1to3, 2to4
3-10	1to2, 1to3, 2to3, 3to4	1to3, 2to4
3-12	1to2, 1to3, 2to3, 3to4	1to3, 2to4, 3to4
4-14	1to3, 2to3, 3to4	1to3, 2to4, 3to4
4-16	2to3, 3to4	1to3, 2to4, 3to4

Table 2 Scales to be used in each input road size and threshold dependent

To form the product in each scale using the alternative product with shift method[7], we consider initially finding the result of two scales, then combining the result with each additional scale, one scale at a time. For example, considering wavelet coefficients at scale b_1, b_2 and b_3, we initially formed the product with shift method on the two largest scales, b_2 and b_3. Then, we combined the result with b_1 using the product with shift method.

The block diagram of our algorithm is illustrated in Figure 1. First, we applied the wavelet transform to the levels 1-4 of the original image in both vertical(V1-V4) and horizontal(H1-H4) directions separately. In order to avoid the misrepresentation in each subimage and make the size of each subband same as original, we did not use downsampling. Then, we have to merge the different scales by using alternative product with shift method and labeled the results as Wcv and Wch, followed by thresholding to get the binary images (Wh and Wv).

We then form the product with the wavelet coefficients at the first scale to get the directional road 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.

$$M(x,y) = \left(|w_h b_{1h}|^2 + |w_v b_{1v}|^2 \right)^{1/2} \quad (4)$$

4.ROAD LINKING

Some experiment results of road detection using our road detection approach are shown on figure 2. We focus on low resolution aerial image, figure 2(a), where a road is a few pixels wide. We set the parameter of the road size and threshold value equal to 1-4 and 70% respectively. The algorithm used the product of scale 1 to 2 and 1 to 3 and sums all the results to get the road pixel image, 2(b). Now we focus on high resolution aerial images, figure 2(c). We set the parameter of the road size and threshold value equal to 3-12 and 70% respectively. The algorithm used the product of scale 1 to 2, 1 to 3, 2 to 3 and 3 to 4 and sums all the results to get the road pixel image, 2(d).

After detecting possible road pixels by using our approach, we used a graph searching algorithm to identify roads.[8] To create complete road network, a user selects a start and stop point with a mouse and the road is found between these two pixels. The experiment of road detection result is shown in Figure 3.

5.CONCLUSION

In this paper, we proposed a wavelet-based method for road detection from aerial images. We found that our approach leads to an effective method to form the basis of a road extraction approach.

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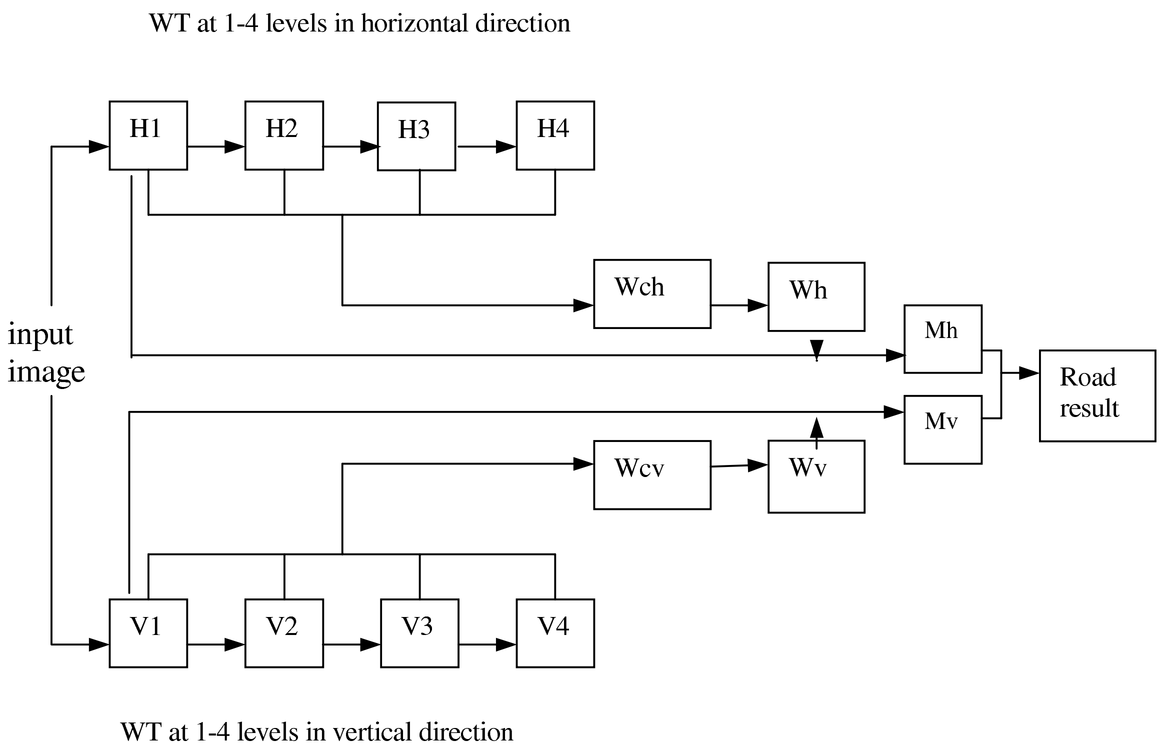

