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Evaluation of Fusion Methods: Pan-Sharpening Methods

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Abstract: ***Image fusion in the field of remote sensing deals with combination of multispectral and panchromatic image. The idea of such combination is to derive best information out of it. A multispectral image is spectral rich whereas a panchromatic image is spatially sound so their combination gives better information in terms of best spatial and spectral parameters. This Paper aims at evaluating various fusion methods available so far and helps to analyze the comparisons between them. To determine the best approach it must have high computational efficiency, preserve the high spatial resolution and minimize the color distortion.***

Keywords: Image Processing, Image Fusion, Panchromatic image, Multispectral Image**.**

1. Introduction

Satellites often capture two different types of images: multispectral and panchromatic.

1. A multispectral image (MS) is a four-band image (R, G, B, and IR) which has low spatial resolution but accurate color data.
2. A panchromatic image is a gray scale image which has higher spatial resolution.

In remote sensing various types of sensors are available like space borne and air borne. The images those who are taken by using those sensors can be classified into two types as Panchromatic and Multispectral images. The panchromatic images are taken by using SAR radar which is having the wavelength of 1 Millimeter to 1 Meter. SAR sensor is a wavelengths going to combine to get a composite image and each wavelength will displayed as a Red, Green and Blue in the final image. By combining different wavelength images in various methods helps to find the features from earth surface. The multispectral images are captured by receiving the reflectance of the microwaves from the earth surface. [1]

Image Fusion

Image fusion is the process that combines information from multiple images of the same scene. These images may be captured from different sensors, acquired at different times, or having different spatial and spectral characteristics. The object of the image fusion is to retain the most desirable characteristics of each image. With the availability of multisensory data in many fields, image fusion has been receiving increasing attention in the researches for a wide spectrum of applications. We use the following four examples to illustrate the purpose of image fusion:

(1) In optical remote sensing fields, the multispectral (MS) image which contains color information is produced by three sensors covering the red, green and blue spectral wavelengths. Because of the trade-off imposed by the physical constraint between spatial and spectral resolutions, the MS image has poor spatial resolution. On the contrast, the panchromatic (PAN) images has high spatial resolution but without color information. Image fusion can combine the geometric detail of the PAN image and the color information of the MS image to produce a high-resolution MS image. Fig. 1.1 shows the MS and PAN images provided by IKONOS, a commercial earth observation satellite, and the resulting fused image [1].

(2) As the optical lenses in CCD devices have limited depth-of focus, it is often impossible to obtain an image in which all relevant objects are in focus. To achieve all interesting objects in focus, several CCD images, each of which contains some part of the objects in focus, are required. The fusion process is expected to select all focused objects from these images.

(3) Sometimes the "in focus" problem is due to the different characteristics of different types of optical sensors, such as visual sensors, infrared sensors, Gamma sensors and X-Ray sensors. Each of these types of sensors offers different information to the human operator or a computer vision system.

(4) In medical imaging, different medical imaging techniques may provide scans with complementary and occasionally conflicting information, such as magnetic resonance image (MRI), computed tomography (CT), positron emission

tomography (PET), and single photon emission computed tomography (SPECT).

2. Literature Review

The image fusion is performed at three different processing levels which are pixel level, feature level and decision level according to the stage at which the fusion takes place. There are many image fusion methods that can be used to produce high resolution multispectral images from a high resolution pan image and low resolution multispectral images. [29]

This paper deals with traditional algorithms for image fusion at pixel level. There are various methods that have been developed to perform image fusion.

