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Performance Analysis of Image Fusion Techniques to Improve Quality of Satellite Data

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ABSTRACT

Satellite Image data are now collected with different spatial, spectral, and temporal resolutions. Image fusion techniques are used extensively to combine different images having complementary information into one signal composite. The fused image has rich information that will improve the performance of image analysis algorithms. Pansharpening is a pixel level fusion technique used to increase the spatial resolution of the multispectral image using spatial information from the high resolution panchromatic image while preserving the spectral information in the multispectral image. Resolution merge, image integration, and multisensory data fusion are some of the equivalent terms used for pansharpening. Pansharpening techniques are applied for enhancing certain features not visible in either of the single data alone, change detection using temporal data sets, improving geometric correction, and enhancing classification. This paper mainly focus on incorporating various image fusion techniques that are available in the literature. Using commercial remote sensing software package Erdas Imagine V9.2. The performance of these image fusion techniques varies both spectrally and spatially. Hence, in this work qualitative and quantitative metrics for evaluating the quality of pansharpend images have been analysed. For this study, the principal component analysis, Brovay sharpening method, High pass filter, Ehlers method and Modified IHS methods are used.

Keywords: Remote sensing, Image Fusion, BT, PCA, HPF, Ehlers, Modified-HIS

I. INTRODUCTION

Image fusion is a useful technique for merging similar-sensor and multi-sensor images to enhance the image information. The purpose of multi-sensor fusion is to synthesize different pieces of image data coming from different sensors into a single data set. Other terms such as the enhancement of the spatial resolution of different information from different sensor are used to describe multi-sensor fusion. Multi-sensor fusion is more convenient and economical than designing an advanced sensor with both resolution characteristics. The aim of image fusion is to integrate different data in order to obtain more information than that can be derived from each of the single sensor data alone, image fusion has been applied to achieve a number of objectives like image sharpening, improving geometric corrections, providing stereo-viewing, complement data sets for improved classification, change detection, substitute missing information, replace defective data. In remote sensing, the fusion of a high resolutions panchromatic image (HRPI) with a low resolution multi-spectral image (LRMI) to produce a high resolution multi-spectral image (HRMI) is referred to as pan-sharpening.

To understand the basic concept of the remote sensing we have referred to the text books of Robert A. Schowengerdt [1], B.C. Panda [2]. They explain the basic concept remote sensing, information extraction, EMR and different factors associated with RS data.

A comparative merits and demerits of image fusion technique are discussed by Susmitha Vekkot and Pancham Shukla [3]. S. G. Nikolov [4] considers a hybrid algorithm based on maximum selection rule to low frequency approximation and filtering mask based fusion to high frequency details. They also discuss various types of image file format and objective performance evaluation. Image registration is a process of geometrically aligning two or more images of the same scene acquired at different time or with different sensor or from different view point. Several image registration algorithms have been explained by Brown L.G [5].

YAO Wang-quang, Zhang [6] considers wavelet based transformation for multispectral image. They evaluate image quantitatively based on Root mean square error and other factor. Zhijun Wang [6], Kirankumar [7] and S. G. Nikol [4] evaluate quantitative techniques of image fusion matrices such as entropy, standard deviation quality index, ratio of spatial frequency error in medical image fusion. A complete detail of comparatives analysis methods used in image fusion methods are described by Y. Kiran Kumar [8]. The various challenges that are presented in high resolution images considering high spatial, spectral and temporal resolution and the technique that should be exclusively used for data fusion is disused by Roger. L. KING [9]. E. J. Stollnitz and D. H. Salesin [10] describes the images as a piecewise constant function on the half open interval for the concept of vector space.

Pixel based fusion technique for multifocus image fusion for IKONS image and SAR data is discussed by J. Liu, Q. Wang and Y. Shen [11]. Gemma Piella and Henk Heijmans [12] describe the regional based image fusion that overcomes the blurring effect in pixel based image fusion. D. A. Yocky [13] and J. Nunez, X. Otazu [14] explains about image fusion method that can provide the essential spectral information and explains image fusion based on Panchromatic and Multispectral image containing both color resolution and high spatial resolution that can improve the visual quality. Effective merging of an RS data and selection of suitable methods are especially significant for improving the multiple images of the same scene obtained by different image sensor, it is particularly important to synthesize a new image by image fusion technology. Existing methods available for image fusion are transformation based fusion, additive and multiplicative technique, multi resolution method, filters fusion method fusion based on interband relation. In our work we have considered the multi resolution analysis method this emphasis is placed on reducing uncertainties in the image and to provide more information than original image.

