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Image fusion method based on adaptive pulse coupled neural network in the discrete fractional random transform domain

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ABSTRACT

In this paper, we present a new approach for the remote sensing image fusion, which utilizes both adaptive pulse coupled neural network (PCNN) and the discrete fractional random transform in order to meet the requirements of both high spatial resolution and low spectral distortion. In the proposed scheme, the multi-spectral (MS) and panchromatic (Pan) images are converted to the discrete fractional random transform domains, respectively, which can make the spectrum distribute randomly and uniformly. In DFRNT spectrum domain, high amplitude spectrum (HAS) and low amplitude spectrum (LAS) components carry different information of original images. We take full advantage of pulse coupled neural network synchronization pulse issuance characteristics of PCNN to extract the HAS and LAS components properly, and give us the PCNN ignition mapping images which can be used to confirm the fusion parameters. In the fusion process, local standard deviation of amplitude spectrum is chosen as the link strength of pulse coupled neural network. Numerical simulations are performed to demonstrate that the proposed method is more reliable and superior than several existing methods based on Hue Saturation Intensity representation, Principal Component Analysis, the discrete fractional random transform, etc.

1. Introduction

Image fusion is to combine multiple images of the same scene with complementary information in order to generate a new composite image with more information and better quality. In remote sensing, multi-spectral (MS) images have sufficient spectral information but poor spatial resolution, while panchromatic (Pan) images have high spatial resolution but low spectral information. According to different fusion operation, it can be divided into three levels: pixel-level, feature-level and decision-level [1]. This paper aims at pixel-level fusion of MS and Pan images to preserve spectral information and meanwhile enhance spatial details as many as possible, which can serve better for applications, such as land classification and road detection.

There are many fusion algorithms at pixel level, which can be mainly divided into three general categories according to the mathematical tools. First, arithmetical and statistical methods are used to image fusion by utilizing the algebraic operations to process images with different band data. The arithmetical methods are simple and with high efficiency, such as addition, subtraction, multiplication and division of corresponding bands. However, it is difficult for this method to achieve satisfactory fusion results, because the difference between the MS and the Pan images will be lost during the calculation process. The typical statistical method is Principal Component Analysis (PCA) [2] which can improve the spatial resolution, but may cause larger spectral distortion in remote sensing image fusion. Second, image representation method is used to image fusion by means of different color channels and frequency-domain analysis to show original data. The typical color transform method is Intensity Hue Saturation (HIS) and Brovey [3,4]. HIS method transforms three MS bands from RGB space into IHS space to separate the spatial information (I) from the spectral components (H, S). After replacing I with Pan, the fused result is converted back into RGB space. Although this method can preserve high spatial resolution, it distorts the spectral information. Brovey is a simple color normalized method. It usually gives rise to the spectral distortion. Compared to changing pixel values directly in the spatial domain which can usually introduce large spectral distortion, fusion method in the spectrum domain is worthy of investigation to reduce the spectral distortion. Among them, the most widely used method is the wavelet transform [5–7], in which Pan and MS images are decomposed into an approximation images and a set of detailed images. Band by band, the approximation image from MS is combined with details from Pan. And the fused images can be obtained

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by inverse wavelet transform. This method can obtain good fusion performance, but the wavelet decomposition level has an impact on the fusion performance. If the decomposition level is low, fused images preserve more spectral characteristic information, but fail to preserve spatial details well. With a higher level of decomposition, the performance of spatial details gradually increases, but the spectral information cannot be preserved because low frequency coefficients are decomposed time after time. Due to the indeterminacy of decomposition levels, serious blocking effect [8] usually appears in the fusion result. Furthermore, wavelet representations have incompleteness and uncertainty. Although wavelet has space and frequency information, it has no exact spectrum concept. And 2-D wavelet bases are isotropy, so it has limited directional representations of image details. Recently, Guo and Liu [9] introduced discrete fractional random transform (DFRNT) to the image fusion field. The energy spectrum of discrete fractional random transform (DFRNT) is uniformly and randomly dispersed, and the high amplitude and low amplitude spectrum components carry different image information so that it is not easy to cause spectral distortion in the fused image. Because of this, it has become a critical and difficult problem on how to extract the high and low amplitudes wisely. Third, image fusion is achieved by adopting intelligence technology, such as genetic algorithm [10], evolutionary strategy [11], Neural Network [12]. All these methods can get satisfactory experimental fusion results, but this kind of method is high complexity and time consuming, because there are many parameters that we needs to deal with. To sum up the above arguments, we should acknowledge that these image fusion methods have their own advantages and limits, in most cases these methods are used alternately in order to get fusion results of high quality.

