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Review on pan shapening techniques for multi-sensory remote sensing images

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ABSTRACT: *With the advent of numerous remote sensing sensors available for the researcher, the fusion of digital image data has become a valuable tool in remote sensing image evaluation. The review on data fusion fusion techniques with the availability of multisensor, multitemporal, Multiresolution and multifrequency image data from operational Earth observation satellite, is presented in this paper. Digital image fusion is a emerging research field at the leading edge of viz. Multi-spetral, Hyper-spectral, and Microwave technology based remote sensing sensors. Since data with different characteristics are combined, Fused images may provide increased interpretation capabilities and more reliable results. The objective in image fusion is to reduce uncertainty and minimize redundancy in the output image while maximizing relevant details particular to an application or task. It open-up doors for researcher all over the world being a rapidly developing area of research in remote sensing domain. This paper exhibits the pros and cons of mainly pixel based image fusion techniques, where it is evaluated primarily for vegetation analysis using remote sensing data.*
Keywords: *Image fusion, Multispectral ,Panchromatic, , Pixel level, Pansharpening .*

I. INTRODUCTION

A general definition of image fusion is given as 'Image fusion is the combination of two or more different images to form a new image by using a certain algorithm' (Genderen and Pohl 1994). It aims to integrate the spatial detail of a high-resolution panchromatic image (PAN) and the color information of a low-resolution multispectral (MS) image to produce a high-resolution MS image (hybrid product). Fused images provide more interpretation capabilities and more reliable results. The paper is structured in four sections. In the introduction a definition of image fusion is given which provides the concepts Involved. Following the introduction, the objectives and applications of image fusion is given that explains why and in which cases image fusion might be useful. Thereafter, the existing techniques are reviewed including the necessary processing performances followed by an overview of the evaluation criteria for fused images.

Image fusion is performed at three different processing levels according to the stage at which the fusion takes place:

1. Pixel
2. Feature
3. Decision level.

This paper explains mainly pixel based image fusion.

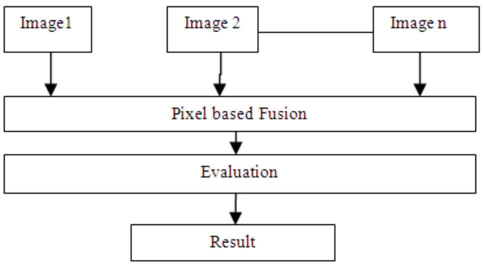

Fig1. Flow of Pixel level Fusion

2. Objectives and Applications of Image Fusion

Image fusion is done in order to:

-provide stereo-viewing capabilities for stereo photogrammetry
-enhance certain features not visible in either of the single data alone
-complement data sets for improved classifcation
- detect changes using multitemporal data

-substitute missing information (e.g. shadows-SAR, clouds-VIR) in one image with signals from another sensor image
- replace defective data.
-sharpen images and improve geometric corrections.

There are number of applications in which multisensor images are used to improve and enhance image interpretation like topographic mapping and map updating, land use, agriculture and forestry, snow-monitoring and geology, flood monitoring.

Data fusion can be applied to various type of data sets:
1. single sensor- single date e.g. a panchromatic Formosat image is fused with its equivalent multispectral image. Both these images are taken on same day by the single sensor [5].
single sensor- temporal (Weydahl 1993), e.g., the fusion of SAR multitemporal data used for change detection.
multi-sensor- temporal (Pohl and Genderen 1995), e.g., VIR/SAR image mapping-the images are taken at different dates.
single sensor- spatial (Cliche *et al.* 1985), e.g., high/ low resolution panchromatic/multi-spectral SPOT
multi-sensor- spatial (Chavez *et al.* 1991), e.g., fusion of high/low resolution SPOT/Landsat data.
single data- multi-sensor (Guyenne 1995), e.g., ERS-1/ERS-2-data is of same type but is taken through different sensors.

III. HISTORY

Data fusion is not a new technique. The concept of data fusion goes back to 1950's and 1960's[1]. A general introduction to multi-sensor data fusion was given by, Hall and Llinas in 1997 [2]. Burt [3] was one of the first to make use of Laplacian pyramid techniques in binocular image fusion. A new approach to image fusion based on hierarchical image decomposition was introduced by Burt and Adelson. Zhang in 2010[4] has listed current situation of pixel level image fusion by dividing those methods into three categories, i.e., component substitution technique, modulation based technique and multi-resolution analysis based technique according to fusion mechanism.

