Modified PCA based image fusion using feature matching

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Abstract— Image fusion is the process that involves combination of two or more images into a single image retaining the certain characteristic features from each of the initially used images. In this paper, a method to optimize image fusion using Modified Principle Component Analysis (MPCA) is proposed. In conventional PCA, principal components based on eigen values of the source images are estimated. Though conventional PCA fuses the images, the probability for principal components to lie in the same region is high. Whereas in case of Modified PCA, the principal components are determined for each block which will eliminate the problem of having principal components over the same region. Performance of the proposed method is experimented on Panchromatic image (PAN) and Multispectral image (MS) of Worldview-2 sensor. The fused image is better in both spatial and spectral information content. Quantitative and visual results demonstrates that MPCA method exhibits superior results than conventional fusion schemes such as IHS, WT and PCA.

Keywords— Modified Principal Component Analysis (MPCA); Panchromatic; Multispectral; principal components; eigen values

1. INTRODUCTION

Satellite image consists of photographs and other informations related to earth and other planets captured by artificial satellite. Satellite images have applications in the field of meteorology, agriculture, warfare and lot more. Generally remote sensing satellites like IKONOS-2, Quick Bird, LANDSAT ETM, are provided with one high spatial resolution panchromatic (PAN) sensors and several multispectral (MS) bands sensors. Because of the incoming radiation energy and the data volume collected by the sensor and several other reasons the images captured are merely not in high resolution.

Image fusion is a process of creating a new image representing combined information composed from two or more source images. The resulting images are more informative than each of the individual images.

The fusion of multispectral (MS) and panchromatic (PAN) images is a useful technique for enhancing the spatial quality of low resolution multispectral images. A multispectral image generally captures image within wide range of wavelength across the EM spectrum. The wavelengths are separated by filters or by the use of instruments that are sensitive to particular wavelengths, that includes light from frequencies other than the visible light range, that is infrared and ultra-violet. A panchromatic image (PAN) is “single band image generally displayed as shades of gray”. Panchromatic images are created when the imaging sensor is sensitive to a wide range of wavelengths of light, typically spanning a large part of the visible part of the spectrum.

Several commercial earth observation satellites carry dual-resolution sensors, which provide high spatial resolution, that is it has more information about the location than information about colour, panchromatic (PAN) images and low-resolution (LR), that is more information about colours than the location, multi-spectral (MS) images. Image fusion methods are therefore required to integrate a low-resolution MS image with a high-resolution pan image to obtain a pan-sharpened image with high spectral and spatial resolutions. Recently used image fusion methods such as the intensity, hue, and saturation method, the principal component analysis method, and the Brovey transform methods provides high resolution multispectral images, but with low spectral quality. Some other image fusion methods, such as the high-pass-filtering (HPF) method, operates on the high frequency components from the High-Resolution pan image, which is further injected into MS Image. This family of methods provides very less spectral distortion and more spectral information compared to the previous fusion methods.

In the domain satellite image sensing, the aim of the fusion process is to obtain a high-resolution multispectral image, which combines the spectral characteristic of the low-resolution data (MS) with the spatial resolution of the panchromatic image. In this paper, we present and discuss about the fusion technique based on Modified Principle Component Analysis (MPCA). In section 2 and 3, the study area and the proposed methodology are discussed. In section
4, experimental results are given and discussed before to conclude the paper with final remarks in section 5.

II. STUDY AREA

In this research, we have chosen Madurai city as our study area. Madurai is the second largest city in the Indian state of Tamil Nadu and is the 25th populated city in India. It is known as the Athens of the East, which is one of the ancient historic cities in the world.

The image has been taken by the World View-2 satellite sensor in the year of June 2012, with the Resolution of 0.46 meter for panchromatic and 1.85 meters for multispectral data. The World View-2 sensor provides a high resolution Panchromatic band and three Multispectral bands (red, green, and blue) for enhanced spectral analysis mapping and observing applications, land-use planning, disaster relief, defense and intelligence, visualization and simulation. In this work, the Worldview-2 MSS (Multispectral data) of Madurai city with size 128×128 and Worldview-2 PAN (Panchromatic data) of Madurai city with size 512×512 are considered.

III. PROPOSED METHODOLOGY

PCA is used to identify similarities and dissimilarities in the data. PCA fusion is to find the principal axes followed by finding of eigen value of the approximation images, further followed by calculation of the corresponding approximation images on the basis of the principal eigen vector. But there is a disadvantage in these traditional PCA based algorithm, it may happen that all the principal components are selected from the same region of the image.

The window based approach over the conventional PCA is discussed. The images are divided into some static window blocks. The principal eigen vector for each window block is computed. Then perform fusion on two corresponding window blocks of the two images to be fused. This assures that the principal component of each of the window blocks will be selected.

Figure 3.1 shows the process carried out in Modified PCA. The input images such as Panchromatic (PAN) and Multispectral (MS) images are taken. The Multispectral (MS) image is resized to the size of PAN image. Then the source images are divided into blocks of equal size. The principal components are determined for these blocks. For example, first principal component is evaluated by considering the block 1 of input images 1 and 2. The average of these principal components are calculated. Finally, the fused image is obtained.

The window size should be same for the entire image. The result will be enhanced as the number of blocks increases.

The procedure involved in this technique,

1. Read the MSS image and PAN image.
2. Resize the MSS image based on PAN image.
3. Divide the MSS and PAN images into static blocks.
4. Generate the data vectors for each block. Blocks in the source images are expressed as column vectors.

\[ x_i = \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_k \end{bmatrix}, \quad y_i = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_k \end{bmatrix} \]

Where \( x_i \) contain the elements of source image 1 (for block 1) and \( y_i \) contain the elements of source image 2 (for block 2).

