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A Method of Color Dodging for Scanned Topographic Maps

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Abstract

Scanned topographic maps of cities may have uneven illumination and creases. They need to go through color dodging. Due to the unsatisfying result by homomorphic filter of Retinex theory and the low efficiency when color dodging, this paper proposes an improved color dodging for scanned topographic maps based on Retinal-cortex theory. The main idea is to introduce Fastest Fourier Transform In The West (FFTW) to get the illumination component of the image on the basis of homomorphic filter of the Retinal-cortex algorithm, and use homomorphic filter to get the reflectance component and get the final image by linear stretching treatment. Experiments have proved that this method keeps the details of the image while erasing the creases so that the brightness distribution is improved.

Keywords: *Scanned topographic maps, Homomorphic filter, Retinex, FFTW, Color Dodging*

1. Introduction

Cities are changing. To improve the overall arrangement of the city, it is significant to refer to historical topographic maps that are kept in hard copies. However, as these hard copies are scanned to electronic maps, there is unavoidably uneven illumination and creases, which make the image of low quality. Thus, how to dodge these grayscales of vast amount becomes an urgent problem.

Currently, one of the representative ways of color dodging is by imitating the brightness distribution of the image by mathematical models and compensate for different part of the image. For example, the color balances function in ERDAS IMAGINE 9.1 to dodge the remote sensing image. Wang Mi and some others [1-3] probe into MASK dodging method that is applied to digital aviation image and propose specific process and steps. E. H. Land and some others [4, 5] propose and develop the Retinex theory, and apply it to tone reproduction of color image. To quickly color dodge the scanned maps of vast amount, this paper proposes an improved dodging method based on homomorphic filter by making comparison between the conventional Retinex dodging method and the new one. This method discards the conventional way of template convolution to get brightness component, but adopts FFTW algorithm for the frequency domain of Gaussian filter of single scale theory through which convolution is replaced by product operation of frequency domain. Results show that the optimized method increases the efficiency of algorithm while guaranteeing the dodging effect.

This paper consists of several sections:

1 Introduction of the realistic significance of the study and a general analysis;

2 Introduction of classical SSR-related theory;

3 Optimized method of homomorphic filter based on SSR theory;

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4 Experiment and analysis;

5. Conclusions.

2. Retinex Theory and Single Scale Retinex Theory

2.1. Retinex Theory

Retinex theory [4, 5] is a representative of algorithm theory of color constancy. Its full name is Retrinex-cortex theory proposed by Land in 1970s. Retinex theory holds that the color of the object felt by human being is closely related to reflectance properties rather than spectral characteristics that caught by human eyes. Based on the simple model, an image can be expressed as:

$$I(x,y) = S(x,y) * R(x,y) \qquad (1)$$

(*x*,*y*) is the coordinate of a pixel. *S* refers to brightness. *R* refers to reflectance property. *I* refer to reflection light which is caught by the sensor to form an image. Due to the influence of the atmosphere, *S* changes variably with different conditions. Based on Retinex theory, *R* influences more on *I* than on *S*. If we can estimate *S* from *I* and remove *S*, we will revive a clear image without considering changes of the brightness. This is what the Retinex theory is trying to do. If *R* refers to reflection property of hard copy topographic maps to the scanner light source and *S* refers to integrated influence of the atmosphere on the scanner light source, formula (1) shall be used to describe the imaging process of the infrared image.

Since the Retinex theory E. H. Land, J. Frankle, J. McCann, D. J. Jobson have proposed and developed Retinex algorithm [4-6] from difference perspectives. The latest version is single scale Retinex (SSR) algorithm proposed by Jobson and the multi scale Retinex (MAR) algorithm based on the former. This paper mainly adopts homomorphic filter based on SSR algorithm to dodge the scanned images.