II. REMOTE SENSING

Remote sensing science has always been a fascinating topic over the years, and with the advent of the earth observation satellite and a host of advanced instruments with the capability to monitor closely the land – air – ocean interactions, the field has expanded dramatically covering almost all the areas, say, from cartography to climate. The advances in the imaging optics, devices, signal processing and materials, not to speak of the developments in modeling & algorithms, remote sensing, as a science, has seen a quantum jump in the recent times. Further, the development in the enabling tools such as image processing, photogrammetry, geographical information system, global positioning system as well as the emergence of powerful computing systems have further pushed the science, technology and applications of remote sensing to hitherto unexplored areas. The remote sensing data-collection and analysis procedures used for earth resource applications are often implemented in a systematic fashion that can be termed the “remote sensing process”.

A. Remote Sensing of the Environment

People responsible for managing the Earth’s natural resources and planning future development recognize the importance of accurate, spatial information residing in geographic information system (GIS). Many most important layers of biophysical, land use/land cover and socioeconomic information in a GIS database are derived from an analysis of remotely sensed data. Consequently, we see a significant increase in the demand for remote sensing data. Hundreds of public and commercial remote sensing systems throughout the world now collect the remote sensor data. Some remote sensor data are available at a reasonable cost per km^2 and may be obtained by the user over the internet. Some remote sensor data are very expensive. The characteristics of electromagnetic radiation and how the energy interacts with earth surface materials such as vegetation, soil, rock, water, and urban infrastructure. How electromagnetic energy reflected or emitted from these materials is recorded using a variety of remote sensing instruments (eg, cameras, multispectral scanners, hyper spectral instruments, RADAR, LIDAR).

Essentially remote sensing has three components. The signal (from an object or phenomenon) the sensor (from a platform), and the sensing (acquiring knowledge about the object or the phenomenon after analysis of the signals received by the sensor at the user's laboratory) However, the interaction of the signal with the object by which we obtain information about it, and the interaction of the signal with the transmission channel which reduces the signal strength are given due considerations for detail information extraction. Remote sensing is a branch of physics, namely reflectance spectroscopy which has now found extensive applications in almost every field of human activity.

B. Natural Remote Sensing

Sensing in general and remote sensing in particular can be taken as a measure of life and activity of all living organisms, from microbes to man. Any living organism whose sense organs are well developed can interact with its environment better, live a better life and can protect itself better from its enemies and hostile environments. Taking the example of man, we have five well developed sense organs: eye, ear, nose, skin and tongue along with highly developed sensing systems- the brain and the nervous system.

C. Artificial Remote Sensing

Seeing is believing – it is said. But, we human beings can see only through the visible light which forms only a very narrow band out of the extremely broad electromagnetic spectrum. This is because our eye is not sensitive to the wavelengths below the violet and above the red region of the electromagnetic spectrum. Similarly our ear is insensitive to the infrasonic and the ultrasonic frequencies- it can sense only in the audible frequency range. Thus the knowledge about objects obtained through our eyes and ears is partial. In the field of artificial remote sensing, man merely tries to imitate the already existing remote sensors in us and improve upon them to include wider information channels so that they can be used efficiently to collect detailed information about objects or phenomena.

D. Passive and Active Remote Sensing

A remote sensing system possesses only a sensor and depends on an external (natural) source to irradiate to be sensed is called a passive remote sensing system. As for example, in visible light RS system, the sun, an external natural source, irradiates the target and the reflected light from the target is detected by the sensor. An active remote sensing system transmits microwave pulses from its transmitter antenna to irradiate the target and receives the radar returns by its receiver antenna.

D. Image Resolution

Resolution is a broad term commonly used to describe:

- the number of pixels you can display on a display device, or
- the area on the ground that a pixel represents in an image file
- These broad definitions are inadequate when describing remotely sensed data. Four distinct types of resolution must be considered: spectral—the specific wavelength intervals that a sensor can record, spatial—the area on the ground represented by each pixel, radiometric—the number of possible data file values in each band (indicated by the number of bits into which the recorded energy is divided), temporal—how often a sensor obtains imagery of a particular area

These four domains contain separate information that can be extracted from the raw data.

