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Satellite Image Fusion using IHS and PCA Method

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Abstract

Image fusion is the process that combines information from multiple images of the same scene. The result of image fusion is a new image that retains the most desirable information and characteristics of each input image. The main application of image fusion is merging the grey-level high-resolution panchromatic image and the coloured low-resolution multispectral image. It has been found that the standard fusion methods perform well spatially but usually introduce spectral distortion. To overcome this problem, fusion methods such as IHS and PCA are used. In this paper experimental result of IHS and PCA are given.

***Index Terms*— Image Fusion, IHS, PCA.**

INTRODUCTION

I.MULTI-SENSOR

Multi-sensor fusion has become an area of intense research and development activity in the past few years. Multi-sensor fusion refers to the synergistic combination of different sources of sensory information into a single representational format. The information to be fused may come from multiple sensory devices monitored over a common period of time, or from a single sensory device monitored over an extended time period. Multi-sensor fusion is a very broad topic that involves contributions from many different it includes academic researchers in mathematics, physics, and engineering, defense agencies, defense laboratories, corporate agencies and corporate laboratories.

Multi-sensor fusion can occur at the signal, image, feature, or symbol level of representation.

Signal-level fusion refers to the direct combination of several signals in order to provide a signal that has the same general format as the source signals.

Image-level fusion generates a fused image in which each pixel is determined from a set of pixels in each source image. Clearly, image-level fusion, or image fusion, is closely related to signal-level fusion since an image can be considered a two-dimensional (2D) signal.

Feature level fusion first employs feature extraction on the source data so that features from each source can be jointly employed for some purposes. A common type of feature-level fusion involves fusion of edge maps.

Symbol-level fusion allows the information from multiple sensors to be effectively combined at the highest level of abstraction. The symbols used for the fusion can be originated either from processing only the information provided or through a symbolic reasoning process that may include a priori information. A common type of symbol-level fusion is decision fusion.

Most common sensors provide data that can be fused at one or more of these levels. The different levels of multi-sensor fusion can be used to provide information to a system that can be used for a variety of purposes.

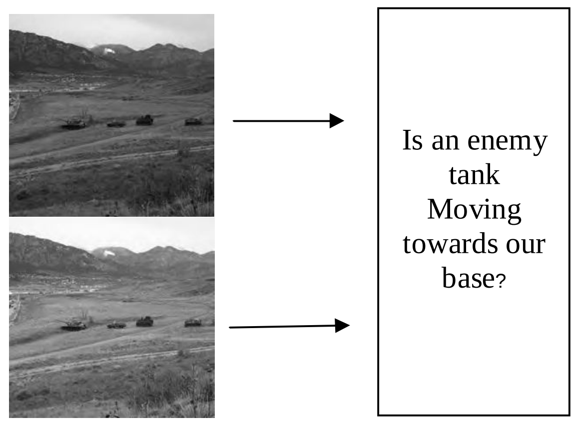

Fig 1.1: Decision fusion using images.

II.SATELLITE IMAGERIES

Satellite imageries are provided in both panchromatic and multispectral images. The former have higher spatial resolutions while the latter have relatively lower spatial resolutions but are rich in spectral information. The two types of images have complementary features of spatial and spectral resolutions as such could be fused or merged to produce a better imagery that would be used in land use classification, cadastral feature analysis, change detection, maps updates, hazards monitoring and many other land related applications as well as for general quantitative image analysis.

Due to the advances in satellite technology, a great amount of image data has been available and has been widely used in different remote sensing applications. Thus, image data fusion has become a valuable tool in remote sensing to integrate the best characteristics of each sensor data involved in the processing.

III.IMAGE QUALITY ASSESSMENT

Image quality assessment is an important but difficult issue in image processing applications such as compression coding and digital watermarking. For a long time, mean square error (MSE) and peak signal-to-noise ratio (PSNR) are widely used to measure the degree of image distortion because they can represent the overall grey-value error contained in the entire image, and are mathematically tractable as well. In many applications, it is usually straightforward to design systems that minimize MSE or PSNR.

