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Remote sensing image enhancement method based on multi-scale Retinex

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***Abstract*—In order to improve the effectiveness of remote sensing image enhancement, an enhancement algorithm based on multi-scale Retinex was presented and which can make up the deficiency of traditional wavelet algorithm that losing part information when image enhancement. The principle and realization methods of multi-scale Retinex and wavelet were calculated. The experiment of panchromatic and multicolor remote sensing image enhancement were carried out based on the two methods, the result showed that: the mean valve of enhanced image by this algorithm is about 125, the entropy and definition can be increased by 5% and 25% compared with wavelet algorithm, and remote sensing images could get better enhancement quality, so multi-scale Retinex is a better method for sensing image enhancement.**

Keywords- multi-scale; Retinex; wavelet transform; image enhancement

I. INTRODUCTION

Remote sensing satellite and its images appeared in the Cold War, which were firstly used in the military field. After the Cold War, military applications of satellite remote sensing images has reached a new stage in breadth and depth .It mainly reflects in military targets reconnaissance, the military topographic mapping, the battlefield environment simulation, military geographic information systems spatial information support, etc.

However, aerospace remote-sensing images are unqualified because of the limitations of modern imaging technology, thus affecting remote sensing information extraction and interpretation later. Therefore, it has become a research hotspot worldwide that how can get clear picture in order to extract valuable information, one of which methods is image enhancement technology[1].

There are many image enhancement methods, such as spectral improvement, spatial enhancement and multi-band increase, etc. The multi-scale Retinex algorithm and wavelet transform will be researched and compared in the paper.

II. MULTI-SCALE RETINEX (MSR) ENHANCEMENT ALGORITHM

Retinex algorithm[2] was derived from the research of Edwin Land [3,4] for the human visual system to light and color perception mechanism, the term “Retinex” originated from the synthesis of retina (Retina) and the cerebral cortex (cortex). The current implementation of the algorithm was proposed by Hurlbert [5] which enhances the image using of Gaussian surround function through cirrocumulus.

The algorithm of Single-scale Retinex (SSR) is as follows:

$$R(x, y)=\log I(x, y)-\log[F(x, y)* I(x, y)] \tag{1}$$

Note: $R\ (x, y)$ is enhancement output for the Retinex, $I\ (x, y)$ denotes the image that demanded to enhance, "*" is cirrocumulus operator, $F\ (x, y)$ denotes surround function, the expression is as follows:

$$F(x, y)=K_{\exp}[-(x^2+y^2)/\ \sigma^2\ ] \tag{2}$$

Note: σ is Gaussian surround space constant, which also known as scale parameter, K is coefficient, and the selection of the coefficient to be met:

$$\iint F(x,y)dxdy=1 \tag{3}$$

The MSR can be regarded as a weighted combination of SSR multi-scale, mathematical expression is as follows:

$$R_m(x,y)=\sum_{n=1}^{N} w_n\left\{\log\left[I_m(x,y)\right]-\log\left[I_m(x,y)*F_n(x,y)\right]\right\} \tag{4}$$
$$m=1,...,k$$

Note: $R_m(x,\ y)$ is enhanced output for the MSR, the subscript m represents the m[th] spectral band, k is the number of spectral bands, k=1 represents gray-scale image, k=3 represents color images (RGB). W_n represents weight coefficients associated with F_n, n is the number of environmental functions, in which environmental functions F_n select different standard deviation σ_n to control the environment function range of the scale. The expression is as follows:

$$F_n(x, y)=K_n\exp[-(x^2+y^2)/\ \sigma_n^2\ ] \tag{5}$$

Note: σ_n is scale parameter for the first n-surround function. Coefficient K_n to be met:

$$\iint K_n \exp\left[-\left(x^2+y^2\right)/\sigma_n^2\right]dxdy=1 \tag{6}$$

It is obviously that better self-adaptability can be achieved for MSR scale through the combination of multi-measure [6], also it can attain image adjustment under dynamic scope, which result in image enhancement. It is demanded that separately disposal each ribbon of color image using MSR for color image enhancement. Experiment showed that for most images can select large, medium and small three-scale (optional 15,80 and 250), and

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the weight of each scale can be the identical, you can also select emphasize on dynamic range compression or focus on demand of sense of consistency.

III. WAVELET TRANSFORM ENHANCEMENT ALGORITHM

A. Wavelet Transform

It is inevitable necessity that the combination of image enhancement because Wavelet has capabilities in multi-resolution analysis. Image enhancement based on wavelet analysis technique uses wavelet transform, specially disposes low-frequency components in order to enhance the target information in the image, just as the Fig.1 following.