2.2. Homomorphic filter based on SSR algorithm

Homomorphic filter based on SSR algorithm holds that the reflective image has details of high frequency while illumination image regards it as spacesmoothing. This method uses single-direction convolution and can be expressed by the following mathematic model in (2). *i* refers to No. *i* channel of the image.

$$R_i(x,y) = \log I_i(x,y) - \log[G(x,y) * I_i(x,y)] \qquad (2)$$

As this paper deals with grayscale, fomula (2) can be simplified to (3):

$$R(x,y) = \log I(x,y) - \log[G(x,y) * I(x,y)] \qquad (3)$$

R(x,y) refers to reflective image. *I(x,y)* refers to pending image."*" refers to convolution. The result of *G(x,y)*I(x,y)* is illumination image. *G(x,y)* refers to Gaussian template convolution function, as shown in (4) .

$$G(x,y) = \lambda \exp\left[-\frac{x^2+y^2}{c^2}\right] \qquad (4)$$

λ is a normalization constant.*c* is a surrounded scale factor. *G(x,y)* is adaptive to:

$$\iint G(x,y)dxdy = 1 \qquad (5)$$

Thus, the effect of SSR largely rests upon *c*.

The process of dodging of homomorphic filter based on SSR is as Figure 1:

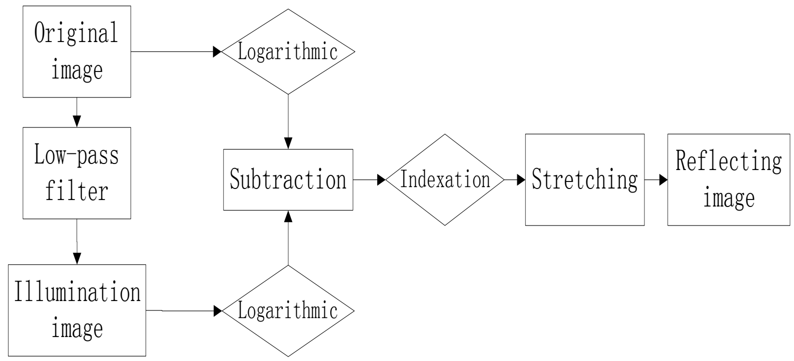


Figure 1. The Process of Dodging of Homomorphic Filter based on SSR

3 Optimizing Homomorphic Filter Algorithm

3.1. Generation of Illumination Image

Generation of illumination image is a key step of color dodging, whose quality would affect the effect of the final result of the removal. Given that the uneven brightness and the contrast distribution are irregular and hard to describe with a mathematic model, this paper will use Gaussian filter to get the image as illumination image and reflect changes of brightness.

In formula (4), it is clear that c determines the scope of convolution. The bigger *c* is, the wider the scope of the convolution and the greater the influence of the surroundings when calculating a pixel, and as a result, the better the overall effect will be. Otherwise, the image may appear to be sharp in details. When *c*is small, the detailed part of the image is apparent, and then a wide range of part can be compressed. When *c* is large, the details are not enough, but the whole effect will be natural. Thus, how to select a proper *c* becomes the problem and here introduces convolution and its related theory, that is, replace the convolution of space domain by product operation of frequency domain. FFT (Fastest Fourier Transform)is an effective way of replacing space domain by frequency domain but in a low efficiency. Thus, FFTW (Fastest Fourier Transform in the West) developed by Laboratory for Computer Science supercomputing technology group of MIT is encouraged.

The mathematic model is as follows:

$$S(x,y) = G(x,y) * I(x,y) \quad (6)$$

$$S(x,y) = FFTW^{-1}\{(-1)^{(x+y)} G(x,y) I^{'}(x,y)\} \quad (7)$$

$$I^{'}(x,y) = FFTW\{(-1)^{(x+y)} I(x,y)\} \quad (8)$$

In formula (6), *I(x,y)* refers to brightness value of the image. *S(x,y)* is the illumination image. In formula (7), $(-1)^{(x+y)}$refers to adverse operation of centralization of frequency domain, that is, to move the original point from the center of the image to the upper left of the space domain. *G(x,y)* refers to Gaussian filter, as in formula (9). The image of filters is shown in Figure 2. *I'(x,y)*refers to intermediate value of the process. $FFTW^{-1}$ refers to the adverse operation of FFTW. In formula (8), FFTW refers to that it is changing and $(-1)^{(x+y)}$ refers to centralization of frequency domain, that is, to move the original point from the upper left of the image to the center.

