High-fidelity fusion method for optical satellite remote sensing images

Optical satellite imaging has a wide range, is free from national boundaries, and is of great importance to national security, economic construction and social development. Since the year of 2000, most optical satellites simultaneously capture panchromatic (Pan) and multispectral (MS) images. Pan images mainly offer high-resolution texture information, while MS images mainly provide low-resolution spectral information. Different from Pan and MS images, fused images can provide high-resolution texture and spectral information, and can reveal the objects which cannot be seen in gray images, so that it plays an important role in military intelligence interpretation.

Image fusion aims to sharpen MS images by using the high-resolution texture information of Pan images, and to generate high-resolution MS images that can accurately reflect the textural and spectral information of ground objects. Image fusion is the key technology of satellite remote sensing image processing, and we are subject to the long-term blockade of advanced remote sensing image processing technology from the United States, Canada and the European Union. For example, in 2012, the Canadian government blocked the proposed sale of Canadian firm PCI Geomatics to the Chinese firm NAVInfo for national security reasons. In the case that the strongly reflected objects are over-saturate, and the synthesized low-resolution Pan images have gray-scale distortion, the existing additive transformation based methods will cause texture distortion and spectral distortion problem [1]. To address this problem, a novel remote sensing image fusion model based on multiplicative transformation has been proposed in our research. This model has two steps, as follows:

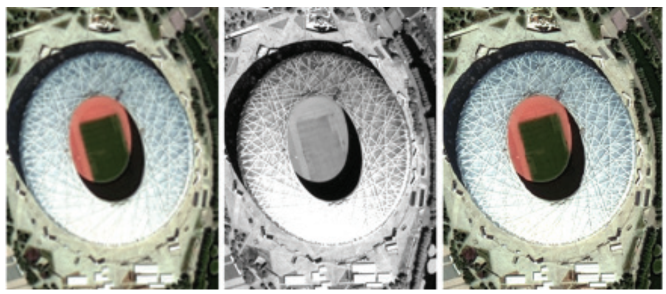
(1)Low-resolution Pan image synthesis based on ground object classification and bilateral error regression

The synthesis of low-resolution Pan image is the generation of a low-resolution Pan image that corresponds to the original pan image by the weighted summation of MS image bands. The existing methods do not distinguish the spectral responses of different ground objects to the different bands of Pan and MS images. These methods take unilateral error regression to calculate the weights of different bands for synthesizing low-resolution Pan images, thus causing the gray-level distortion of the synthesized low-resolution Pan images. To tackle this problem, we accurately analyze the spectral response difference of ground objects from two viewpoints, i.e., ground objects and image bands [2], and propose a ground object classification and bilateral error regression based low-resolution Pan image synthesizing method.

Firstly, the precondition of an accurate synthesis of low-resolution Pan images is accurate analysis of the ground objects that have similar relative spectral response in Pan and MS bands. However, the existing classification methods only consider relative relationship of MS bands. It leads to great reflectance difference of Pan band in the same ground object class. To solve this problem, the values of each Pan and MS pixel are combined as a vector, and then the ground objects are classified according to the direction of these vectors. Secondly, since the Pan image (dependent variable, P) and the MS image (independent variable, M) have measurement errors(e_P , e_M), the bilateral error regression model, i.e., $P + e_P = [M + e_M]a$ is employed to calculate the weights of different bands for different ground objects (a), so that the low-resolution Pan image ($\bar{P}$) has been accurately synthesized in our method.

(2)High-fidelity Pan and MS remote sensing image fusion model based on the multiplicative transformation

The existing additive transform based methods, i.e., $F_k(i,j) = [P(i,j) - \bar{P}(i,j)] + M_k(i,j)$, generate fused images by adding the texture information of Pan image and the spectral information of MS image. In optical satellite imaging, due to the strong spectral reflection, aircraft, ships and other military targets are easy to engender over-saturation problem. In such situation, the edge of Pan image is difficult to be precisely matched with the spectral information of MS image while generating the fused image, so that the edge of fused image will be blurred. To address this problem, the representation approach of texture information and spectral information of fused image has been changed on mechanism, and has established Pan and MS image fusion model based on multiplicative transformation [2][3].



MS image　　Pan image　　Fused image

Fig. The example of fused image of Pan and MS images from GF—2 satellite

Specifically, the texture information of fused image is represented by the ratio between Pan image and low-resolution Pan image, i.e., $P(i,j) / \bar{P}(i,j)$, the spectral information of fused image is represented by up-sampled MS image. And the new fusion model based on multiplicative transformation, i.e., $F_k(i,j) = [P(i,j)/\bar{P}(i,j)] \times M_k(i,j)$, has been constructed. Here, the damage to the texture information of the fused image caused by the over-saturation is suppressed by the ratio transformation of the MS band to the low-resolution Pan image (see Fig). Compared with the GS fusion method (implemented by ENVI software) and UNBPansharp

Table: Quality assessment of different fusion method

Fusion methods	Distortion (the smaller, the better)	
	Texture	Spectral
GS	12.37%	10.21%
UNBPansharp	9.16%	9.25%
Our method	2.01%	2.07%

fusion method (implemented by PCI software), our method has solved the texture and spectral distortion problem. We have validated our method on about 1000 test samples. The experimental result demonstrated that the texture distortion and the spectral distortion of our method are 3 times lower than those of GS fusion method and UNBPansharp fusion method (see Table).