(1) Intensity-hue-saturation (IHS) transform based fusion
(2) Principal component analysis (PCA) based fusion
(3) Brovey transform
(4) Wavelet transform

Multisensor data fusion has become a discipline to which more and more general formal solutions to a number of application cases are demanded. Several situations in image processing simultaneously require high spatial and high spectral information in a single image; especially in the field of remote sensing. However, the instruments are not capable of providing such information either by design or because of observational constraints. One possible solution for this is data fusion. Image Fusion techniques, though initially developed as an image quality enhancement technique, finds practical application in medical field and satellite imaging. The concept of multivariate image fusion now promotes research into fusing simple optical images, medical images and satellite images ranging through the multi spectra. For example, in satellite imaging, two types of images are available. Panchromatic image acquired by satellites is transmitted with the maximum resolution available and the multispectral data are transmitted with coarser resolution. This will be usually, two or four times lower. At the receiver station, the panchromatic image is merged with the multispectral data to convey more information. Many methods exist to perform image fusion. The very basic one is the high pass filtering technique. Later techniques are based on DWT, uniform rational filter bank, and pyramidal methods. Image fusion methods can be broadly classified into two - spatial domain fusion and transform domain fusion. The fusion methods such as averaging method, Brovey method, principal component analysis PCA) and high pass filtering based technique are examples of spatial domain fusion methods. Here the high frequency details are injected into upsampled version of MS images. The disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image. Spectral distortion becomes a negative factor while we go for further processing, such as classification problem, of the fused image. The spatial distortion can be very well handled by transform domain approaches on image fusion. The multi resolution analysis has become a very useful tool for analyzing remote sensing images. The discrete wavelet transform has become a very useful tool for fusion. Some other fusion methods are also there, such as pyramid based, curvelet transform based etc. These methods show a better performance in spatial and spectral quality of the fused image compared to other spatial methods of fusion.

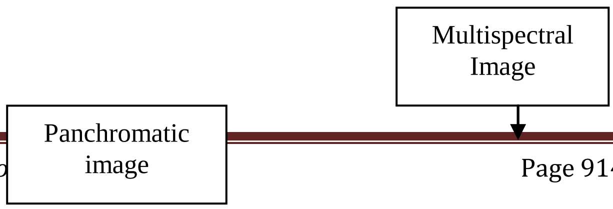
A broad list of applications of image fusion can be the following:

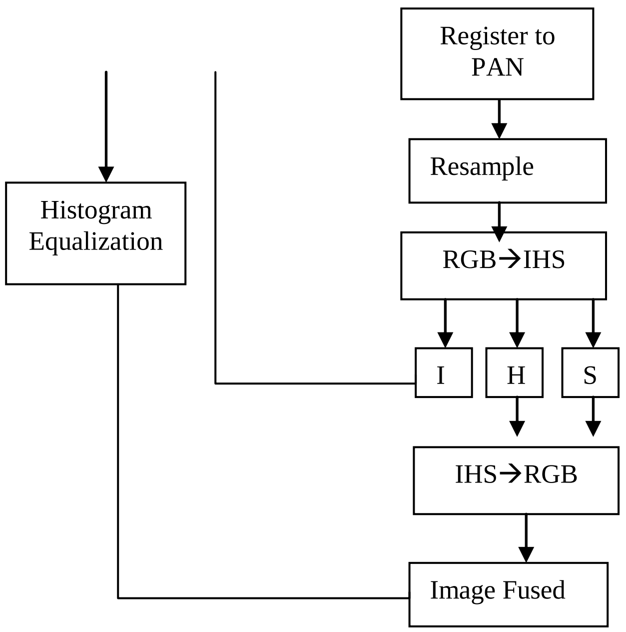
• Image Classification
• Aerial and Satellite imaging
• Medical imaging
• Robot vision
• Concealed weapon detection