1) Spectral Resolution

Most RS investigations are based on developing a deterministic model between the amount of electromagnetic energy reflected, emitted, or back-scattered in specific bands or frequencies and the chemical, biological, and physical characteristics of the phenomena under investigation. Spectral resolution refers to the specific wavelength intervals in the EM spectrum that a sensor can record. For example, Band-1 of the Resourcesat-I LISS IV sensor s records energy between 0.76 and 0.9µm in the visible part of the spectrum. The Band-2 of Resourcesat-I LISS IV sensor records energy between 0.62 and 0.68 µm in the visible part of the spectrum on the other hand, Band-3 of the Resourcesat-I sensor records energy between 0.52 and 0.60 µm in the visible part of the spectrum. Similarly, Cartosat-I panchromatic sensor is considered to have coarse spectral resolution because it records EMR between 0.45 & 0.99µm. Wide intervals in the EM spectrum are referred to as coarse spectral resolution, and narrow intervals are referred to as fine spectral resolution.

2) Spatial Resolution

Spatial resolution is a measure of the smallest object that can be resolved by the sensor, or the area on the ground represented by each pixel. The finer the resolution, the lower the number always. For instance, a spatial resolution of 79 meters is coarser than a spatial resolution of 10 meters.

III. IMAGE FUSION TECHNIQUES

Image fusion is a technique of obtaining images with high spatial and spectral resolution from low spatial resolution multispectral and high spatial resolution panchromatic images. There is often an inverse relationship between the spectral and spatial resolution of the image. It has not been possible to propose a single sensor package that will meet all our application requirements, while the combined image from multiple sensors will provide more comprehensive information by collecting a wide diversity of sensed wavelengths and spatial resolutions. Due to the demand for higher classification accuracy and the need in enhanced positioning precision there is always a need to improve the spectral and spatial resolution of remotely sensed imagery. These requirements can be fulfilled by the utilization of image processing techniques at a significantly lower expense. The goal is to combine image data to form a new image that contains more interpretable information than can be gained by using the original information.

A. Image Fusion Schemes

Image fusion is a concept of combining multiple images into composite products, through which more information than that of individual input images can be revealed. The goal of image fusion is to integrate complementary multi sensor, multi temporal and/or multi view data into a new image containing more information.The actual fusion process can take place at different levels of information representation a generic categorization is to consider the different levels as, stored in ascending order of fusion. The lowest possible technique in image fusion is the pixel level, in which the intensity values of pixels of the source images are used for merging the images. The next level is feature level, which operates on the characteristic such as size, shape, edge etc. The next level is the decision level fusion deals with symbolic representation of the images.

