Sharpening the multispectral GF-2 imagery using the modified intensity-hue-saturation approach: the different spectral settings in comparison

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Abstract. The modified intensity-hue-saturation (mIHS) is one of the widely applied pansharpening approaches on remote sensing imagery. In this work, we try to compare the pansharpened images from the mIHS approach with the different spectral settings applied to sharpen GF-2 multispectral images. Visual inspection and quantitative assessments indicated that the mIHS with the SPOT 5 spectral settings was not suitable for sharpening the GF-2 multispectral imagery. There was no evidence to suggest that the pansharpened image with the GF-2 spectral settings performed over the other four kinds of spectral settings. The mIHS with IKONOS spectral settings was recommend for applications if there were not spectral settings for GF-2 data.

1. Introduction

Remotely sensed imagery has been widely used to map the surface features of the Earth and classify land use and land cover at global, regional, and local scales. In general, a lot of applications require a single or multi-date imagery with high spectral and spatial resolutions [1-3]. However, because of the limitations from sensor hardware and data transmission, most of on-orbit optical remote sensing satellites such as Landsat, Sentinel, CBERS-04, ALOS, SPOT, IKONOS, QuickBird, OrbView, WorldView, Gaofen 1, and Gaofen 2 (GF-2) are usually equipped with a high spatial resolution panchromatic band (PAN) and several low spatial resolution multispectral bands (MS) [4-5]. Therefore, it is necessary to sharpen the low spatial resolution MS bands with a high spatial resolution PAN band. Many pan-sharpening approaches have been developed, and were reviewed and explained in the literatures [3,4,6,7]. Some approaches have been implemented in commercial remote sensing image processing systems such as ERDAS Imagine, PCI Geomatica, and ENVI software [8]. The typical approaches include the modified intensity-hue-saturation (mIHS), color spectral sharpening, Gram-Schmidt spectral sharpening (GS), and principal component analysis sharpening methods [8-11]. When some methods are implemented in the commercial software, it is necessary to select or set some conditions. For example, it is necessary to set the different select methods for low resolution pan for carrying out the GS pan-sharpening approach in ENVI software [12]. For implementing the mIHS approach in ERDAS Imagine software, it is necessary to select the spectral settings for the PAN and MS bands. The different selections and settings on these parameters can produce the different fusion results, so it is necessary to compare and assess the fusion results with the different parameters. In addition, when the existing pan-sharpening approaches are applied on imagery acquired by new
satellites, spectral distortion may be happened because of the different spectral ranges and resolutions of the PAN and MS bands from the different sensors [13].

The previous studies have demonstrated that the mIHS sharpening method can improve the spatial resolution with preserving the spectral information of the MS imagery well, and has been widely used to fuse remotely sensed image [8,9]. Now, there is an urgent need for high-quality pansharpened GF-2 images to satisfy different application purposes. Therefore, the aim of this work is to compare the fusion results from the mIHS sharpening approach with the different spectral settings applied on GF-2 multispectral image at the full resolution using several reliable quality indices such as the spectral mean, standard deviation (Stdev), normalized difference vegetation index (NDVI), correlation coefficients (CC) between multispectral bands, and Moran’s I and Geary’s C spatial autocorrelation indices [14,15].

2. Materials and Methods

2.1. GF-2 data and pre-processing

GF-2 satellite launched in 2014 in Taiyuan, China images the Earth with a PAN band and four MS bands (see Table 1). One scene of GF-2 Level 1A image acquired on April 30, 2016 (spring season) was downloaded from China Centre for Resources Satellite Data and Application (CRESDA, http://www.cresda.com), and used for a quality assessment of the pansharpened images. The GF-2 Level 1A image has a Geographic Latitude/Longitude projection with WGS84 Earth Ellipsoid. Firstly, the original PAN and MS images were re-projected into UTM projection (UTM, zone 50N, WGS84). To reduce the image processing time and remove the effects of black background (digital number of the pixel is 0), a subset of the GF-2 image was clipped to use in this study (see Figure 1).