Figure 1 Block diagram of the road detection algorithm

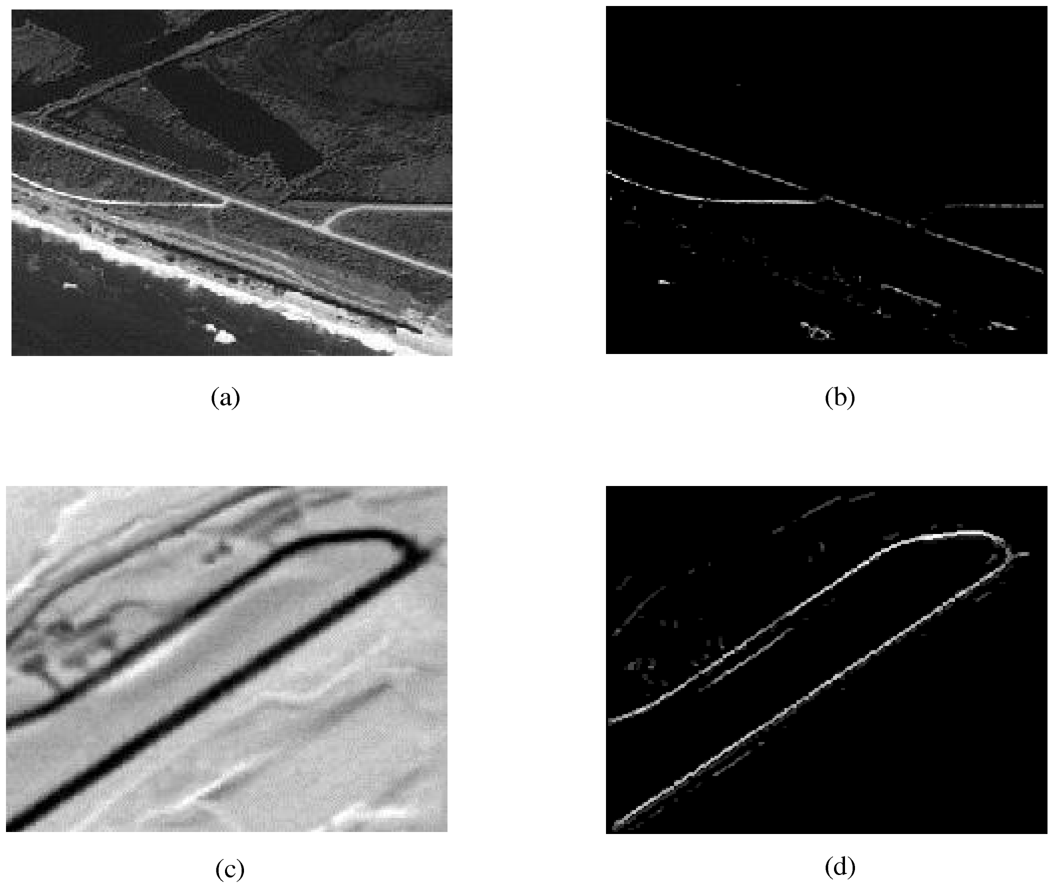

Figure 2 Results of experiments (a) original image (b) road detection using our approach (c) original image (d) road detection using our approach