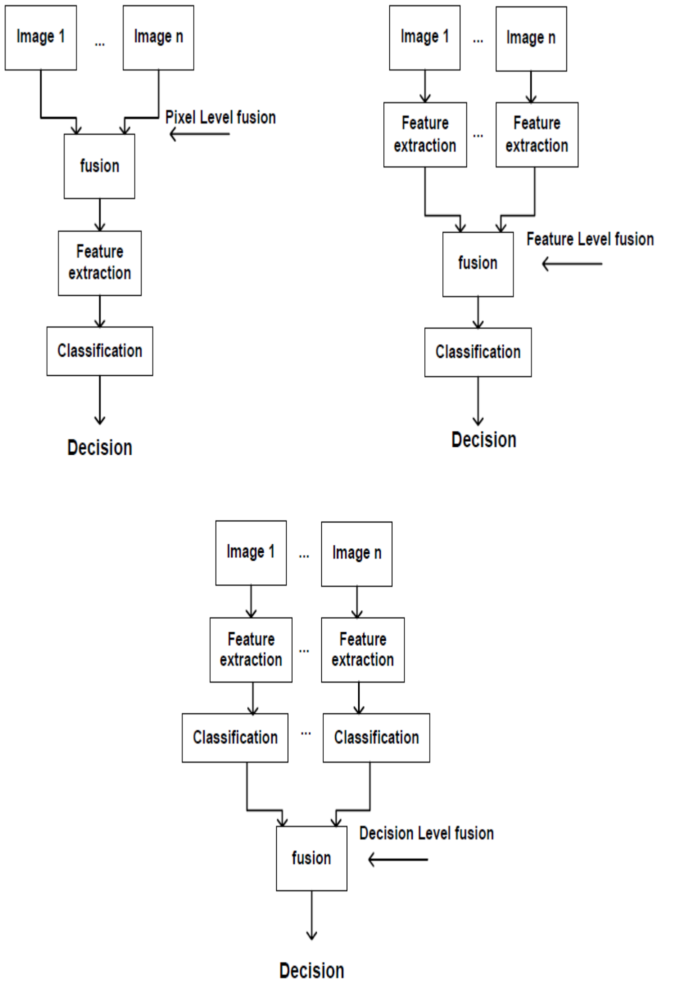


Figure 1: Levels of Image Fusion

B. Conventional Image Fusion Techniques

Image fusion methods are all based on pixel-level, Region-Level and Decision Level fusion method is a process to analysis the original information.

1) Brovey Transformation Method

The Brovey transform is a formula based process that is based on the band to display in a given colour, the sum of all the colour layers, and the intensity layer. The Brovey transform uses a formula that normalizes multispectral bands used for an RGB display, and multiplies the result by any other higher resolution image to add the intensity or brightness component to the image. The formula is as follows:

$$R = (R / (R + G + B)) * I$$
$$G = (G / (R + G + B)) * I \quad \ldots\ldots\ldots \quad \textbf{(1)}$$
$$B = (B / (R + G + B)) * I$$

Where, R = Red, G = Green, B = Blue, I = Intensity

The Brovey transform can also be expressed as:

$$DN_{fussedMSI} = \frac{DNb}{DNb_1 + DNb_2 + \ldots\ldots + DNb_n} DN_{PAN} \ldots\textbf{(2)}$$

The Brovey transform provides excellent contrast in the image domain but affects the spectral characteristics a great deal.

2) Principal Component Analysis Method

Generally, the PCA is used to statistically compress all the information contained in an original multivariate inter-correlated n-band set into fewer than n new uncorrelated bands or components. It is also viewed as mapping the total variance of the original images onto new components referred to as principal component axis. In other words, PCA removes redundancy of information content. The first principal component (PC1) has the greatest percentage of the total variance and each succeeding component (PC2, PC3, …,PCn) contains a decreasing percentage of the total variance. Hence, it is assumed that the first principal component (PC1) image normally contains all the information that is common to all the bands input to PCA, while the spectral information that is unique to any one of the bands is mapped to the other principal components. The number of principal components is equal to the number of low resolution multi-spectral bands.

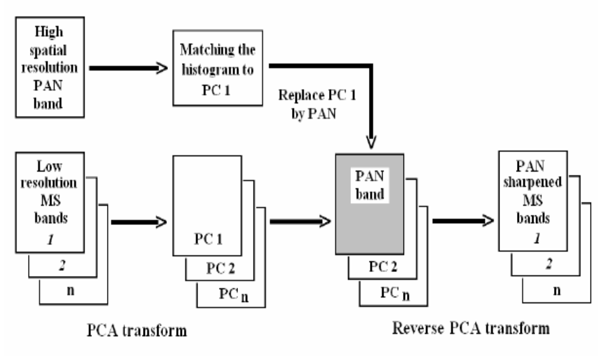


Figure 2: Flowchart of PCA image fusion method

The flowchart approach for PCA image fusion is shown in Figure 2. During the forward PCA transformation, the higher spatial resolution panchromatic image is substituted for the first principal component image. Finally, the data is mapped back to the original image space by performing the inverse PCA transformation. Histogram matching of PAN to PC1 is mandatory before substitution, because the mean and variance of PC1 are generally far greater than those of PAN. The forward and reverse PCA transformations are described the relation Equation 3.

$$\begin{bmatrix} PC1 \\ PC2 \\ \cdots \\ PCn \end{bmatrix} = \begin{bmatrix} v11 & v21 & \cdots & vn1 \\ v12 & v22 & \cdots & vn2 \\ \cdots & \cdots & \cdots & \cdots \\ v1n & v2n & \cdots & vnn \end{bmatrix} \begin{bmatrix} DN^{l}{}_{MS1} \\ DN^{l}{}_{MS2} \\ \cdots \\ DN^{l}{}_{MS3} \end{bmatrix}$$

where the transformation matrix

$$v = \begin{bmatrix} v11 & v12 & \cdots & v1n \\ v21 & v22 & \cdots & v2n \\ \cdots & \cdots & \cdots & \cdots \\ vn1 & vn2 & \cdots & vnn \end{bmatrix}$$