Table 1. Spectral range and spatial resolution of the different sensor used in this study

| Sensors           | GF-2   | IKONOS | QuickBird | OrbView-3 | SPOT 5 |
|-------------------|--------|--------|-----------|-----------|--------|
| Band name         | Spectral ranges (µm) | Spectral ranges (µm) | Spectral ranges (µm) | Spectral ranges (µm) | Spectral ranges (µm) |
| Panchromatic      | 0.45-0.90 | 0.45-0.90 | 0.45-0.90 | 0.45-0.90 | 0.48-0.71 |
| Band 2            | 0.45-0.52 | 0.45-0.53 | 0.45-0.52 | 0.45-0.52 | 0.50-0.59 |
| Band 3            | 0.52-0.59 | 0.52-0.61 | 0.52-0.60 | 0.52-0.60 | 0.61-0.68 |
| Band 4            | 0.63-0.69 | 0.64-0.72 | 0.63-0.69 | 0.63-0.70 | 0.78-0.89 |
| Band 5            | 0.77-0.89 | 0.77-0.88 | 0.76-0.90 | 0.76-0.90 | 1.58-1.75 |

2.2. Spectral settings in the mIHS approach

The mIHS sharpening method is an improved version of the intensity-hue-saturation transformation, and can sharpen four MS bands through iteratively repeating the fusion process, each for three different MS bands. In this paper, two iterations using false color composition of Band 4, Band 3, Band 2, and true color composition of Band 3, Band 2, Band 1, and were selected to produce a sharpened image with all four bands. More details about the mIHS method can be referred to the literatures [8,9], and the operational procedures can be found in ERDAS imagine v9.2 software manual and help document.

During the implementation of the mIHS method, the parameters for high resolution spectral settings (IKONOS, IRS, Landsat 7, OrbView-3, QuickBird, SPOT 4, SPOT, and Custom) and multispectral spectral settings (IKONOS, IRS LISS III, Landsat IV MSS, MTI Visible, OrbView-3, QuickBird, SPOT 4 XI, SPOT 5 XI, SPOT XI DIMAP-BIL, SPOT XI DIMP-TIFF, and Custom) must be selected and set. You can enter the wavelengths and other parameters of your remotely sensed data if the Custom is selected. In this work, we added a new *.sat file (the regular ERDAS IMAGINE Sensor Attribute Files) that defined the GF-2 sensor with its spectral ranges of the PAN and MS bands, which was located in the <IMAGINE HOME>/etc directory, so the ERDAS Imagine is able to determine the relative wavelengths and proportional band coverage of the GF-2 data. The high spatial
resolution GF-2, IKONOS, QuickBird, OrbView-3, and SPOT 5 spectral settings were selected to evaluate the quality of the pansharpened images through comparing the spectral ranges of the sensors with that of GF-2 data (see Table 1).

Figure 1. (a) MS image (false-color NIR, red and green composition), (b) the sharpened image with GF-2 spectral settings, (c) the sharpened image with IKONOS spectral settings, (d) the sharpened image with OrbView-3 spectral settings, (e) the sharpened image with QuickBird spectral settings, (f) the sharpened image with SPOT 5 spectral settings.
3. Results and Discussions

3.1. Visual inspection

Visual inspection is often implemented according to the different band compositions associated with color preservation [16]. In this work, a visual assessment of the spectral quality was performed using the false color image (Red-Band 4, Green-Band 3, and Blue-Band 2). Figure 1 represents the pansharpened images which shows a distinct improvement in spatial quality compared with the original MS image. Comparison of the fused images resulted from the different spectral settings indicated that there were color distortions, as evidenced by the tone changes of land covers in these images. The sharpened image with SPOT 5 spectral settings was different with those of four kinds of the spectral settings, which showed the worse color-preserving result (see Figure 1f).

3.2. Quantitative assessments

The quality assessment was justified by the relative difference (percentage) between the metric values of the original MS image and the pansharpened data. Figure 2 to Figure 6 showed the relative difference (percentage) of the mean, Stdev, Moran’s I, and Geary’s C of four bands and NDVI, and of the CC value of between four bands.