$$G(x,y) = e^{-D^2(x,y)/2D_0^2} \quad (9)$$

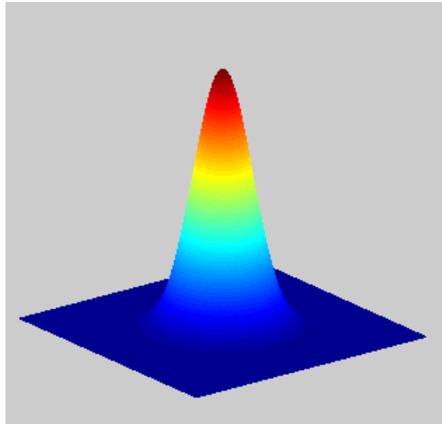


Figure 2. Gaussian Filter

3.2. Stretching Method of the Result Image

The image treated by the abovementioned method usually has low contrast and brightness. To increase contrast between neighboring details and the overall contrast, it is necessary to stretch the result image. Linear contrast stretching is a simple and efficient way, that is, to stretch the grayscale image from both ends. (10) is for scanned topographic maps.

$$I_{out} = \begin{cases} 0 & I_{in} \leq I_{low} \\ \dfrac{I_{in} - I_{low}}{I_{hi} - I_{low}} d_{max} & I_{low} < I_{in} < I_{hi} \\ d_{max} & I_{in} \geq I_{low} \end{cases} \qquad (10)$$

In (10), I_{in} and I_{out} are input and output respectively. d_{max}refers to the dynamic range of the output. The value is 25 in scanned topographic maps. I_{in} and I_{out} are the maximum and minimum value of the grayscale. Obviously, the value of I_{in} andI_{out}shall influence the result of SSR treatment.

Experiments show that histograms output image of SSR are approximately normally distributed. Thus, I_{in} and I_{out} can be gotten by the average and variance of the grayscale value as (11).

$$\begin{cases} I_{hi} = \mu + 2.5\sigma \\ I_{low} = \mu - 2.5\sigma \end{cases} \qquad (11)$$

After the normally distributed stretching, the contrast and brightness of scanned topographic maps are improved with better visual effect.

The whole algorithm is shown in Figure 3:

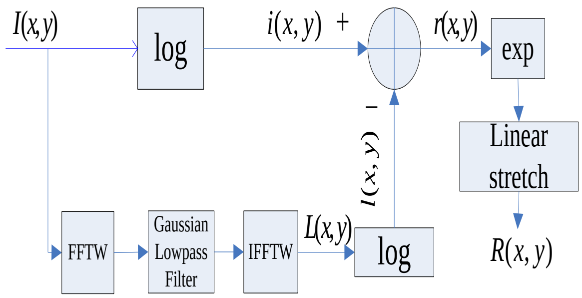


Figure 3. Improved Algorithm of Dodging of Homomorphic Filter

I(x,y) refers to the input of scanned topographic maps. *R(x,y)* refers to the final image after normally distributed stretching.

4. Experiments and Analysis

Hardware condition of the computer: Intel(R) Core(TM)2 Duo CPU T8100 @ 2.10GH,Memory 2.00GB, Operating system: Microsoft Windows XP Professional Version 2002.