$$\begin{bmatrix} DN^{l}{}_{MS1} \\ DN^{l}{}_{MS2} \\ \cdots \\ DN^{l}{}_{MS3} \end{bmatrix} = \begin{bmatrix} v11 & v12 & \cdots & v1n \\ v21 & v22 & \cdots & v2n \\ \cdots & \cdots & \cdots & \cdots \\ vn1 & vn2 & \cdots & vnn \end{bmatrix} \begin{bmatrix} DN^{h'}_{PAN} \\ PC2 \\ \cdots \\ PCn \end{bmatrix} \quad \ldots \ \textbf{(3)}$$

where, $DN^{h'}_{PAN}$ is DN^{h}_{PAN} stretched to have the same mean and variance as PC1, andreplaces PC1. Suffix *l* and *h* represent low and high spatial resolutions, respectively. The transformation matrix *v* contains the eigenvectors ordered with respect to their eigenvalues. The eigenvectors are ordered and determined either from the covariance matrix or the correlation matrix of the input multi-spectral bands. The PCA performed using the covariance matrix is referred to as unstandardised PCA, while PCA performed using correlation matrix is referred to as standardised PCA.

3) Intensity-Hue-Saturation Method

The Intensity-Hue-Saturation (IHS) transformation decouples the intensity information from the color carrying information. The hue attribute describes a pure color and saturation gives the degree to which pure color is diluted by white light. This transformation permits the separation of spatial information into one single intensity band. There are different models of IHS transformation. The models differ in the method used to compute the intensity value. Hexacone and triangular models are two of the more widely used models. The hue and saturation values are computed based on a set of complex equations. The intensity value for the hexacone model and triangular model is computed as shown in equations, 4, 5 & 6.

$$I = Max(R,G,B) \quad ..... \quad \textbf{(4)}$$

$$I = \frac{Max(R,G,B)}{3} \quad ..... \quad \textbf{(5)}$$

$$I = \frac{Max(R,G,B) + Min(R,G,B)}{2} \quad .... \quad (6)$$

This model ignores one of the three components to compute the intensity. The changes in the intensity values are not distributed evenly in all the three R, G, and B components when the inverse transform is performed. All the three models have different set of equations to compute the hue and saturation values.

4) Modified-IHS (Intensity Hue Saturation) Method

Here the input intensity (PAN band) is modified so that it looks more like the intensity of the input MS bands. The steps are:

a) **Choose the β coefficients:** β coefficients represent the relative contributions of each portion of the electromagnetic spectrum to the PAN band. A regression analysis is performed on M bands vs. the PAN band. If the MS and PAN data come from the same sensor, a linear regression is sufficient to derive a good relationship between the two datasets otherwise it may be possible to improve by using higher-order terms.

b) **Choose the α coefficients:** The desired output is equally weighted toward Red (R), Green (G), and Blue (B). In such cases, the α coefficients are equal and given by,

$$\alpha = \frac{\sum_m \beta_m \overline{MS}_m}{3\overline{PAN}} \quad .... \quad \textbf{(7)}$$

MSm=average of band m; *PAN* =average of PAN band; *j* b =coefficient for band m.

c) **Generate modulation ratio:** Apply an RGB-to-HIS transform on the three MS bands and generate intensity modification ratio (r1),

$$r_1 = \frac{a_r d_r + a_g d_g + a_b d_b}{\sum_m \beta_m d_m} \quad .... \quad \textbf{(8)}$$

where, ar=numerator coefficient for red DN value, dr=DN value of band used for red output, ag=numerator coefficient for green DN value, dg=DN value of band used for green output, ab=numerator coefficient for blue DN value, db=DN value of band used for blue output, βm=denominator coefficient for DN value of band m and dm=DN value of band m.

d) **Reverse transformation:** Multiply the modification ratio r1 by the PAN band. Transform the modified HIS data back to RGB space to generate the final product using the modified intensity.

