A Survey of Remote Sensing Image Enhancement using Pixel Level Fusion

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***Abstract* – Remote sensing image enhancement and processing is emerging area as it has demanding applications in land cover, land classification, precision agriculture and environmental monitoring fields. It becomes necessity to have high spatial, spectral and temporal resolution for further processing and use. As remotely sensed images may get affected by many physical factors, position of airborne and specifications of the sensors used, it's difficult to have very high spatial and spectral resolution in same image, it's always been a tradeoff. The fused image is expected to incorporate the high spatial and spectral resolution components of input images. High spectral resolution is required for accurate description of texture and shapes. In this article author reviews state-of-art pixel level fusion methods for remotely sensed multi-sensor images and parameters used for subjective and objective evaluation. Though ample amount of research has been done and going on in this field, attention needs to be given to the registration process and to preserve the important information from original multi-sensor input images.**

Keyword – Remote Sensing Image, Image registration, Panchromatic Image (PAN), Multispectral Image (MS), Pixel level fusion.

I. Introduction

Remote sensing imagery is having wide area of applications in real life land cover, land use analysis, land monitoring, agriculture, hydrology, geology, drought and flood monitoring [3]. As remotely sensed images are captured from large distance between the object and the sensor, it results in the degradation of quality of the image. This in turn affects classification accuracy of the geographical study area. Research work in this area is an effort to investigate and apply development of new technologies for remote sensor image enhancement and which will lead to solve the problem of administrators for accurate monitoring the environment changes and managing the natural resources to some extent. As explained above the remote sensor images are obtained with different spatial, spectral, temporal and radiological resolution according to the sensor used. Two popularly used images are a high spatial resolution panchromatic (PAN) image and a high spectral resolution multispectral (MS) image [2]. Land cover classification, feature detection, change monitoring often demand the highest spectral and spatial resolution for the successful achievement of their objectives [1]. Hence, to comply accurate and most unambiguous description of the observed area of earth surface, it is required

to merge the high spatial and the high spectral resolutions of different images into one [3].

Remote sensing image fusion is broadly categorized into three different levels 1) pixel level 2) feature level 3) decision level. This article discusses briefly about all steps involved in remote sensing image fusion using pixel level methods, for better enhancement results.

II. Data Set Selection And Preprocessing

A. Data Set Selection

Few frequently used mingling choices of remote sensing data for better accomplishment are, Landsat Thematic Mapper (TM) – PAN, Synthetic-aperture radar (SAR) – optical sensor images and *Satellite Pour l'Observation de la Terre (*SPOT) or SPOT XS - PAN. The SAR image gives more details about surface roughness which is advantageous for improving spatial structure details in image fusion. QuickBird and IKONOS, most popularly used combination is PAN and MS, the fused image is called as "pansharpening". Few sample remote sensing images are shown in Fig. 1, Fig. 2, Fig. 3.

B. Preprocessing

Before fusing the images collected from different remote sensors, those images need to be properly registered. Image registration process is, the mapping different co-ordinate system input images into one common co-ordinate system. Image registration process incorporates feature detection, feature matching, transform model estimation, image sampling and transformation of the input images. Though multi-sensor images of same area are used for registration, still there can be minute time mismatch present which may cause significant quality difference in registered image. Registration process plays very important role in image fusion, as mis-registration causes false colors or features in multi-sensor image, which falsify the interpretation. Research on analyzing this process has long history but still this step remains one of the paramount steps in various applications [14]. Sometimes in remote images, specific development is required according to the characteristics of the remote sensing image. Therefore,

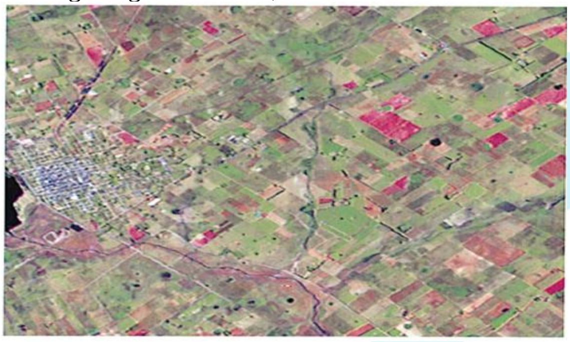

Fig. 1. LANDSAT (30 m) [9]

Fig. 2. IKONOS Panchromatic image (256 * 200 pixel subset), Fredericton, Canada [6].

increased accuracy can be achieved by using advanced approach called sub pixel registration [4]

Few researchers have tried applying different Artificial Neural Network algorithms to minimize the time complexity and improved results. Applying Convolutional Neural Network (CNN) algorithms or Deep learning algorithms for image registration would be a near future in this area.

III. Pixel Level Image Fusion Methodologies And Comparison

A. Introduction

Most of the remote sensed image fusion work has been done using pixel level fusion as a single pixel covers a large area on earth surface. Pixel level fusion is process of merging multiple source images into single resolution image, which is expected to have improved resolution and synthetic than the input images or able to identify the changes between data sets obtained at different times. A rigorous research is going on to enhance high spectral resolution MS images by pixel level fusion with high spatial resolution images which aims to reduce the spectral distortion of MS image. Pixel level fusion methods for remote sensing images can be broadly partitioned into four general categories, are as follows:

Fig. 3. IKONOS Multispectral Image (256 * 200 pixel subset), Fredericton, Canada, [6]

1. Component Substitution (CS)

CS method predominantly focuses on extracting high spatial resolution components from PAN image and injecting it into the bands of MS image. CS can be implemented using various methods. The different algorithms of component substitution fusion technique are Intensity-Hue-Saturation (IHS) transform fusion algorithm (Carper, 1990) and other versions of it (Fast IHS, Generalized HIS), Principal Component Analysis (PCA) transform fusion algorithm (Shettigara,1992). In these methods, some amount of color distortion is observed which means predominance of one color on others. Local Correlation Modeling (LCM) fusion algorithm (Hill,1999), Regression Variable Substitute (RVS) fusion algorithm, Brovery tansform (BT), Gram-schmidt(GS) these are quite sporadically used algorithms. Spectral components preservation is challenging task in these methods [10]. In addition to this few methods applies to the entire image globally, which ultimately leads to a non quantifiable consequence on every modality during the inverse transformation process [8].