![Graphs showing relative differences](image)

**Figure 2.** The relative difference between the original MS and fused data. (a) mean, (b) standard deviation, (c) Moran’s I, (d) Geary’s C, (e) correlation coefficient between bands.
After image fusion, the mean values in four bands decreased slightly. Compared with the original MS data, Band 2 exhibited the smallest difference of all four bands for five kinds of different spectral settings. The difference ranges in Band 2, Band 3, Band 4, and Band 5 was from -0.14% (IKONOS) to -0.21% (QuickBird), -0.35% (GF-2) to -0.43% (SPOT 5), -0.33% (GF-2) to -0.42% (SPOT 5), -0.21% (SPOT 5) to -0.45% (QuickBird), respectively. The differences in NDVI value from five kinds of different spectral settings were less than 0.01%. It indicated that the NDVI was relatively insensitive to the different spectral settings. The differences in Stdev values from five kinds of different spectral settings were less than 1% except Band 3 that was from -8.9% (SPOT 5) to 4.4% (QuickBird). It indicated that the spectral variant features of the pixels of the fused images were similar to those of the original MS images. From view of preserving the mean and Stdev values, the SPOT 5 spectral settings produced the worst results, which may be due to lack of blue band and increase of shortwave infrared band.

From view of preserving global spatial statistical indices (Moran’s I for measuring the local homogeneity and Geary’s C for measure the dissimilarity within a dataset), the biggest difference in Moran’s I values was 1.2% (Band 4 of SPOT 5 spectral settings), which did not change the characteristic of positive spatial autocorrelation of the original MS Bands. Although the difference in Geary’s C value was bigger, the Geary’s C values of the pansharpened images were approximately zero. It indicated that the pansharpened images from five kinds of different spectral settings did not change the positive spatial autocorrelation characteristics of the original MS image.

The pansharpening with GF-2, IKONOS, OrbView-3, and QuickBird spectral settings decreased the CC values between Band 2 and Band 3 (-6.55% to -8.00%), of Band 2-4 (-4.60% to -2.15%), Band 3-5 (-4.23% to -3.36%) and Band 4-5 (-1.47% to -1.25%), and slightly increased the CC values between Band 3 and Band 4 (the biggest difference was 0.41% from that of QuickBird), and significantly increase the CC values between Band 2 and Band 5 (the smallest difference was 23.6% from that of IKONOS). The pansharpening with SPOT spectral settings decreased the CC values of Band 2-3 and Band 2-4, and increased the CC values of Band 3-4, Band 2-5, Band 3-5, and Band 4-5. The differences in six CC values between four bands from SPOT spectral settings were more than those of the other four kinds of spectral settings, which may be also due to lack of blue band and increase of shortwave infrared band.

Overall, the GF-2 spectral settings preserved the smallest difference in mean and Stdev values with the original MS bands, which is not surprising. The second was from the IKONOS spectral settings. From the view of the mean and Stdev values in NDVI, there was no evidence to suggest that the pansharpened image with the GF-2 spectral settings performed over the other four kinds of spectral settings. From view of global spatial statistics, the IKONOS spectral settings preserved the smallest difference in Moran’s I index. Moreover, the IKONOS spectral settings preserved the smallest differences of the CC values of Band 2-3, Band 3-4, and Band 2-5. The findings indicated that the GF-2 multispectral imagery could be sharpened by the mIHS approach with GF-2, IKONOS, OrbView-3, and QuickBird spectral settings which have the similar spectral ranges of the PAN band and MS bands.

4. Conclusions

When the GF-2 multispectral imagery was pansharpened using the panchromatic band by the mIHS approach, the IKONOS, OrbView-3, and QuickBird spectral settings which have the similar spectral ranges of the PAN band and MS bands with that of GF-2 data could be applied, and produced better fusion results. The IKONOS spectral settings could obtain the pansharpened image close to that of the GF-2 spectral settings, which be recommend for applications if there were not spectral settings for GF-2 data.

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