5) Ehlers Method

A very direct approach to image enhancement is the use of high resolution data and panchromatic images, to sharpen images of lower spatial resolution. Once a set of multisensor images is placed in register with a high resolution reference image, the digital numbers (DNs) of the various multispectral band may be merged with those for the single band (panchromatic) reference image using:

$$DN_i^1 = \alpha i * + \sqrt{DNi * DN(h)} + \beta i$$

$$DN_i^1 = \alpha i * + (\gamma_i * DN_i + \delta_i * DN(h)) + \beta i \quad .. \quad \textbf{(9)}$$

Where, DN_i and DN_i^1 are the DNs for the ith band of the original and fused multispectral image, respectively; DN(h) is the DN for the high resolution reference image; αi , βi are scaling factors; and γ_i, δ_i are weighting factors.

6) High-pass Filter Fusion Method

High-pass filter fusion method a method that make the high frequency components of high-resolution panchromatic image superimposed on low resolution multispectral image, to obtain the enhanced spatial resolution multispectral image.

$$F_k(i,j)=M_k(i,j)+HPH(i,j) \quad .... \quad \textbf{(10)}$$

In the formula $F_k(i,j)$ is the fusion value of the band K pixel (i,j), $M_k(i,j)$ the value of multi-special of band k pixel (i,j) HPH(i.j) show the high frequency information of the high resolution image.

High pass filtering fusion adds High-resolution images geometric information into the low-resolution images by-pixel. The result of high-resolution images of high-pass filter corresponds high-frequency spatial information, namely, extracting high-resolution images of the corresponding high frequency components of spatial information by high-pass filter. This kind of spatial filter removes most of the spectral information, and then adds high spectral resolution images into high-pass filter results to form the fusion images with high-frequency feature information is highlighted.

IV. STUDY AREA & METHODOLOGY

A. Study Area

The study area considered for our work is semi urban area is situated in Hassan, Karnataka, India, its geographical coordinates are 13° 18' 50" North, 76° 15' 22" East and its name is Arsikere. It is spread over an area of approximately 104 km. It has an average elevation of 807 meters (2647 feet). These images show the presence of a Railway stations, National highway, Queen's lake, Brownfield's, bare land, shrubs and tress with some residences. It also has a good mixture of classes comprising of man-made structures and natural land cover feature. The image dimension of the study area is 580×596 pixels size in Panchromatic and Multispectral data as well.

B. Satellite data product

Table I gives the specification of the image data products that has been used in the study. The data are of LISS-IV (Linear Mapping and Self Scanning) sensor of IRS P-6 (Indian Remote Sensing Satellite). Multispectral data in Blue, Green, Red and NIR bands and Panchromatic data of 2.5m Spatial resolution.

TABLE I
DETAILS OF SATELLITE DATA USED IN THE STUDY

Satellite Data	Band	Spatial Resolution	Wavelength
Multi-spectral Data	Infrared	5.0 m	0.76-0.90µm
	Red	5.0 m	0.62-0.68µm
	Green	5.0 m	0.52-0.60µm
PAN Data	GrayScale	2.5 m	0.45-0.99µm

C. Methodology

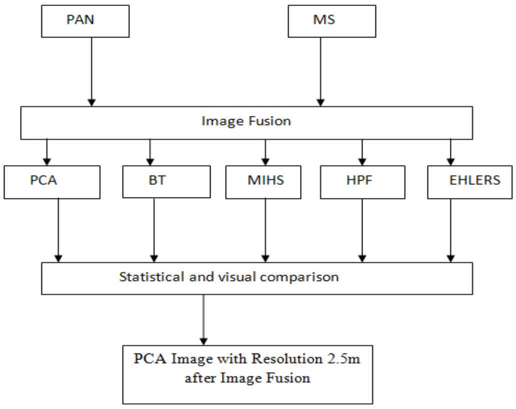


Figure 3: Flowchart of Image Fusion Methodology to improve quality of satellite data

V. RESULTS & DISCUSSION

Several approaches are proposed by several authors to image fusion quality evaluation. The major image fusion techniques employed are Brovey Transformation (BT), Principal Component Analysis (PCA), Modified-HIS, HPF and Ehlers. These approaches could be divided in subjective tests, usually psycho visual ones, and quantitative tests. But accessing the performance in practical applications is a complicated issue because the ideal composite image is normally unknown. To overcome this handicap, it is possible to have statistical measures like Standard Deviation (SD) and Mean from the histogram of fused images. The size of the both the images considered for fusion is 580*596.

A. Panchromatic Satellite Image for Fusion & its Histogram

Figure 4: Snapshot of Panchromatic image with 2.5m spatial resolution of size 580*596.