MSE works satisfactorily when the distortion is mainly caused by contamination of additive noise. However the problem inherent in MSE and PSNR is that they do not take into account the viewing conditions and visual sensitivity with respect to image contents. With MSE or PSNR, only grey-value differences between corresponding pixels of the original and the distorted version are considered. Pixels are treated as being independent of their neighbors. Moreover, all pixels in an image are assumed to be equally important. As a matter of fact, pixels at different positions in an image can have very different effects on the human visual system (HVS).

METHODOLOGY

I.IMAGE REGISTRATION (IR)

Image Registration is the process that transforms several images into the same coordinate system. For example, given an image, several copies of the image are out-of-shape by rotation, shearing, twisting, etc. With the given image as reference, Image Registration can align the out-of-shape images to be the same as the given image. Therefore, Image Registration is essential pre-processing operation for image fusion.

Steps in image registration

Image registration works usually in four steps.

I. Feature detection: Salient and distinctive objects (corners, line intersections, edges, contours, closed boundary regions, etc.) are manually or, preferably, automatically detected. For further processing, these features can be represented by their point representatives (distinctive points, line endings, centers of gravity), called in the literature control points.

II. Feature matching: In this step, the correspondence between the features detected in the sensed image and those detected in the reference image is established. Various feature descriptors and similarity measures along with spatial relationships among the features are used for that purpose.

III. Transform model estimation: The type and parameters of the so-called mapping functions, aligning the sensed image with the reference image, are estimated. The parameters of the mapping functions are computed by means of the established feature correspondence.

IV. Image resampling and transformation: The sensed image is transformed by means of the mapping functions. Image values in non-integer coordinates are estimated by an appropriate interpolation technique.

II.IMAGE RESAMPLING (RS)

Resampling is the mathematical technique used to create a new version of the image with a different width and/or height in pixels. Increasing the size of an image is called upsampling; reducing its size is called downsampling.

Resampling Methods

I. Nearest Neighbor:

Nearest neighbor interpolation determines the grey level from the closest pixel to the specified input coordinates, and assigns that value to the output coordinates. Or simply said, NN uses the digital value from the pixel in the original image which is nearest to the new pixel location in the corrected image.

1. This method is considered the most efficient in terms of computation time.

2. Because it does not alter the DN (digital number, or grey level) value, a nearest neighbor interpolation is preferred if subtle variations in the grey levels need to be retained, if classification will follow the registration, or if a classified image

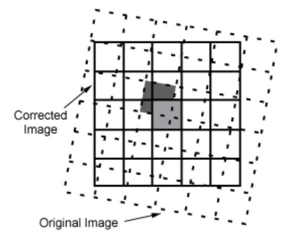

Fig 3.1: Nearest Neighbor

II. Bilinear interpolation:

Bilinear interpolation determines the grey level from the weighted average of the four closest pixels to the specified input coordinates, and assigns that value to the output coordinates, or BI takes a weighted average of 4 pixels in the original image nearest to the new pixel location.

1. This method generates an image of smoother appearance than nearest neighbor, but the grey level values are altered in the process, resulting in blurring or loss of image resolution (equivalent to a low pass filtering). The image is less “blocky” but linear features still remain sharp.

2. Because of these changes in the grey level values, any image classification processes should be performed before the interpolation.

3. Bilinear interpolation requires 3 to 4 times the computation time of the nearest neighbor method.

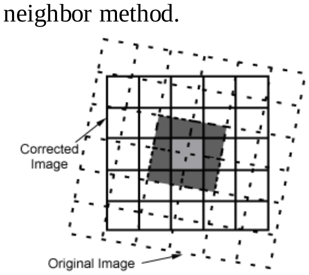

Fig 3.2: Bilinear interpolation

III. Cubic convolution:

Cubic convolution determines the grey level from the weighted average of the 16 closest pixels to the specified input coordinates, and assigns that value to the output coordinates or CC calculates a distance weighted average of a block of 16 pixels from the original image which surround the new output pixel location.

