Optik 139 (2017) 407–414

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Original research article

An efficient remote sensing image compensation method based on assessed modulated transfer function

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ARTICLE INFO

Article history:
Received 16 September 2016
Accepted 25 March 2017

Keywords:
Image compensation
MTF
Second filtering

ABSTRACT

In the acquisition process of a remote sensing image, remote sensing image quality degradation is caused by fuzzy and noise. However, how to compensate the image degradation remains a crucial but unsolved issue until now. In this work, we propose an efficient remote sensing image compensation method based on assessed modulated transfer function (MTF). First, the MTF is assessed from multiple edge sub-images. We use homomorphic filter algorithm to enhance the local sub-image because the MTF extraction process needs high quality image. The added enhancement filter makes the assessed MTF not consistent with the original one. Based on this condition, we adopt a second-filter algorithm to perform the image compensation. Experiments confirm that the proposed method is enough good, and it can obtain the better detailed information and visual effect than before compensation.

1. Introduction

During the acquisition process of a remote sensing image, it is subject to the influence of various links, such as optical system, atmospheric environment, imaging system, satellite platform and so on and therefore, appears fuzzy image and noise which would cause the quality reduction of image [1–4].

Recently, the compensation of remote sensing image is generally solved by the two most common used methods. One is to compensate the image through a degradation model and knowledge and the other is to compensate the image under the unknown situation of the degradation model, therefore it is also called blind compensation [5–8]. Blind compensation methods do not need many priori knowledge to directly invert compensated images [9,10]. However, the most of this algorithm exist many weaknesses, such as complex algorithm, large amount of calculation and slow rate of convergence. The most common methods adopted in the knowledge-based compensation are based on the modulated transfer function (MTF). Therefore, accurate and rapid estimation method of MTF plays an important role in the image compensation field. The estimation method of MTF can be obtained through either calculation of model method or extraction method of on-track image [11–15]. The model-based MTF estimation methods can accurately calculate the degradation model of imaging system, optical system and satellite platform that are taken by remote sensing image in laboratory. However, it is influenced by uncertain factors during the shooting process, such as atmospheric environment, defocusing and mismatch of displacement. Therefore, MTF error of image is usually big and the compensated image also exists big deviation. For the on-track image extraction method, the commonly used methods include tilt knife-edge method of IS012233 standard [16]. Because it is

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http://dx.doi.org/10.1016/j.ijleo.2017.03.118
0030-4026/

based on on-track image, the calculation process includes all the factors that the satellite exerts on the image when the satellite is on-track operation, therefore, MTF is more accurate and the compensated image can achieve better effect at image compensation. However, because the tilt knife-edge method has higher requirement of the image which limits the use of this method, and at the remote sensing image with larger noise, the MTF that is acquired by this method exists bigger error.

In this paper, we propose a second-filtering method to compensate remote sensing image based on assessed modulated transfer function (MTF). Our method try to improve the traditional method and gets better effect in order to make the compensation method based on MTF perform well.

2. Compensation principle of remote sensor

The imaging process including all degradation factors can be abstracted as a system degradation function H and the original image $f(x, y)$ produces a degradation image $g(x, y)$ through system degradation function H, which can be displayed as the following formula

$$g(x, y) = H * f(x, y) \tag{1}$$

If considering the influence of additive noise $n(x, y)$, then the degradation image can be displayed as the following formula

$$g(x, y) = H * f(x, y) + n(x, y) \tag{2}$$

To compensate the image based on this model is a process that acquires one approximate estimation $f'(x, y)$ of $f(x, y)$ on the basis of a given $G = H(s) * F + N$ image degradation function H and additive noise item $n(x, y)$. The degradation function is usually unknown in reality and the approximate degradation function directly in the time domain exists much difficult.

Therefore, make Fourier transform to the two sides of Formula (2) and change the image from the time domain to frequency domain, which is shown as Formula (3), at this time, the system function H also converts to the frequency domain. It can be seen from Formula (3) that this system would be a linear unchangeable system if ignoring the noise item.

$$G = H(s) * F + N \tag{3}$$

We consider an extreme special situation according to Formula (1). Supposing on the real condition of the earth's surface which is represented by $g(x, y)$, a bright spot (pixel) about the size of sensor element at a homogenous dark background (for example the water body of visible optical band) would exist, and this pixel is located in the position of (m, n), which can be expressed by the mathematical expression:

$$\delta(\mathrm{x, y}) = \begin{cases} 1 & x = m, y = n \\ 0 & x \neq m, y \neq n \end{cases} \tag{4}$$

According to Formula (1), at this time, we can use the value within the neighborhood range of this point at the sensor image $f(x, y)$ centered as the position (m, n) to approximately display the response of system to the unit pulse, usually we can use this function to characterize the distribution of this pulse response, which is called PSF. And at this time, the Formula (1) can be written as

$$PSF = H * \delta \tag{5}$$

We can know that the degradation function of the system can be acquired through accurate calculation of PSF value by Formula (5). However, PSF can be acquired through accurate estimation of MTF.

3. The extraction of MTF

As a key problem of image compensation, many estimation methods have been put forward during the development process of PSF. The iterative image restoration algorithm which is put forward based on Contourlet conversion, the image restoration of hidden Markov Tree Model which is put forward based on wavelet domain and the obscure estimation and image restoration which is discussed based on the least square criterion all exist weaknesses, for example, large amount of calculation and complex algorithm. The method that is discussed at this paper is to estimate PSF by taking use of the relationship between MTF and PSF on the basis of estimation of image MTF.

The traditional PSF estimation method based on MTF, for example, calculates MTF at the single direction and then extends to two dimensions. However, considering the shooting environment, remote sensing image is shooting image at the relative motion of satellite and earth. Influenced by the satellite's speed, the imaging cannot satisfy with the complete same vertical track direction and along track direction of MTF. Targeting on this problem, the reference [17] comes up with the method that calculates along track direction, vertical track direction and also 45°direction of MTF and then make interpolation that expands one dimension of MTF to two dimensions. However, because PSF is the image that is mapping by point light source through imaging system, therefore it has the feature of symmetry, and as the model of PSF, MTF also has the same feature as PSF, therefore, this paper improves the existing method and makes comparative calculation through estimating MTF of