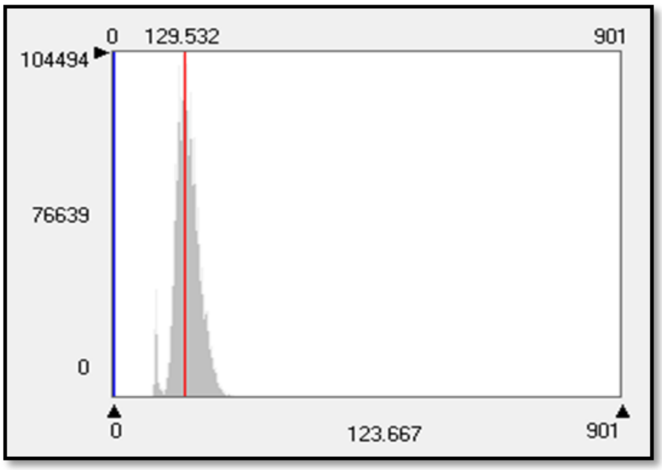
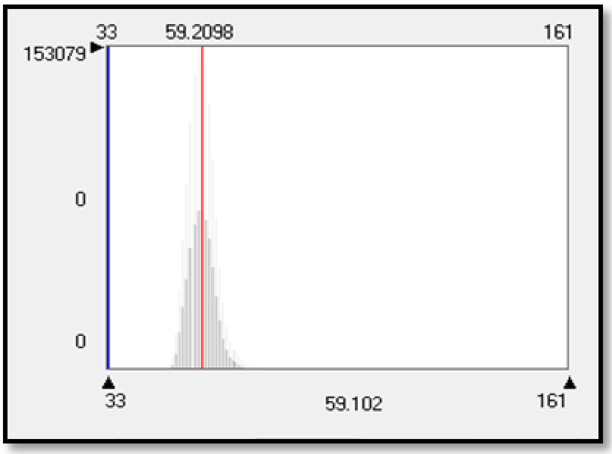


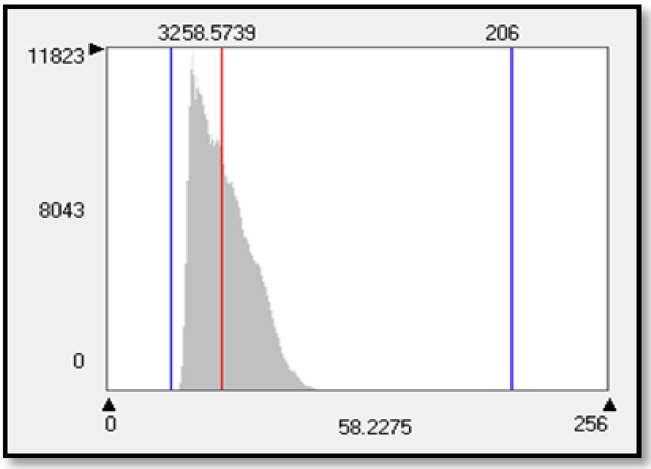
Figure 5: Histogram of PAN Image

B. Multispectral Satellite Image for Fusion & its Histogram

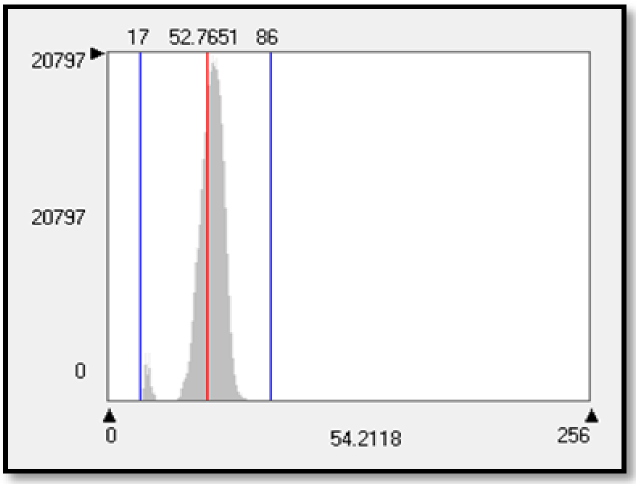
Figure 6: Snapshot of Multispectral image with 5.8m resolution of Size 580*596.