4.1. The Effect of Color Dodging for the Whole Image

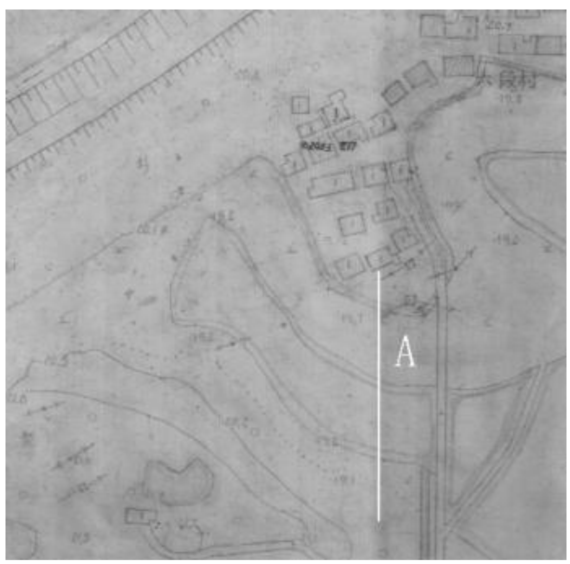
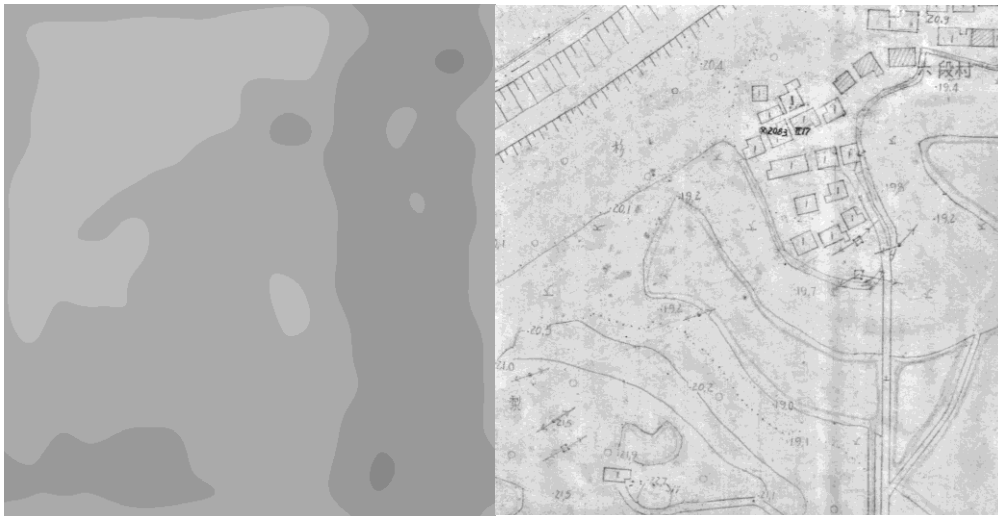


Figure 4. Original Scanned Topographic Map

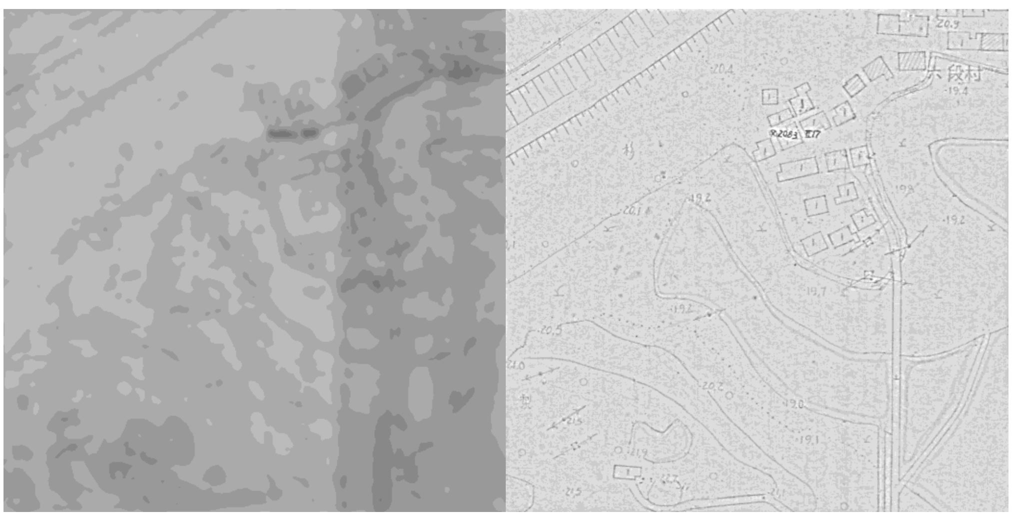
For better contrast, the experiment selects large pictures of 1024*1024 and different value of D_0 in (9) to observe the effect of dodging. The original scanned topographic map in Figure 4, the map has uneven illumination because the hard copy topographic maps are folded, which leads to a dim backlight surface (On the right of line A) and clear creases.

The effect of color dodging for the whole image in Figure 5.The linear contrast increasing algorithm will saturate the bright area while bright the dark area. So non-linear contrast increasing improved algorithm of homomorphic filter is encouraged. As the value of D_0

increases, shadow and creases gradually disappear and useful information (lines and numbers) in scanned topographic maps get kept and the quality of image gets improved.