1. As with bilinear interpolation this method results in completely new pixel values. This method is closer to the perfect sin(x)/x resample than nearest neighbor or bilinear interpolation.
2. The image is theoretically slightly sharper than that produced by bilinear interpolation (although this statement is not confirmed by our experiments), and it does not have the disjointed appearance produced by nearest neighbor interpolation.
3. Because the grey level values are altered by this method, any image classification processes should be performed before the interpolation.
4. Cubic convolution requires about 10 times the computation time required by the nearest neighbor method.

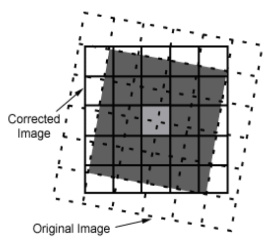

Fig 3.3: Cubic convolution

IV. Image Fusion Schemes

In this section, two type of image fusion schemes are used which, including intensity-hue-saturation (IHS) transform fusion, principal component analysis (PCA) fusion. The fusion of panchromatic (PAN) and multispectral (MS) satellite images is done in this paper. The fused image is requested to combine the high-resolution spatial information of the PAN and the color information of the MS image.

Panchromatic and multispectral image fusion

Consider that the PAN and MS images are acquired from a remote Quick Bird sensor. Quick Bird is a commercial earth observation satellite. It offers MS and PAN imagery characterized by 4-meter and 1-meter spatial resolution respectively. The PAN image is without color information while the MS image covers three spectral bands (MS1=red, MS2=green, MS3=blue) as shown in Table. In order to take benefit of the high spatial information of the PAN image and the essential spectral information of the MS image, HIS and PCA based image fusion method is used in this paper.

Satellite	Sensor	Bands	Spectral Range	Scene Size	Pixel Res
QuickBird-2	Multi-spectral	1=Blue	450 - 520 µm	16.5 km X 16.5 km	2.44 - 2.88 meter
		2=Green	520 - 600 µm		
		3=Red	630 - 690 µm		
		4=NIR	760 - 900 µm		
	Panchromatic	Pan	760 - 850 µm		61 - 72 cm

Table: Sensor of Quick Bird Satellite Image

Standard IHS fusion method

IHS method consists on transforming the R, G and B bands of the multispectral image into IHS components, replacing the intensity component by the panchromatic image, and performing the inverse transformation to obtain a high spatial resolution multispectral image. The three multispectral bands, R, G and B, of a low resolution image are first transformed to the IHS color space as

$$\begin{pmatrix} I \\ V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \qquad (1)$$

$$H = tan^{-1}\left(\frac{V_2}{V_1}\right) \qquad (2)$$

$$S = \sqrt{V_1^{\,2} + V_2^{\,2}} \qquad (3)$$

Where I, H, S components are intensity, hue and saturation, nd V1 and V2 are the intermediate variables. Fusion proceeds by replacing component I with the panchromatic high-resolution image information, after matching its radiometric information with the component I (Figure 1). The fused image, which has both rich spectral information and high spatial resolution, is then obtained by performing the inverse transformation from

IHS back to the original RGB space as

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1 & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{1}{\sqrt{6}} & -\frac{1}{2} \\ \frac{11}{\sqrt{2}} & -\frac{2}{\sqrt{6}} & 0 \end{pmatrix} \begin{pmatrix} I \\ V_1 \\ V_2 \end{pmatrix} \quad (4)$$

The main steps, illustrated in Figure, of the standard HIS fusion scheme are

1. Perform image registration (IR) to PAN and MS, and resample MS
2. Convert MS from RGB space into IHS space.
3. Match the histogram of PAN to the histogram of the I component.
4. Replace the I component with PAN.
5. Convert the fused MS back to RGB space

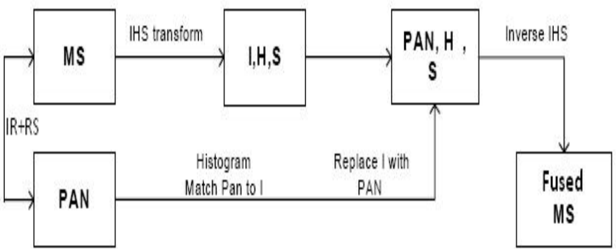

Figure: Standard IHS fusion scheme.

