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An efficient PAN sharpening technique by merging two hybrid approaches

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Abstract

To improve the spatial quality in multispectral satellite images by injecting high spatial details from the panchromatic image using two hybrid techniques namely local variation+contourlet transform(local variation+CT) and Adaptive Principal Component Analysis +Contourlet transform(APCA+CT). This process of injecting information from the high spatial resolution panchromatic image into the low spatial resolution multispectral image to get a high spatial and spectral quality satellite image is known as Pan-Sharpening. The final pan-sharpened image is required to retain the natural color of the multi-spectral input image with minimum spectral distortion and enhanced spatial details of the panchromatic image. The proposed technique by merging two hybrid approaches performs better than the existing techniques. The performance of this proposed fusion technique is highlighted by comparing with conventional techniques like PCA, PCA+CT, APCA, APCA+CT in terms of ERGAS and universal image quality index, Q.

Keywords: APCA; CT; Pan Sharpening; ERGAS

1. Introduction

With the launch of high-resolution satellites, IKONOS and Quick Bird images of various spatial and spectral characteristics have been obtained. The panchromatic (Pan) image is usually acquired with the maximum resolution allowed by the imaging sensor and the data link throughout, and hence contains detailed geometric features, while the multispectral (MS) data are acquired with a coarser spatial resolution (typically two or four times lower) because of the signal-to-noise ratio -constraints and the transmission bottleneck, and contain a rich spectral information. After being received at the ground stations, the Pan image may be merged with the MS bands to enhance their spatial resolution. This process is called PAN-SHARPENING. In many remote sensing and mapping applications, pan-sharpening is an important issue for the purpose of photo analysis, feature extraction, modeling, and classification. In this paper we perform pan-sharpening by merging two hybrid approaches local variation+CT and APCA+CT [1, 3]. The PCA approach which replaces the first principal component with the Pan image may result in spectral distortion. The adaptive PCA approach provides efficient spectral transformation between the two images by selecting the best principal component to be replaced by the Pan image with high spatial resolution [1]. The selection is facilitated by measuring a statistical measure, the correlation coefficient between the PAN image and the different principal component images. The spatial transformation is brought about by making use of the Contourlet transform[2,4].The contourlet transform is preferred to the wavelet transform due to its

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advantage of representing directional information efficiently and capturing intrinsic geometrical structures of objects which plays a major role in remote sensing images. The images used are IKONOS, SPOT and LANDSAT satellite images. A fusion method merging two hybrid pan sharpening techniques is proposed in this paper and its performance is highlighted in terms of ERGAS and universal image quality index. The two hybrid techniques used are Local variation+CT and APCA+CT.

2. Implementation

2.1. Proposed method [1], [3]

The pan sharpening technique proposed in this paper merges two hybrid pan-sharpening techniques namely Local variation + CT and APCA + CT. In **[3]** a fusion technique using IHS transform and Local variation was suggested. The fused image with Local variation shows high spectral quality. The fused image with IHS shows better spatial quality than local variation. The merged image using these two approaches shows the best visual effect and provides high spatial quality, as well as the maximum resemblance to natural color, particularly in the green vegetation areas. Since APCA+ CT performs better than IHS transform in terms of both spatial and spectral quality, and since CT helps increase the spatial quality of local variation algorithm, a fusion technique merging APCA+CT and Local variation+ CT has been proposed and is found to give better results than the existing techniques.

2.2. Block Diagram and description

The proposed method is implemented in three steps.

i) Algorithm 1 which implements the local variation + CT technique.

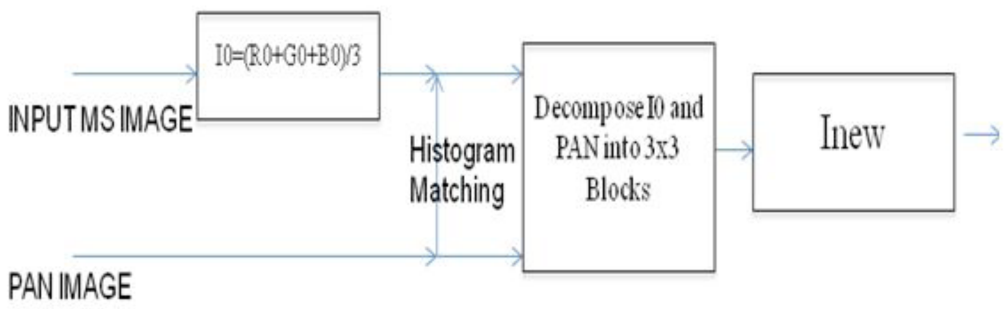

Fig 1. Algorithm1

The input images are the MS image which consists of different bands and the high spatial resolution panchromatic image.