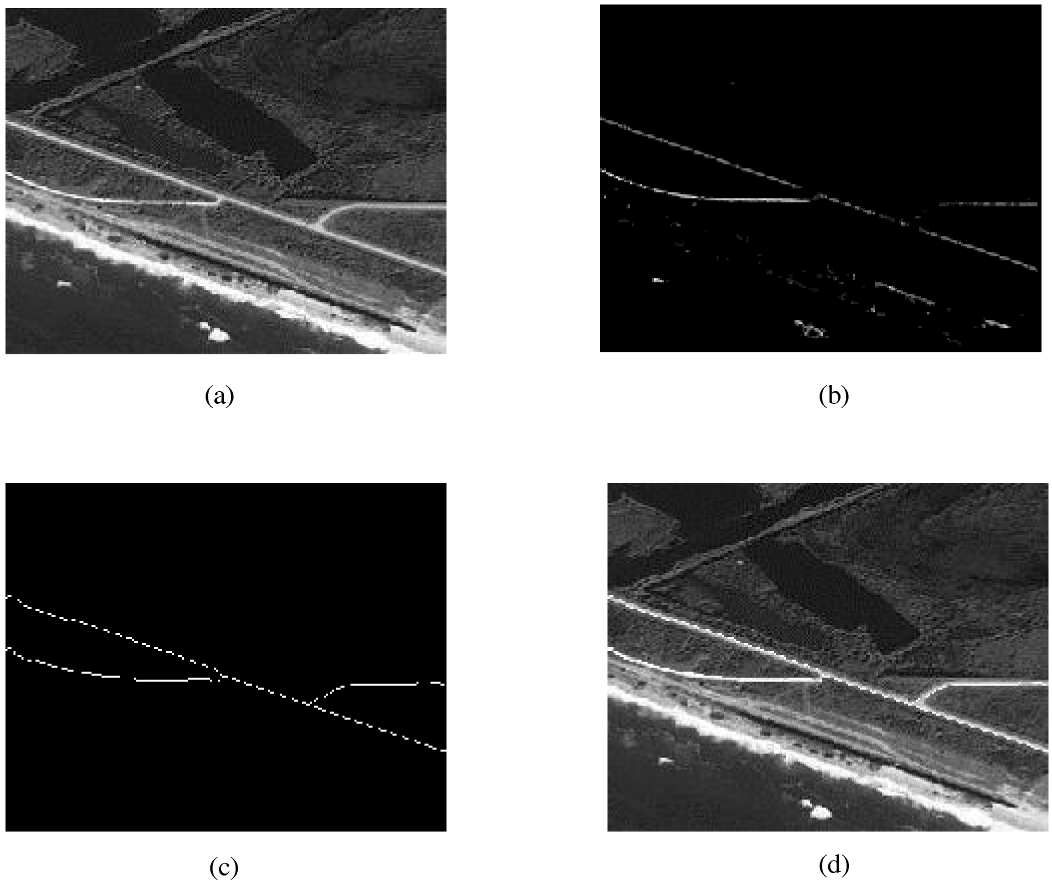

Figure 3 Results of experiments (a) original image (b) road detection using our approach (c) final result after using graph searching algorithm (d) superimpose result.