(a) Brightness Component (b) Result when D_0=10 when D_0=10

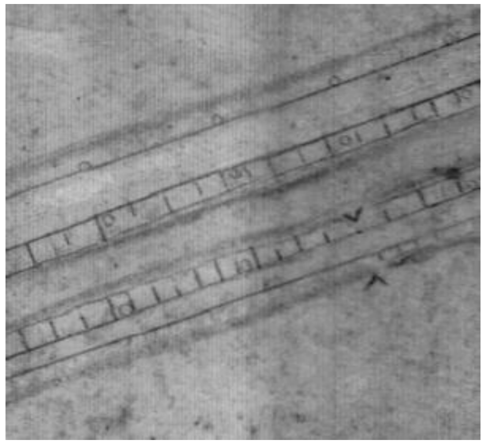


(c) Brightness Component (d) Result when D_0=25 when D_0=25

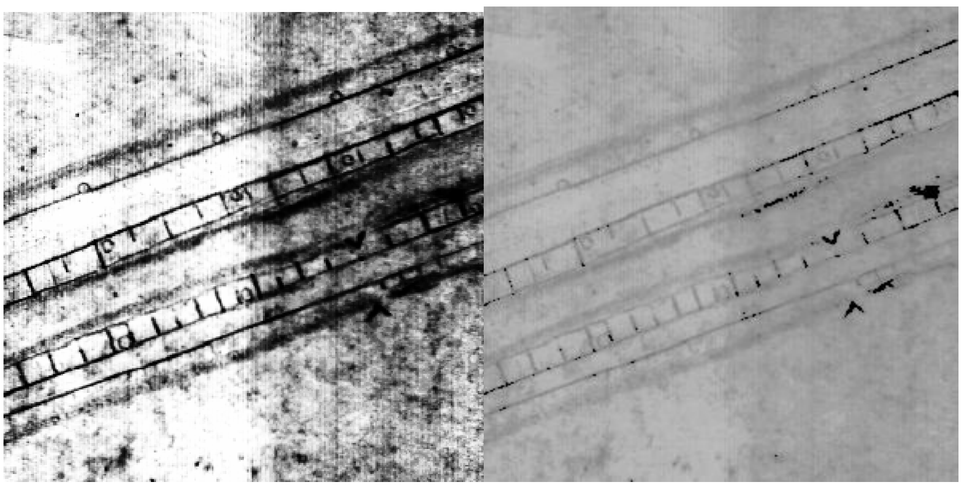
Figure 5. The Effect of Color Dodging for the Whole Image

4.2. The Effect of Dodging for the Detail

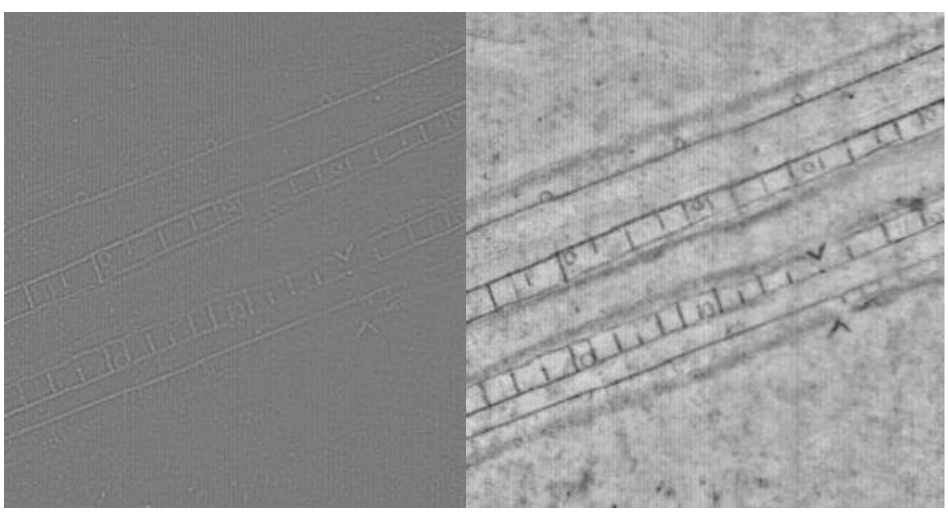
In Figure 6, When Gaussian filter δ equals to 20, apply the normally distributed dodging of homomorphic filter to the image and compare it with the conventional image enhancement algorithm.