The intensity component of the input MS image is calculated by using the formula

$$I0=(R+G+B)/3 \qquad (1)$$

Where R,G and B are the red, green and blue components of the color image.

Histogram match is applied to the Pan image according to I0 to obtain the modified-Pan image.

Then decompose the modified Pan Image and I0 into image blocks with the size 3x3. This decomposition into blocks helps in rapid execution compared to the transform based methods.

The new intensity component Inew is calculated from the modified pan image and I0 blocks using the formula

$$I_{new}(i,j) = E_0[I_0(i,j)] + \{Pan(i,j) - E_0[Pan(i,j)]\}$$

(2)

Where

E [・] is the mathematical expectation.

Q is a local area which contains 3 × 3 image blocks and is centered at the image block that includes the pixel (i, j).

Finally the merged image F1 is achieved using the formula

$$\begin{bmatrix} R_F \\ G_F \\ B_F \end{bmatrix} = \begin{bmatrix} R_0 + (\mathrm{Pan} - I_0) \\ G_0 + (\mathrm{Pan} - I_0) \\ B_0 + (\mathrm{Pan} - I_0) \end{bmatrix} \tag{3}$$

Where

RF, GF, BF and R0, G0, B0 are the corresponding values of R, G, B channels of the fused image and the original MS image, respectively.

ii) Algorithm 2 which implements APCA+CT technique

The Adaptive PCA in combination with contourlet transform is applied to the input MS and Panchromatic images is explained in section 3.4.Let the resultant image F2.

iii)Algorithm 3 which merges the above two methods to get a high definition pan sharpened image

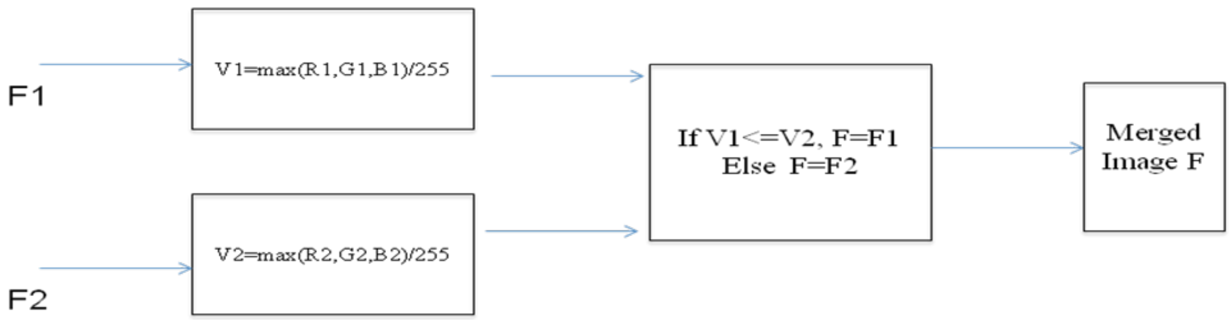

Fig. 2. Algorithm 3

Algorithm 3 is implemented in HSV color space. In HSV color space the value component for a pixel in color image is defined as

V=max(R, G, B)/255. (4)

The value component is calculated for the two merged images F1 and F2. Let the value components of F1 and F2 are V1 and V2 respectively. Then,

The merged image F is obtained by choosing each pixel either from F1 or F2 according to the following rule.

$$F(i,j) = \begin{Bmatrix} F_1(i,j) & V_1(i,j) \le V_2(i,j) \\ F_2(i,j) & V_1(i,j) \ge V_2(i,j) \end{Bmatrix} \tag{5}$$

2.3 Implementation

First step is to calculate the intensity component I_0 of the MS image. The Pan image is histogram matched according to I_0.The modified Pan image and intensity component I_0 are decomposed into image blocks of size 3x3. The new intensity component is calculated according to the formula given in (2).The merged image F1 is achieved by the formula (3).APCA+CT is applied to the input MS and Pan images to get merged image F2.The value components for F1 and F2 are calculated by (3).The final merged image F is achieved according to the rule given by (4).

3. Existing techniques

3.1 Principal component analysis (PCA)

The first step involves calculating the principal components (PC) for the input multispectral bands. Then apply the matching between the PC^1 and PAN image to obtain a modified-Pan image. The other principal components are unaltered. Inverse PCA is applied to the modified-pan image and the principal components other than PC^1 to obtain a high spatial resolution pan-sharpened multispectral image.

