An Adaptive Spectral Transformation Approach to Pan-Sharpening

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1. INTRODUCTION

Pansharpening has been an active research topic in the last few decades and numerous methods have been developed. These methods are generally categorized as arithmetic combination based (AMC) and component substitution (COS) techniques. The AMC methods involve direct arithmetic operation such as multiplication, addition, division, weighted adding, etc. on the low resolution multispectral (MS) images to obtain high resolution images. The commonly known methods are Brovey method, Synthetic Variable Ratio (SVR) method, and high pass filtering [1]. The COS-based substitution methods are performed after taking spectral or spatial transformation of the low resolution MS image. The popular COS approaches are the intensity-hue-saturation (IHS), the principal component analysis (PCA), and Multiresolution Analysis (MRA) based pansharpening.

The PCA approach has been very commonly used for spectral transformation due to its ability to optimally compress the high dimension data [2]. For this approach, the first principal component (PC) is substituted with the high resolution histogram-matched Pan image. However, the PCA approach is data dependent. For images with mostly vegetation/agricultural contents, this method yields very poor results with high spectral distortion [3]. To alleviate this problem, González-Audícana et. al. proposed a PCA-wavelet merger pan-sharpening method that took the advantage of the component substitution and the currently popular multiresolution approach [4]. Recently our work showed that for the PCA based methods, the standard approach of selecting the first PC is not always a suitable choice, and presented an adaptively method for selecting the component required to be replaced or injected with high spatial details. The spectral distortion in pansharpened images obtained by adaptive PCA (A-PCA) approach was much less than the standard PCA-based approach [5].

There are different approaches to perform spectral transformation – PCA, IHS, Discrete Cosine Transform (DCT), Fast Fourier transform (FFT), wavelets, etc. The transformation obtained by these methods is very data dependent. Previous work indicated that substitution of the component with high variance always yielded good results. Similarly, a single type of transformation does not always yield an optimal component required for substitution or transformation. In order to alleviate this problem, this paper proposes the method to adaptively select the component required for the substitution or injection of the high frequency information.

2. METHODOLOGY

The steps involved in adaptively selecting the appropriate spectral transformation approach are:

- Perform spectral transformation (A-PCA [5] and DCT) on the MS image.
- Calculate the cross-correlation coefficient between the resultant components in transferred domain and the Pan image.
- Select the component having the highest value of absolute correlation coefficient (CC).
- Adjust the histogram of the Pan image with the selected component.
- Use the histogram-matched Pan image in the Spectral transformation-based algorithm for the substitution or injection of higher spatial details in the selected transformation component.

3. PRELIMINARY RESULTS

A preliminary experiment is conducted on two IKONOS datasets – ik1 and ik2. The MS image is 256 x 256 with 4 bands, while the Pan image is 1024 x 1024 pixels. In order to have the reference original image, fusion is carried out after degrading each image by a factor of 4. This paper uses only the adaptive-PCA approach and the DCT for the spectral transformation. Literature survey on previous research shows that the DCT method have not been used for spectral transformation in pan-
sharpening. The wavelet transformation is not used in this paper because the numbers of spectral bands are too low. For few mother wavelets, the length of the signal would be less than the filter and hence would not give accurate transformation. The IHS transformation can make use of only three bands at a time, hence not useful when the numbers of spectral bands are greater than 3.

Table 1 illustrates the cross-correlation (CC) value between different spectral components (adaptive-PCA component and the DCT coefficients). For the DCT method, the DC coefficients have the highest CC value with the PAN image. Hence, the CC value shown in the table is between the DC coefficients and PAN image.

Table 1: CC of the optimal spectral component of each method with the Pan Image

<table>
<thead>
<tr>
<th>Image</th>
<th>DCT</th>
<th>A-PCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ik1</td>
<td>0.8364</td>
<td>0.818</td>
</tr>
<tr>
<td>Ik2</td>
<td>0.8606</td>
<td>0.904</td>
</tr>
</tbody>
</table>

Global evaluation index ERGAS, RASE, SAM, SID, Qavg are used to evaluate quality of pan-sharpened image. Table 2 compares the results obtained from the A-PCA-based method and the DCT-based method Pan-Sharpening. This table shows that for sample image Ik1, spectral transformation performed using DCT based method gives better result, while for Ik2 A-PCA methods gives better results. Thus, it can be seen that single type of transformation does not always yield good results, adaptive selection of the approach used for transformation is necessary. This problem is eased by adaptively selecting spectral transformation approach.

Table 2: Comparison of PCA- and DCT-based pan-sharpening methods

<table>
<thead>
<tr>
<th>Images</th>
<th>Method</th>
<th>ERGAS</th>
<th>RASE</th>
<th>SAM</th>
<th>SID</th>
<th>Qavg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ik1</td>
<td>DCT</td>
<td>2.164</td>
<td>18.401</td>
<td>6.655</td>
<td>6902.8</td>
<td>0.903</td>
</tr>
<tr>
<td></td>
<td>A-PCA</td>
<td>2.411</td>
<td>20.790</td>
<td>7.872</td>
<td>9546.6</td>
<td>0.879</td>
</tr>
<tr>
<td></td>
<td>Proposed Method</td>
<td>2.164</td>
<td>18.401</td>
<td>6.655</td>
<td>6902.8</td>
<td>0.903</td>
</tr>
<tr>
<td>Ik2</td>
<td>DCT</td>
<td>0.939</td>
<td>9.396</td>
<td>2.502</td>
<td>1605.0</td>
<td>0.812</td>
</tr>
<tr>
<td></td>
<td>A-PCA</td>
<td>0.888</td>
<td>8.570</td>
<td>2.051</td>
<td>1263.3</td>
<td>0.899</td>
</tr>
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<td></td>
<td>Proposed Method</td>
<td>0.888</td>
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<td>0.899</td>
</tr>
</tbody>
</table>

Additional results for Quickbird imagery and LandSat imagery will be performed. Furthermore, fusion results obtained by the proposed method will also be compared at the original resolution of the Pan image

11. REFERENCES