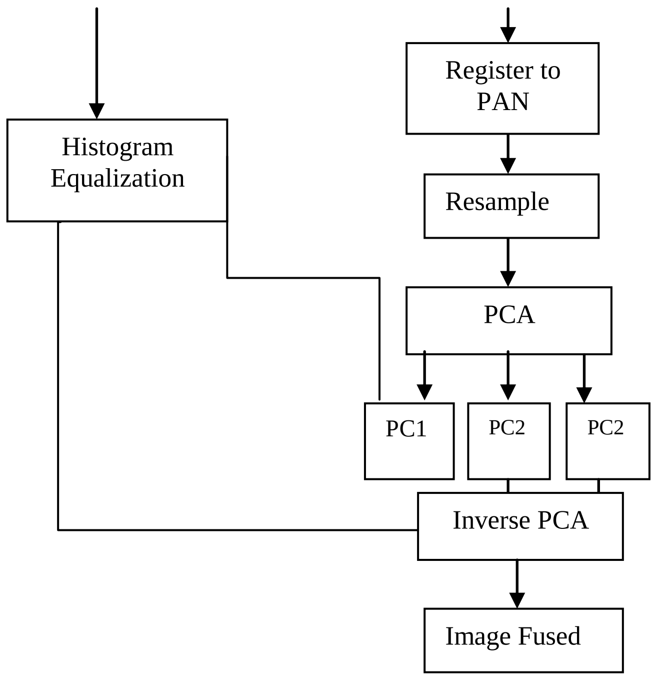
3. Image fusion methods

3.1 HIS

The classical image fusion techniques include intensity-hue-saturation transform technique (IHS). IHS is a common way of fusing high spatial resolution, single band, pan image and low spatial resolution, multispectral remote sensing image. The R, G and B bands of the multispectral image are transformed into IHS components, replacing the intensity component by the pan image, and performing the inverse transformation to obtain a high spatial resolution multispectral image (see Fig.). IHS can enhance spatial details of the multispectral image and improve the textural characteristics of the fused image, but the fusion image exist serious spectral distortion. The IHS transform is used for geologic mapping because the IHS transform could allow diverse forms of spectral and spatial landscape information to be combined into a single data set for analysis. Although the IHS method has been widely used, the method cannot decompose an image into different frequencies in frequency space such as higher or lower frequency. Hence the IHS method cannot be used to enhance certain image characteristics. The color distortion of IHS technique is often significant. To reduce the color distortion, the PAN image is matched to the intensity component before the replacement or the hue and saturation components are stretching before the reverse transform. Also propose a method that combines a standard IHS transform with FFT filtering of both the pan image and the intensity component of the original multispectral image to reduce color distortion in the fused image. Schetselaar modified IHS and presented a new method that preserves the spectral balance of the multispectral image data and modulates the IHS coordinate uniformly. The method takes the limits in the representation of color of the display device into account, which aids in compromising the amount and spatial distribution of the over-range pixels against contrast in intensity and saturation. There are other improvements about IHS such as using wavelet. Also, Image fusion based on the nonsubsampled Contourlet transform (NSCT) and IHS achieved increased in retaining the spectral information and spatial details, and better integration effect with IHS transform, the segment based fusion was developed specifically or a spectral characteristics preserving image merge coupled with a spatial domain filtering . With experiment on SPOT and TM remote sensing images demonstrates that the IHS fusion method can improve the fused result with a viewpoint of synthetically quality evaluation. It is a practical and effective method for these two types of images .







3.2 Brovey Transform

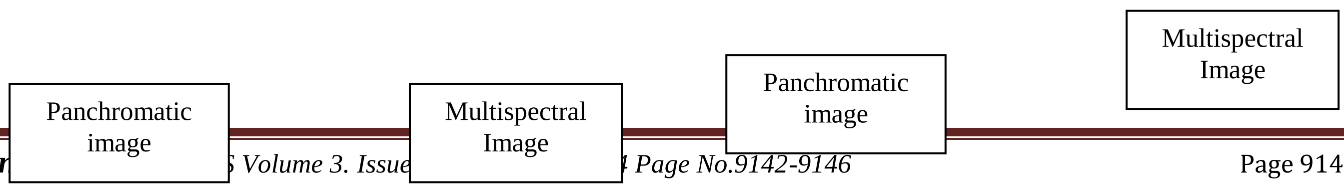
The Brovey transform image fusion technique uses a mathematical combination of the MS bands and PAN band. Each MS band is multiplied by a ratio of the PAN band divided by the sum of the MS bands. The fused R, G, B bands. Many researchers used the BT to fuse a RGB image with a high resolution image. The BT image fusion is used to combine Landsat TM and radar SAR (ERS-1) images and successful for Spot pan fusion. The BT is limited to three bands and the multiplicative techniques introduce significant radiometric distortion. In addition, successful application of this technique requires an experienced analyst for the specific adaptation of parameters. This precludes development of a user-friendly automated tool