3.2 Adaptive principal component analysis (APCA)

The first step is to perform standardization on the input MS bands using two approaches namely
a) Each band should have zero mean and unit variance. b) Each band should have only zero mean.
Then PCA transformation is performed on the standardized MS image. The cross-correlation (CC) coefficient is calculated between the PAN and the PC images. The PC having the highest absolute cross correlation is selected for histogram matching. The Pan image is inverted if the sign of the CC of the selected PC is negative. The Pan image is histogram matched with the selected PC image. Inverse APCA is applied to the modified Pan image and the other PCs of the same normalized method. The obtained image is a high spatial resolution pan-sharpened multispectral image.

3.3 PCA +CT [1, 2]

The first step is to perform a PCA transformation along the spectral axis for determining PC^1 and other principal components. The PAN image is histogram matched to the PC^1 image for injection of high detailed information. Apply the CT spatial transformation along the spatial dimension of the PC^1image and the PAN image. Replace only the detail contourlet coefficients of the PC^1 image by the detail contourlet coefficients obtained by transformation of the histogram matched PAN image. Perform inverse spatial transformation i.e. inverse contourlet transform. Perform inverse spectral transformation i.e. inverse PCA to get the final pan-sharpened image.

3.4 APCA+CT [1, 2]

The first step is to perform an APCA transformation along the spectral axis for determining selected PC and other principal components. The PAN image is histogram matched to the selected PC image for injection of high detailed information. Apply the CT spatial transformation along the spatial dimension of the PC image and the PAN image. Replace only the detail contourlet coefficients of the PC image by the detail contourlet coefficients obtained by transformation of the histogram matched PAN image. Perform inverse spatial and spectral transformations to obtain the pan-sharpened image.

4. Results and discussion

In all the datasets taken, the MS and pan images are registered and the MS image is resampled to have the same size as the pan image. The results are explained both quantitatively and analytically using tabular columns and discussion respectively [6].The algorithms have been implemented using MATLAB 7.1.

4.1 Results for IKONOS dataset

The IKONOS dataset comprises of one panchromatic image and four multispectral bands namely blue band, green band, red band and near IR band whose wavelengths fall within the wavelength range of the Panchromatic image. The images are of size 364x443 and show the area of Wisconsin, Madison, USA.

Fig.3.(from top to bottom)Input images-blue band, green band, red band, near IR band, PAN image,MS image, Output images-APCA,PCA+CT,PCA,APCA+CT.

Fig.4 Proposed technique

4.2. Quantitative analysis

The performance of all the pan sharpening methods discussed are compared in terms of two performance indexes namely ERGAS and Q. The Ideal value of ERGAS is 0 and that of Q is 1. In this section the results of four image datasets namely; one IKONOS dataset, one SPOT dataset and two LANDSAT datasets, for different Pan-Sharpening methods are tabulated.

Input	**PCA**		**APCA**		**PCA+CT**		**APCA+CT**		Proposed method	
	ERGAS	Q	ERGAS	Q	ERGAS	Q	ERGAS	Q	ERGAS	Q
SPOT	9.5003	0.9031	7.4489	0.9691	6.5065	0.9604	6.5005	0.9768	3.8245	0.9918
IKONOS	1.6052	0.9701	2.1132	0.969	1.5163	0.9797	2.0312	0.971	1.5174	0.9798
LANDSAT1	12.611	0.9723	7.9048	0.9837	12.3037	0.975	7.8565	0.9842	2.8414	0.9981
LANDSAT2	5.9869	0.949	5.9296	0.9492	5.9148	0.9519	5.8535	0.9526	4.8888	0.9715

Table.1. Comparison of various PAN sharpening methods

4.3 Discussion

From the results it can be observed that the PCA technique results in spectral distortion which is highlighted with a blue box in the SPOT dataset. The APCA method helps to reduce the spectral distortion. The CT further helps to represent the directional and spatial information efficiently. The ERGAS and Q values are used as performance indexes. The ERGAS value is minimum and the Q value is maximum for all the datasets when the proposed method has been implemented. Hence, the proposed method which merges two hybrid approaches gives the best results in terms of both visual quality and performance measures.

5. Conclusion

The Pan-sharpening techniques help to make the best use of satellite images by fusing the high spectral information from the multispectral image and the high spatial information from the panchromatic image to produce a high spatial and spectral resolution pan-sharpened image. An efficient pan-sharpening technique based on merging two fusion approaches is proposed and is found to give better results than PCA, APCA, PCA+CT, APCA+CT, PCA+WT and APCA+WT. The final pan-sharpened image is found to retain the natural color of the multi-spectral input image producing minimum spectral distortion and the spatial details of the panchromatic image as proved with the performance measures ERGAS and Q.

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