5. Find the covariance matrix.

\[ C = \begin{bmatrix} \text{cov}(X_1, X_1) & \text{cov}(X_1, Y_1) \\ \text{cov}(Y_1, X_1) & \text{cov}(Y_1, Y_1) \end{bmatrix} \]

\[ \text{cov}(X,Y) = \frac{\sum_{i=1}^{n}(x_i-\mu_x)(y_i-\mu_y)}{n-1} \]
Mean of x (\(\mu_x\)) = \(\frac{\sum_{i=1}^{n} x_i}{n}\)

Mean of y (\(\mu_y\)) = \(\frac{\sum_{i=1}^{n} y_i}{n}\)

6. From the covariance matrix, find the eigen values and eigen vectors (principal components correspond to the largest eigen values).

7. Average of the principal components are taken.

8. Finally fused image is obtained.

### Quality Assessment Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entropy</td>
<td>Entropy is a measure of randomness in the data that can be used to characterize the image.</td>
<td>(\sum_{i,j=0}^{N-1} P_{i,j} \left( -\ln P_{i,j} \right))</td>
</tr>
<tr>
<td>Mean Square Error</td>
<td>The MSE is a measure of the quality of an estimator—it is always non-negative, and values closer to zero are better.</td>
<td>(\frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2)</td>
</tr>
<tr>
<td>Peak Signal to Noise Ratio</td>
<td>PSNR is defined as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation</td>
<td>(\frac{\max{ s^2(n) }}{MSE})</td>
</tr>
</tbody>
</table>

### RESULTS AND DISCUSSION

So by fusing these two images, we get both spatial and spectral information in a single focused image.

The Panchromatic (PAN) and Multispectral images are divided into blocks of equal size. We split the images into four blocks of equal size. Here all the sides of the blocks are of same length. The purpose for considering them as square blocks is, this would make the operation of finding eigen vectors or values easier. Moreover Eigen values or vectors can be determined only for square matrices. If the sides of the blocks are of different size, then it will make the operation complex.

![Fig 4.1 MSS image into blocks](image1.png)

![Fig 4.2 PAN image into blocks](image2.png)

Then apply PCA for each block in the source images. The principal components from each block is determined. The average of the principal components are taken. PCA gives results but still we go for MPCA, this is because here we split the entire image into smaller window blocks and we apply PCA for each block. In traditional PCA, there are chances that the principal components can be chosen from the same region but whereas in Modified PCA, the principal components are chosen from each block which would further enhance the result.

![Fig 4.2. PAN image into blocks](image3.png)
Thus an image is formed by combining all the blocks that underwent Principal Component Analysis (PCA). The division of images into blocks enhances the fused image by reducing the probability of having all the principal components accumulated in particular region in the image.

The results of the existing fusion techniques such as Intensity Hue Saturation (IHS), Wavelet Fusion and Principal Component Analysis (PCA) are shown below.

1) Intensity Hue Saturation (IHS)
   Intensity Hue Saturation based image fusion involves the replacement of intensity element of a Multispectral image (MS) by a Panchromatic image.

2) Wavelet Fusion Technique
   Wavelet transformation is a mathematical and analytical tool that can detect local features present in a signal process. Three new panchromatic images are produced according to the histogram of R, G, B bands of multispectral image. Then the decomposition of each of the new high resolution panchromatic images is done to produce a low-resolution approximation image and a wavelet set of three wavelet coefficients. These decomposed L-R panchromatic images are then replaced by the original L-R multispectral image bands.

3) Principal Component Analysis (PCA)
   The PCA is process that involves a mathematical procedure that includes the transformations of number of correlated variables into number of uncorrelated variables called principal components. PCA is a data compression technique.

On comparing these existing fusion techniques with the proposed method modified PCA on basis of Mean square error (MSE), Peak Signal to noise ratio (PSNR) and Entropy, the following results were obtained.
<table>
<thead>
<tr>
<th>Fusion algorithm</th>
<th>MSE</th>
<th>PSNR</th>
<th>Entropy</th>
</tr>
</thead>
<tbody>
<tr>
<td>WT</td>
<td>0.4622</td>
<td>51.51</td>
<td>7.3668</td>
</tr>
<tr>
<td>HIS</td>
<td>0.4543</td>
<td>51.58</td>
<td>7.6208</td>
</tr>
<tr>
<td>PCA</td>
<td>0.4166</td>
<td>51.96</td>
<td>7.6934</td>
</tr>
<tr>
<td>Modified PCA</td>
<td>0.4104</td>
<td>52.03</td>
<td>7.6948</td>
</tr>
</tbody>
</table>

Table 4.1 Comparison of different Fusion algorithms

From the experimental results as shown in Table 4.1, it can be observed that the values of Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Entropy of the fused image generated by our Modified PCA algorithm are greater than the values for the fused image generated by other algorithms like HIS and traditional PCA.

V. CONCLUSION

A method to optimize image fusion using feature matching based on Modified Principle Component Analysis is proposed here. Even though pixel level fusion methods result in spatial distortions, proposed method demonstrates superior results with respect to state of the art fusion methods. Our fusion technique proves to be better than the existing techniques proposed in recent literatures, in terms of the information content of the resultant fused image. Comparison of quality parameters clearly shows that the proposed method outperforms many existing algorithms for the fusion of Panchromatic (PAN) and Multispectral (MS) images.

REFERENCES


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