(a) Original Image



(b) Equalization Enhancement (c) Standardization Enhancement



(d) Homomorphic Filter Enhancement (e) Improved Method

Figure 6. Effect Before and After Dodging

From Table 1 concluded from Figure 6, the improved homomorphic filter method increases the whole brightness of the picture, keeps the basis contrast, has compensated for the lack of brightness and contrast resulted from a removal of background. Besides, it erases the shadow and creases to form a better visual effect that achieves the original purpose.

Table 1. Comparison of Different Method

Image	Bright	Contrast	Shadow	Crease	Visualeff ect
(a)	139	22.01	More	Obvious	Normal
(b)	162	77.12	Much more	Moreobvious	Poor
(c)	159	19.66	Some	Partlyerased	Normal
(d)	123	5.27	Little	Bettererased	Poor
(e)	169	18.31	Little	Bettererased	Good

4.3 Treatment of White Spot on the Image

White spot is common to see on the scanned image as shown in Figure 7, three places marked in rectangular. It should be treated when dodging. In Figure 8 is the result image by using the method proposed in this paper. By comparing Figure 7 and Figure 8, it is obvious that the treatment of white spot is effective.

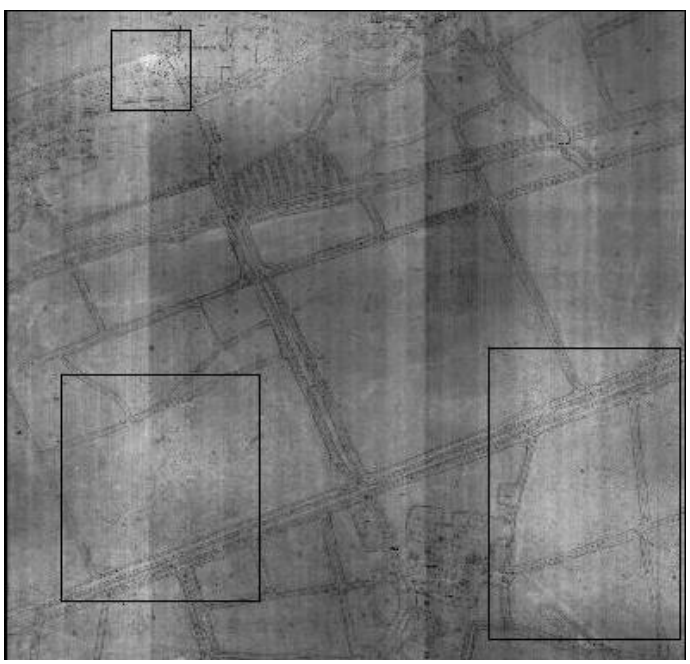


Figure 7. Original Image with White Spot

Figure 8. Result Image

4.4 Time Comparison between Homomorphic Filter and Improved Algorithm

To compare the time consumed between homomorphic filter and improved algorithm, the experiment selects three scanned topographic maps of different sizes. As is shown in Table 2, A is the method of homomorphic filter, B is improved method.

Table 2. Time Comparison of Different Scales

	1024*1024	2048*2048	3936*3936
A (C=15)	9s	36s	158s
B (D_0=15)	0.9s	4s	9s

In Table 2, it is clearly that improved homomorphic filter algorithm can increase the efficiency of dodging. The larger the size is, the more apparent the result is.

5. Conclusions

The department of map production keeps a large amount of hard-copy historical topographic maps. After scanned to electronic version, these hard copies usually have uneven illumination and obvious creases. For keeping the original information, improving the quality of the map and erasing the crease in a quick way, this paper proposes an improved homomorphic filter method based on FFTW (Fastest Fourier Transform in the West), and applies it to thousands of scanned topographic maps for dodging from 1992 to 1999. The results show that compared to homomorphic filter method, the proposed algorithm increases the efficiency of dodging, in particular the large-size images. Meanwhile, the algorithm has improved the quality of the image and erases the creases so that it can be used in real generation of images.

Different images have different requirements on dodging. Especially filter coefficients vary from one to another. How to find out the common point of dodging in accordance to different requirements and reduce the supervision of humans on dodging is the next key focus of the research.

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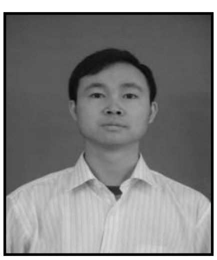

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