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Color transfer based remote sensing image fusion using non-separable wavelet frame transform

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Abstract

In order to fuse two registered high spatial resolution panchromatic image and low spatial resolution multispectral image of the same scene, we proposed a new color transfer based fusion algorithm by using the non-separable wavelet frame transform (NWFT). Three bands are selected from the source multispectral image as the channels to be fused. A grayscale image is obtained by averaging these three bands. Histogram matching is performed on the source panchromatic image to obtain a new panchromatic image with a uniform histogram as the grayscale image acquired from the source multispectral image. The histogram matched panchromatic image is decomposed by the NWFT. The lowest frequency subband of the NWFT coefficients is substituted by the grayscale image acquired from the source multispectral image in order to produce the composite NWFT coefficients. A composite image is obtained by performing the inverse NWFT transform on the combined coefficients. Three bands selected from the source multispectral image are mapped into the RGB (red–green–blue) color space. The color information (strictly speaking, it is the spectral information of the source multispectral image) is transferred into the composite image by using a color transfer method in order to get the finally fused image. Experiment results show that the proposed algorithm works well in remote sensing image fusion.

Keywords: Remote sensing; Image fusion; Color transfer; Non-separable wavelet frame transform

1. Introduction

With the rapid improvement of sensor technology, multisensor data, which often contain complementary and redundant information about the

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region surveyed, are now obtained for remote sensing. Fusion of multisensor data becomes a promising research area. Through combining registered images generated by different imaging systems, image fusion can produce new images with more complete information that are more suitable for human vision perception, object detection and automatic target recognition. Image fusion can be divided into signal, pixel, feature, and symbol levels. This paper mainly considers pixel level image fusion. Multispectral imaging sensors collect poor spatial resolution multispectral images, while panchromatic imaging sensors provide adequate spatial resolution panchromatic images. In remote sensing, fusing high spatial resolution panchromatic images with low spatial resolution multispectral images becomes popular since it can produce high spatial resolution multispectral images.

Various remote sensing image fusion algorithms have been proposed. The commonly used remote sensing image fusion algorithms include those based on the IHS transform (Carper et al., 1990; Chavez et al., 1991), the principal component analysis (PCA) (Chavez and Kwarteng, 1989; Chavez et al., 1991), the Brovey transform (Civco et al., 1995), and the high-pass filtering (Shettigara, 1992). Recently, multiresolution decomposition based algorithms are widely used in remote sensing image fusion, such as the DWT based fusion algorithms (Li et al., 1995; Yockey, 1995; Zhou et al., 1998) and the DWFT based fusion algorithm (Li et al., 2002). Both the DWT and the DWFT can decompose a signal into several components, each of which captures information present at a given scale. The DWT or the DWFT decomposition of an image can break down into 1-dimensional wavelet decomposition on rows and columns respectively. In practice, for 2-dimensional signal $f(x,y) \in L^2(R^2)$, it cannot be processed separately in x and y directions in most cases. The 2-dimensional separable wavelet transform also yields a shift variant data representation by the down-sampling process and is not appropriate for multi-sensor image fusion. The non-separable wavelet transform (Kovačević and Vetterli, 1992, 1995) allows true processing of images. Images are treated as areas instead of rows and columns. The advantage of the non-separable wavelet transform is having better frequency characteristics, directional properties and more degree of freedom, resulting in better design. By eliminating the decimator and interpolator process and changing the filter coefficients of the non-separable wavelet transform, we will obtain the non-separable wavelet frame transform (Pan and Wang, 1999). All the subbands after the NWFT decomposition will have the same size as the source image. The NWFT has the property of shift-invariance and is more suitable for image fusion. In this paper, we developed an approach based on the NWFT for the fusing of multispectral and panchromatic remote sensing images.

This paper is organized as follows. The general image fusion methods in remote sensing are described in Section 2. In Section 3, the proposed color transfer based image fusion algorithm using the NWFT is presented in details. Section 4 shows the experimental results and comparison with conventional methods. Section 5 concludes the paper.

2. General image fusion methods in remote sensing

2.1. Fusion with the intensity-hue-saturation (IHS) transform

The IHS transform (Carper et al., 1990; Chavez et al., 1991) is one of the widespread image fusion methods in the remote sensing community. Three bands of the source multispectral image are mapped into the RGB color space and the RGB color space is then transformed to the IHS color space:

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ -\frac{\sqrt{2}}{6} & -\frac{\sqrt{2}}{6} & \frac{2\sqrt{2}}{6} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \tag{1}$$

$$H = \tan^{-1}\left(\frac{V_2}{V_1}\right), \tag{2}$$

$$S = \sqrt{V_1^2 + V_2^2}, \tag{3}$$