2. Multi-resolution Analysis (MRA)

MRA fusion algorithms incorporate the multi-scale analysis, wavelet decomposition. This type of image merging can be performed in two ways: 1) Some wavelet coefficients of the multispectral image are replaced with respective coefficients of the high resolution image and 2) by appending multispectral image with high-resolution coefficients.

MRA includes Laplacian pyramid decomposition based fusion algorithms and undecimated wavelet transform algorithms and the discrete wavelet transform (DCT) algorithm known as "`a trous" ("with holes") fusion algorithm which adopts translation invariant [14], [9]. In [6] experimental results shown that color distortion observed due to IHS and tradition wavelet fusion technique can be reduced by combination of IHS and Integrated Wavelet methods. In this method IHS transform is used to merge high resolution spatial information from PAN image and the low resolution multispectral image. Next method under MRA family is additive wavelet-based (AWL) method. This method can be assumed as an improvement on the classical IHS or LHS methods. These methods perform insertion of specific wavelet planes of the PAN image to the intensity component of the low-resolution image [9].

3. Hybrid methods

It is a combination of both CS and MRA methods, taking advantages of both. Here the combination of wavelet with ICA or wavelet with sparse representation or curvelet and ICA etc. are the methods used for pixel level fusion of the remote sensed images. Some amount of spectral distortion is present in fused image. The suitability of these methods for different applications depends on their spatial and spectral resolution.

4. Modulation Based

Fundamental principle of modulation based fusion is spatial details modulation of MS images. This is performed by multiplication of ratio of PAN image to the synthetic image and the MS image. Classically used algorithms of the modulation-based fusion techniques include Smoothing Filter-based Intensity Modulation (SFIM), Brovery tansform (BT), Synthetic Variable Ratio (SVR) and High pass Spatial Filter (HPF) fusion algorithms. Experimentation on SPOT5 and Landsat ETM have shown that, gray values becomes more difficult to predict and interpolate when ground objects of the neighboring pixel turns to be more heterogeneous.

IV. EVALUATION MECHANISM

This task is very important and difficult too. The basic objectives of image fusion should be: 1) the designed algorithm should be robust enough to some imperfect conditions i.e. mis-registration and noise. 2) The fused image should be able to preserve maximum important information from original images. 3) Lowest inclusion of visual artifacts.

Evaluation can be done in either of the way by comparison with reference image (ground truth) or by using different approaches which does not require reference image. Mostly reference image is not available for assessment. Evaluation can be performed with subjective (qualitative) and objective (quantitative) analysis [11].

A. Subjective Analysis:

Subjective analysis is done by the group of experts by giving rating on the basis of how much the spatial resolution is improved by visual testing. Subject analysis can be done by observing these parameters contrast, regularized-histogram equalization and Discrete cosine transform (RHE-DCT), retinex with robust envelop (RWRE) [16].

Vijayaraj et al. [32] and Yocky [33] stated that subjective anaiysis are well suited to certain applications such as cartography or the localization of specific phenomena like target recognition[8].

B. Objective analysis with reference image:

In these methods first the reference image is formed by manually and then different parameters are observed. Most popularly used measurement parameters are root-mean-square-error (RMSE) and peak-signal-to-noise-ratio (PSNR) [11], Spectral angle mapper (SAM), erreur relative global adimensionnelle de synthese (ERGAS), Q-index, Q4 vector index and $Q2^n$-index. This comparison can be done band to band or pixel values [12]. Till now there have been many methods tried and tested like pixel-wise-gradient magnitude similarity and standard deviation based pooling scheme are combined to construct a novel full image quality metrics but still there are some lacunas [11].

C. Objective analysis with no reference image:

There are three different approaches to deal with no reference image for assessment:

1] This approach operates on relationship among original and pansharpened image by observing the quality indexes.

2] This approach considers the original MS image as reference image and the image with spatial resolution lower than the original for comparison (Wald's protocol).

3] In this approach first the approximations of both PAN and MS are obtained from resultant fused image and those are compared with original PAN and MS .

Some of the popularly used quality measures are as follows:

- Fusion quality index.
- Standard deviation.
- Fusion mutual information.
- Entropy and cross entropy.
- Fusion similarity metric.
- Spatial frequency.

V. CONCLUSION

From the above discussion, remote sensing physics should be carefully considered using image registration algorithm. As it plays very vital role in preprocessing for further fusion processing. Inferences from above discussion would be, about all the pixel level fusion methods, CS methods are quite easy for implementation but the major drawback is spectral distortion is present in fused image [10]. This spectral distortion is noticed due to low frequencies modification of original MS image or may be by the reason of minor mistakes in registration process. Few methods in CS follow global approaches which eventually lead to loss of original information. In comparison with standard techniques based on CS, AWL based methods are better suited for image merging.

Modulation based methods are having disadvantage of spatial distribution ambiguity. In case of preserving the spectral characteristics of the MS image wavelet approach is better than the standard IHS or LHS methods.

Irrespective of a fusion method, for good quality of fusion, researcher needs to pay attention at the characteristics and differences between input images [3]. Also according to the application, data set selection and fused image assessment plays important role.

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