In this paper, we propose a new image fusion approach by utilizing the pulse coupled neural network (PCNN) technique in the discrete fractional random transform (DFRNT) domains. The DFRNT originates from the discrete fractional Fourier transform (DFRFT) [14] and has excellent mathematical properties inherited from the DFRFT, in addition to some special spectrum distribution features of its own. Its randomness makes the changed information by fusion random, which ensures less spectral distortion. Its uniformity assures most of the acceptable fusion results when distortions occur in any position of the spectrum, which makes the method with some robustness. Furthermore, DFRNT has a real output for a real signal at half periodicity, which can save storage space for image data and is convenient for storage. In the DFRNT spectrum domain, high amplitude spectrum (HAS) and low amplitude spectrum (LAS) components carry different information of original images. The high amplitudes carry the spectral information and the low amplitudes just carry the spatial detail. Therefore, performing fusion in such spectrum domains is an indirect change of the original image simultaneously based on the space image features and the different spectrum distribution features. For different frequency components, different fusion rules are adopted according to different fusion goals. Excessive fusion of LAS leads to spectral distortion. On the contrary, it is easy to lose the detail information of the image. Therefore, how to extract the high and low amplitude spectrum properly becomes a critical and difficult problem for good fusion result. In the traditional DFRNT image fusion method as illustrated in Fig. 1, ratios of different parts of energy to the total energy are calculated to extracted the HAS and LAS components [9]. It is evident that the ratio needs to be reset again and again except for good result. Due to choosing the inappropriate ratio, this algorithm will output a bad performance in time complexity, especially processing the large images. In addition, if the ratio cannot be enumerated completely, we are likely to miss the optimal solution. Furthermore, the relationship among the amplitudes is ignored, which may have a bad influence on the fusion image. The fusion of pulse coupled neural network (PCNN) is a global fusion algorithm which can reserve more detail information. Its signal form and processing principle are more in line with the physiological basis of human visual system (HVS). In 1999, Broussard et al. [13] used pulse coupled neural network (PCNN) to fuse image, which improved the accuracy of target recognition, confirming the feasibility of applying pulse couple neural network (PCNN) to image fusion field. The pulse coupled neural network (PCNN) is a global fusion algorithm, which can reserve more detail information and its principle is conform to the physiological basis of human visual system (HVS). Therefore, the motivation of our research is to utilize PCNN to design fusion strategy for extracting the high and low amplitude spectrum of DFRNT wisely to improve the fused image effect. In order to combine the complementary advantages of both DFRNT and PCNN for image fusion, this algorithm uses DFRNT to decompose the images and gets amplitude spectrum. Meanwhile, it uses adaptive pulse coupled neural network (PCNN) to extract the high and low amplitude spectrum in order to improve the spectral effect. Experiment results show the desirability and superiority of the proposed algorithm in the image fusion of multi-spectral image and panchromatic image.

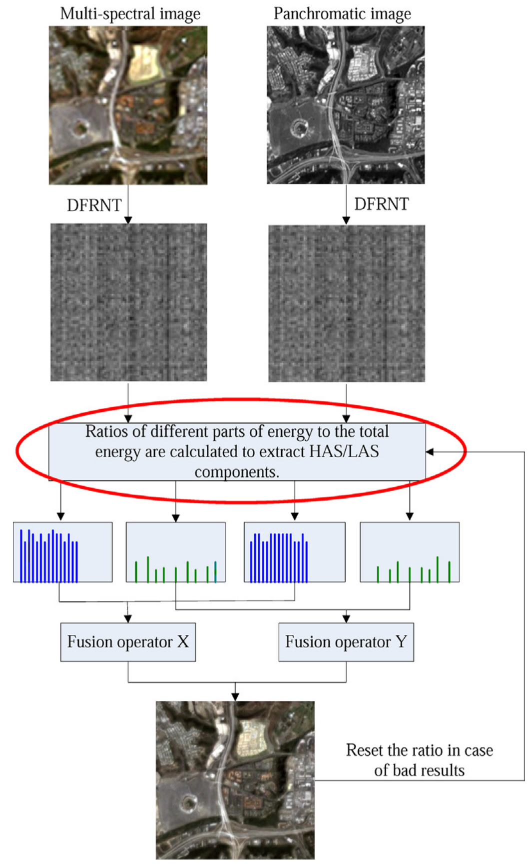

Fig. 1. The conventional image fusion based on the discrete fractional random transform (DFRNT).

The remaining sections of this paper are organized as follows. Section 2 presents the definition and properties of the discrete fractional random transform. The basic principle of PCNN model and why we choose local standard deviation as PCNN link strength is shown in Section 3. Section 4 discusses the image fusion process of proposed algorithm in detail and Section 5 presents the computer simulation results, analysis, and evaluation. Conclusions are stated in Section 6.