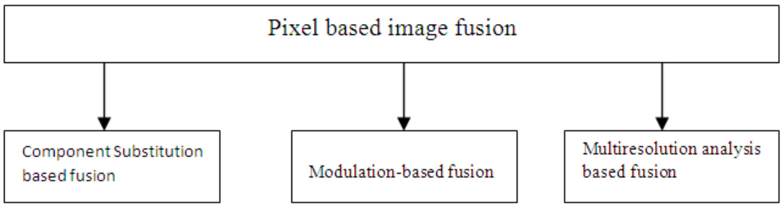

Fig.2 Three categories of pixel level image fusion

3.1 Modulation-based fusion technique: In Modulation-based fusion, the spatial details are modulated into the multispectral images by multiplying the multispectral images by the ratio of the panchromatic image to the synthetic image, which is a lower resolution version of the panchromatic image generally. Modulation based fusion algorithms include Brovey Transform fusion algorithm (Vrabel 2000),Smoothing Filter Based Intensity Modulation (SFIM) fusion algorithm (Liu, 2000) , High-pass filter (HPF) method (Chavez, 1991) in which a spatial High Pass Filter is used for extracting high frequency components, i.e. spatial detail, from the panchromatic image , then the spatial detail is injected into the low-resolution multi-spectral image, so as to produce a fused image with sharp high frequency characteristics[6].

3.2 Component substitution fusion technique: The Component Substitution fusion Technique consists of three main steps [4]:
Step 1: Forward transform is applied to the MS bands after they have been registered to the PAN band;
Step 2, A component of the new data space similar to the PAN band is replaced with the higher resolution band;
Step 3, Finally, inverse transform is taken to obtain the actual fused results.
The typical algorithms of component substitution fusion technique include IHS transform fusion algorithm (Carper, 1990, Shettigara, 1992, Chavez,1991).Other CS based algorithm include Gramschmidt algorithm,Principal component analysis Transform etc.

3.3 Multi-Resolution Analysis Fusion Technique: MRA-based fusion techniques (Amolins, et al. 2007) use multi-scale decomposition methods such as multi-scale wavelet (Núñez et al. 1999) and Laplacian pyramid (Aiazzi 2002) for decomposing multi-spectral and panchromatic images with different levels, and then spatial details are derived that are imported into finer scales of the multi-spectral images in the light of the relationship between the panchromatic and multi-spectral images, resulting in enhancement of spatial details.

MRA-based fusion techniques consist of three main steps:
1) MRA: Wavelet multi-resolution decomposition;
2) Fusion: Replacement of approximation coefficients of PAN by those of multispectral band; and
3) IMRA: Inverse multi-resolution transform.

Data fusion methods have been used for number of applications. Many researchers have used different datasets, evaluated traditionally used data fusion algorithms on these datasets and suggested improvement in the existing algorithm or developed a new algorithm for specific application [5]. A New technique has been proposed for fusion of Multispectral and Panchromatic Image of Quickbird in which FOCC (fourth-order correlation coefficient) is used as criterion to select PC and the relative entropy is used as criterion to reconstruct high-frequency detailed images [5]. An overview of archaeological sites recognition by different multi-resolution satellite has suggested that Pansharping method is satisfactory to detect the archaeological site. The spectral channels of SPOT5 and the panchromatic channel of SPOT5 are used [6]. In general, image fusion techniques can be categorized into two groups: Statistical/numerical-based techniques, such as Principal Component Analysis (PCA), and Color related techniques, such as Intensity-Hue-Saturation (IHS). The statistical-based fusion techniques were found to be more advantageous than the color-based techniques to fuse the ASTER-L1B and RADARSAT-1 SAR data [7]. For IKONOS Panchromatic and Multispectral data (PAN band at 1m spatial resolution and MS 4 bands at 4m spatial resolution) results with HPF and HPM were more satisfactory than with other techniques [8]. The difference in spatial resolution between the PAN and the MS mode may vary between 1:2 and 1:5. This ratio gets worse if data from different satellites are used. For example, the resolution ratio between Ikonos (pan mode) and SPOT 5 (multispectral mode) is 1:10. Data fusion techniques can also be evaluated for single sensor/single date fusion. For example, Ikonos or Quickbird panchromatic images are fused with the equivalent Ikonos or Quickbird multispectral image. However with the advent of new sensors, which are either only panchromatic (Worldview 1) or multispectral (Rapid Eye), it becomes very important to fuse multitemporal data from different sensors. The effectiveness and quality of evaluation techniques can be evaluated for multitemporal case also [9].

Agriculture is the main occupation of our country. It is always required to undertake a survey of our agricultural or vegetation land to determine how much area is occupied by forests or to determine annual production of grains. Spot Panchromatic Image, Landsat TM multi-spectral RS image and vector data are used to identify tree species. After a lot of experiments, it is found that integration of Principal Component Analysis and Brovey Transform is effective among many integration algorithms for Spot Panchromatic Image and Landsat TM multi-spectral RS image to identify tree species [10].

4. Data Fusion Methods

In the past, some pan-sharpening methods applying Multiresolution approaches are proposed, they use discrete wavelet transform (DWT), Laplacian pyramid , or à trous wavelet transform to images, and the detail spatial information from the PAN image is injected in the MS image. In recent years, some approaches use the PCA, Wavelet transform, Gram-Schmidt, HSV, HPF for fusion of images of forest or agricultural areas. A detailed description of these techniques is given below:

Wavelet Transform Fusion Method

Wavelet transform is based on a Multi-Resolution Analysis (MRA).Local features in signal processing can be easily detected by this method. The discrete wavelet transform (DWT) allows the image decomposition in different kinds of coefficients preserving the image information. Therefore, wavelet transform is suitable for performing data fusion tasks. However, the fusion image may suffer from ringing because it discards low frequency component of the panchromatic image completely [6].