Standard PCA fusion method

An alternative to IHS-based method is principal component analysis (PCA). PCA is a general statistical technique that transforms multivariate data with correlated variables into one with uncorrelated variables. These new variables are obtained as linear combinations of the original variables. PCA has been widely used in image encoding, image data compression, image enhancement and image fusion. In the fusion process, PCA method generates uncorrelated images (PC1, PC2, …, PCn, where n is the number of input multispectral bands). The first principal component (PC1) is replaced with the panchromatic band, which has higher spatial resolution than the multispectral images. Afterwards, the inverse PCA transformation is applied to obtain the image in the RGB color model as shown in Figure. Therefore, the PCA fusion scheme is similar to the IHS fusion scheme.

The main steps, illustrated in Figure, of the PCA fusion scheme are

1. Perform IR to PAN and MS, and resample MS.
2. Convert the MS bands into PC1, PC2, PC3,… by PCA transform.
3. Match the histogram of PAN to the histogram of PC1.
4. Replace PC1 with PAN.
5. Convert PAN, PC2, PC3, … back by reverse PCA.

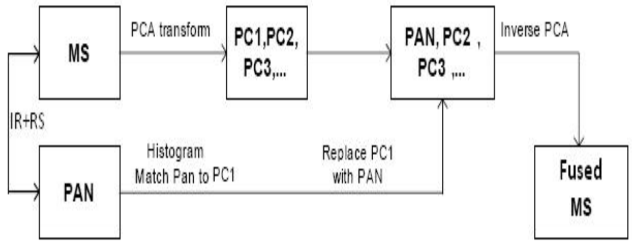

Figure: Standard PCA fusion scheme.

RESULT

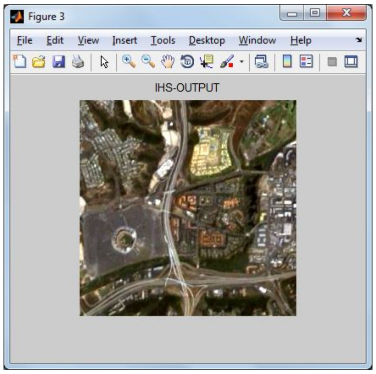

Figure: Image Fusion of Panchromatic and Multispectral Image Using IHS Method

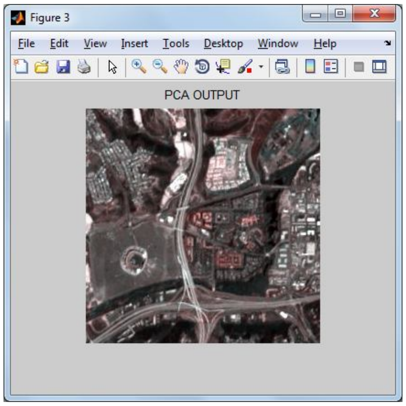

Figure: Image Fusion of Panchromatic and Multispectral Image Using PCA Method

CONCLUSION

In this paper, image fusion is addressed along with its quality analysis using Mean Square Error, Peak Signal -to- Noise Ratio. A two different fusion schemes have been proposed in terms of the fusion application: the panchromatic (PAN) and multispectral (MS) image fusion. In the former application, the object of image fusion is generating a new image that enjoys the high-spatial resolution of the PAN images and the color information of the MS image. Schemes includes the intensity-hue-saturation (IHS) fusion scheme, principle component analysis (PCA) fusion scheme, from the experimental results we can conclude that the PCA scheme outperforms the IHS scheme.

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