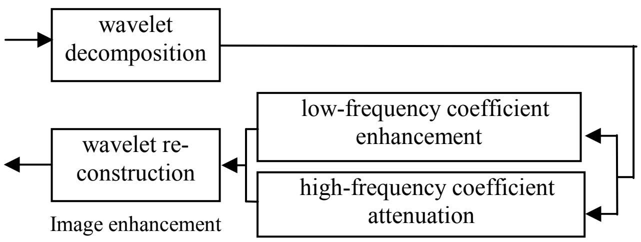

Fig1. The basic image enhancement framework based on wavelet transform.

B. Algorithm

Two wavelet functions are defined as follows:

$$\psi^1(x,y)=\frac{\partial\theta(x,y)}{\partial x}\quad \psi^1(x,y)=\frac{\partial\theta(x,y)}{\partial x} \qquad (7)$$

Recording as:

$$\psi_s^1(x,y)=\frac{1}{s^2}\psi^1\left[\frac{x}{s},\frac{y}{s}\right]$$

Two cirrocumulus continuous wavelet transform of image signal $f(x, y)$ are:

$$W_s^1 f(x,y)=f^*\psi_s^1=s\frac{\partial}{\partial x}(f*\theta_s)$$

$$W_s^2 f(x,y)=f^*\psi_s^2=s\frac{\partial}{\partial x}(f*\theta_s) \qquad (8)$$

According to the laws of two-dimensional wavelet transform, for the qualification that image $f(x,y)\in L^2(R^2)$, appoint f_N is $f|$ orthogonal projection in $V_N^2|$, then the priority wavelet decomposition of $f|$can be regarded as wavelet decomposition of $f_N|$. Assuming scale function in $\{v_j^2\}_{j\in x}|$is $\phi|$, wavelet function. The image is decomposed according to tower as follows:

$$f_j=\sum_{k_1,k_2\in z}C_{j,k_1,k_2}\Phi_{j,k_1}\phi_{j,k_2} \qquad (9)$$

$$g_j^{(1)}=\sum_{k_1,k_2\in z}d_{j,k_1,k_2}^{(1)}\Phi_{j,k_1}\psi_{j,k_2} \qquad (10)$$

$$g_j^{(2)}=\sum_{k_1,k_2\in z}d_{j,k_1,k_2}^{(2)}\psi_{j,k_1}\phi_{j,k_2} \qquad (11)$$

$$g_j^{(3)}=\sum_{k_1,k_2\in z}d_{j,k_1,k_2}^{(3)}\psi_{j,k_1}\psi_{j,k_2} \qquad (12)$$

The essential of image signal wavelet decomposition is that decomposes image signal into different images heft in different frequency components spectrum. We can use different ways to enhance image detail heft using different frequency spectrum, highlighting the details of different measure, so as to achieve the purpose that enhance levels of the image. For example, we make single-measure wavelet decomposition for tire image choosing "sym4" wavelet shown as Fig.2. From the theory and practice above it can be seen that wavelet transform is redistribution coefficient of different energy intensity according to certain rules using wavelet time-frequency characteristics [7].

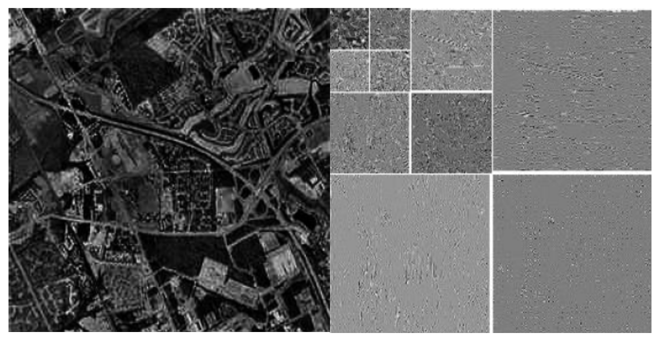

Fig2. The figure of single-measure wavelet decomposition

IV. EXPERIMENT AND ANALYSIS

A. Evaluation method

The evaluation of image enhancement can carry out from both qualitative and quantitative aspects. qualitative evaluation rely mainly on visual of images, while quantitative evaluation mainly select parameter that reflect image brightness which called mean and reflect image details which called information entropy and definition.

- Mean value. The mean value reflects the average image brightness. If the average is moderate (gray value is in the vicinity of 128), then the visual effect is good.
- Entropy. The greater of entropy the more information carried by the image, so the information entropy is an effective indicator to measure the richness of image information.
- Definition. The definition may reflect the small details contrast of the image and characteristics of texture transformation. The greater value clarity the clearer of corresponding picture.

B. *Panchromatic remote sensing images enhancement*

Interception part of panchromatic remote sensing images of a city with pixel resolution (192 × 192), which is shown as Fig.3.