Gram-Schmidt (G-S) transformation

The Gram-Schmidt (G-S) transformation is a common technique and its function is similar to the PC, also with the aim of minimizing redundancy. In GS transform, first, a PAN band simulated from the MS bands. Second, G-S transformation is implemented on the simulated panchromatic band and the spectral bands as the first band. In the next step the first Gram-Schmidt band is swapped with the panchromatic band. Eventually, the fused image is obtained by applying the inverse Gram-Schmidt transform [7].

Principal component analysis (PCA) transformation

PCA is a linear transformation of the multidimensional data. The data are transformed to a new coordinate system such that the first principal component (first coordinate) represents the largest variance by any projection, the second coordinate to the second largest variance, and so forth. PC1 is repkaced by HR image since it contains the information which is common to all bands while the spectral information is unique for each band.

HSV Transform

The main function of transform technique is to separate the spectral information into the Hue (H) and Saturation (S) components, and the Value (V) that represents the image brightness in which high values indicate brighter color (V) component. The process starts with the transformation of a RGB image to HSV color space. Subsequently, the value band replace with the panchromatic image. Then, resample the hue and saturation bands to the panchromatic pixel size using resampling methods. Finally, transform back the image to RGB color space.

High Pass Filter Method

A spatial High Pass Filter is used in this method for extracting high frequency components, i.e. spatial detail, from the panchromatic image , then the spatial detail is injected into the low-resolution multi-spectral image, so as to produce a fused image with sharp high frequency characteristics[6].

5. Evaluation Methods

The effectiveness of fusion algorithm can be checked by performing its qualitative and quantitative analysis. The following techniques may be used:

1) Mean

The mean is the arithmetic average of all the pixels grey values in the image [11].

$$\bar{Z}=\frac{\sum_{i=1}^{M}\sum_{j=1}^{N} Z(x_i,y_j)}{MXN}$$

2) Correlation coefficient

The correlation coefficient between the fused image and the original MS image represents the spectral similarity extent between these two images.

3) Standard deviation (Sd)

Image's gray scale distribution is reflected by the standard deviation . A larger Sd value indicates that the image contains more information and its contrast is more obvious.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(Z(x_i, y_j))^2}{MXN}}$$

4) Information Entropy

An important parameter used to measure the image information abundance extent is Information entropy . It reflects the image's ability presenting spatial details. The greater the information entropy is, the more abundant the image is. If an image's grey value ranges from 0 to L-1, then its information entropy is defined as following:

$$H= -\sum_{i=0}^{L-1} P_i \ln P_i$$

5) RVD

RVD is calculated as relative difference of variation between the fused and original multispectral images.

6) Universal image quality index (UIQI)

To measure the similarity between two images UIQI is used. UIQI is designed by modeling image distortion as a combination of three factors :

Loss of correlation

Radiometric distortion

Contrast distortion.

Its value is between -1 and 1.

$$Q=\frac{\sigma_{AB}}{\sigma_A\sigma_B}.\frac{2\mu_A\mu_B}{\mu^2_A+\mu_B^2}\cdot\frac{2\sigma_A\sigma_B}{\sigma^2_A+\sigma_B^2}$$

8) Per-pixel deviation (PD)

For a per-pixel deviation it is necessary to degrade the fused image to the spatial resolution of the original image. This image is then subtracted from the original image on a per-pixel basis. As final step, we calculate the average deviation per pixel measured as digital number (DN) which is based on an 8- bit or 16-bit range. Zero is the best value here.

IV. CONCLUSION

With the flooding of too many PAN Sharpening algorithms, it is worth to test and evaluate some of them for the application of interest as the selection of data fusion algorithm is basically a problem dependent. This paper discusses various parameters that plays vital role in deciding upon the accuracy of data fusion algorithms, that primarily depends on the spatial resolution ratios of the two images. It is obvious from studies that such ratio must be 1:6, where PAN images having greater clarity with high resolution, whereas multi-spectral images with good color intensities, may be of coarser resolution. It is concluded from the studies that the integration of Principal Component Analysis and Brovey Transform is effective among many integration algorithms, in event Spot Panchromatic Image, and Landsat TM multi-spectral RS image is used. In addition, few researchers propose the Gram-Schmidt (G-S) transformation data fusion algorithms as best option for vegetation analysis. However, there is a scope for evaluating whether integration of these two algorithms will give good results if spatial resolution ratio of image changes. This paper highlighted upon few techniques for evaluating data fusion algorithms quantitatively and qualitatively too. In nut shell, there is always scope for improvement in the existing fusion algorithm or existing evaluation methods towards achieving better accuracies.

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