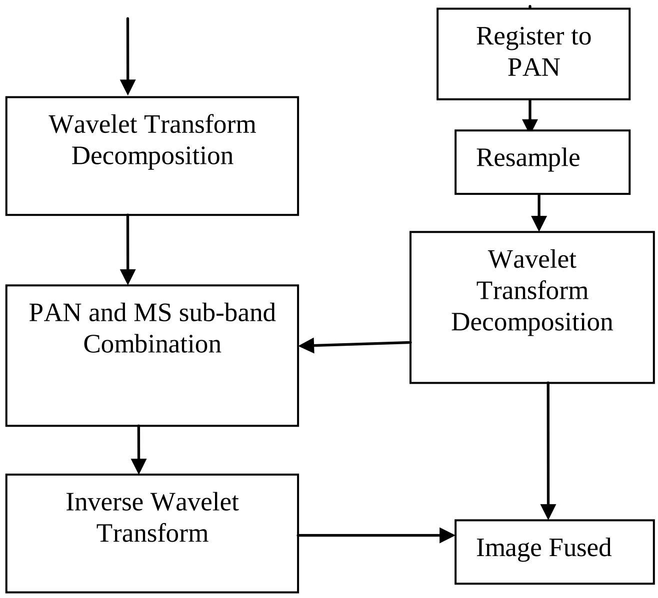
3.3 PCA

PCA transformation is a technique from statistics for simplifying a data set. It was developed by Pearson 1901 and Hotelling 1933, whilst the best modern reference is Jolliffe, 2002. The aim of the method is to reduce the dimensionality of multivariate data whilst preserving as much of the relevant information as possible. It translates correlated data set to uncorrelated dataset. By using this method, the redundancy of the image data can be decreased. One disadvantage of the use of PCA for image fusion is that you are selecting only the first eigenvector to describe your data set. Even though this eigenvector contains 90% of the shared information there is still some information that will not be evident in the final fused image. PCA performs well when compared to other image fusion techniques. PCA was superior to the simple averaging technique and the Morphological pyramid technique for the majority of the measures and only being inferior to the discrete wavelet transform.

3.4 Wavelet Transform

Wavelet theory is related to multi-resolution analysis theory. Since it was invented in 1980, many theoretical and application researches have been conducted. In recent years, wavelet transform has been introduced in image fusion domain, due to its multi-resolution analysis (MRA) characteristic. The traditional wavelet-based image fusion can be performed by decomposed the two input images separately into approximate coefficients and detailed coefficients then high detailed coefficients of the multi-spectral image are replaced with those of the pan image. The new wavelet coefficients of the multi-spectral image are transformed with the inverse wavelet transform to obtain the fusion multi-spectral image (see Fig.). The wavelet image fusion technique can improve the spatial resolution while preserve the spectral characteristics at a maximum degree .but the method discards low frequency component of the pan image completely, it may produce mosaic for the fusion image. When the images are smooth, without abrupt intensity changes, the wavelets work appropriately, improving the results of the classical methods. This has been verified with smooth images and also with medical images, where no significant changes are present. In this case, the type of images (remote sensing, medical) is irrelevant. Recently more studies propose hybrid schemes, which use wavelets to extract the detail information from one image and standard image transformations to inject it into another image, or propose improvements in the method of injecting information .





These approaches seem to achieve better results than either the standard image fusion schemes e.g. (IHS, than either the standard image fusion schemes (e.g. IHS, PCA) or standard wavelet-based image fusion schemes (e.g. substitution, addition); however, they involve greater computational complexity.

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