Fig3. Original image

Multi-scale Retinex and wavelet transform are operated to the selected image respectively, and enhancement effect is compared. Fig.4 can achieve good visual effects with multi-scale Retinex methods, but if want to achieve the best possible enhancement effect requires multiple iterations and to achieve the effect of Fig.4 need to iterate 80 times, what is more the details of the image part will loss. Fig.5 is image after wavelet transform with better impact.

Fig4. Multi-scale Retinex

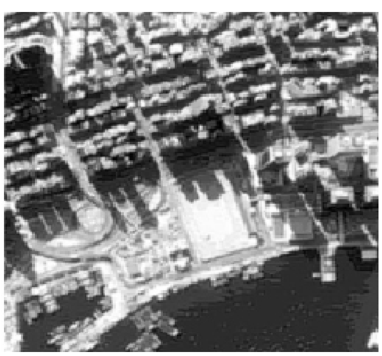

Fig5. Wavelet transform

Application above algorithms we can attain image enhancement evaluation index parameters such as shown in Table I.

TABLE I MEAN VALUE, ENTROPY AND DEFINITION OF ENHANCED PANCHROMATIC REMOTE SENSING IMAGES.

	multi-scale Retinex	wavelet transform
mean value	125	9
entropy	5.0	5.3
definition	29	43

C. *color remote sensing image enhancement*

Also interception part of high spatial resolution color remote sensing image of a city as shown in Fig.6, still using multi-scale Retinex and wavelet transform algorithm, and make comparison with enhancement effect, as shown in Fig.7 and Fig.8. It is demanded to iterate 300 times to achieve the effect of Fig.6 if adopting multi-scale Retinex algorithm [8].

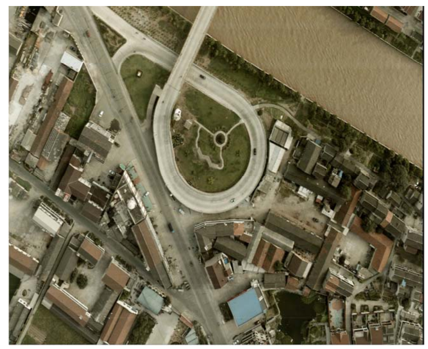

Fig6. Original image

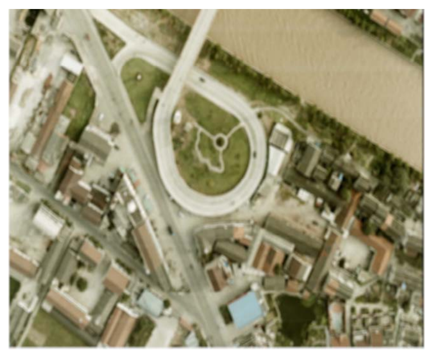

Fig7. Multi-scale Retinex

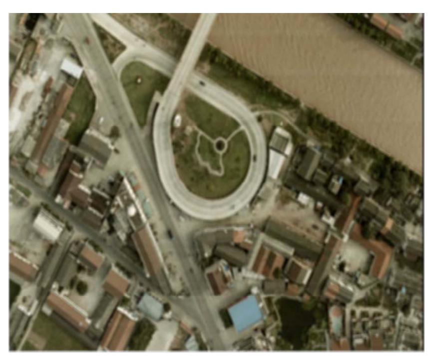

Fig8. Wavelet transform

The mean value, entropy and definition of image RGB after two algorithms as shown in Table Ⅱ.

TABLE Ⅱ. MEAN VALUE, ENTROPY AND DEFINITION OF ENHANCED COLOR REMOTE SENSING IMAGE

	multi-scale Retinex			wavelet transform		
	R	G	B	R	G	B
mean Value	102	96	91	86	79	78
entropy	5.2	5.2	5.1	5.2	5.2	5.3
definition	28	29	28	35	34	35

D. *Analysis*

Through the contrast of principle for wavelet transform and MSR enhancement method above, as well as the compare of enhancement results of remote sensing images, we can find that wavelet transform deeply depend on the low-frequency approximation signal enhancement, while the low-frequency approximation signal enhancement is limited, so wavelet transform enhancement method is not ideal method for poor quality image. MSR enhancement algorithm has more ideal effect compared to wavelet transform which with better capacity of self-adaptation, and the real-time can be guaranteed through the fast Fourier transform, but in advance, the image should be filtering processed. Otherwise, the noise component will also be enhanced. Comprehensive consideration of factors above, it is easy to see MSR enhancement algorithm has a unique advantage in remote sensing image enhancement. It may be a good way to enhance the remote sensing images.

V. CONCLUSION

The method of remote sensing image enhancement based on multi-scale Retinex was mainly introduced in the paper, Retinex was compared with wavelet transform, then the experiment was carried out and its result was analyzed. The result showed that Retinex was a better method for remote sensing image enhancement.

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