(a) MS Band 1



(b) MS Band 2



(c) MS Band 3

Figure 7: Histograms of Multispectral Satellite Image

C. Fused Images for Conventional Fusion Techniques

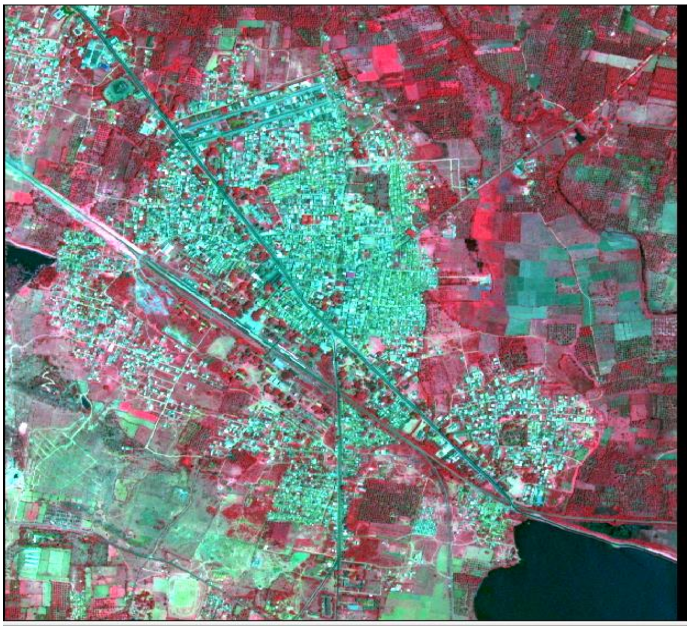


Figure 8: Snapshot of Fused Image using Brovey Transform (BT)

In Brovey transform as shown in Figure 8 the residential area is correctly classified to a greater extent however vegetation is indicated by complete red and vegetation is not correctly classified. Dry land and semidry land are properly classified railway track, national highway and water body is correctly classified.

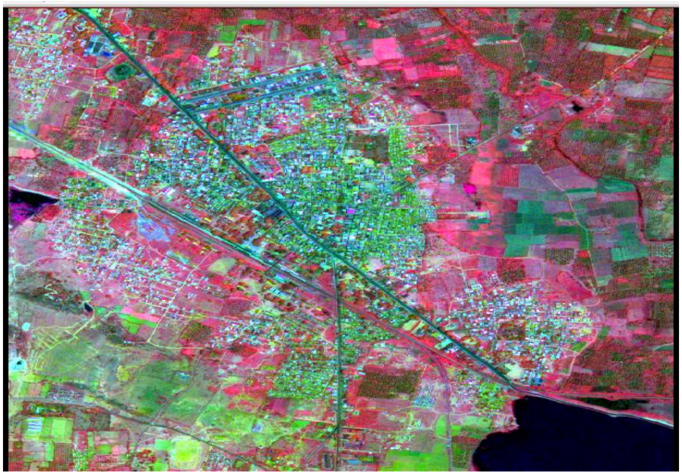


Figure 9: Snapshot of Fused Image using Principal Component Analysis (PCA)

In PCA technique as in Figure 9 it is very clear that the water body is indicated by blue color, the railway track and National highway is not much affected, the dry land area is indicated by greenish tinch, the complete dry area is indicated by a different grey level. We also observe that residential area is also classified well.

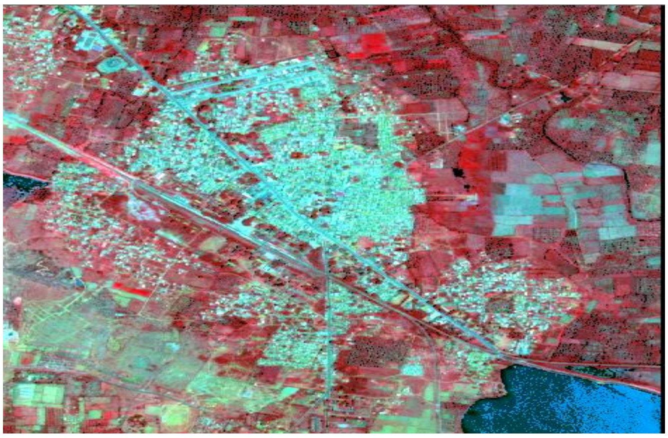


Figure 10: Snapshot of Fused Image using Modified IHS Method

Figure 11: Snapshot of Fused Image using High-pass Filter Analysis

Figure 18: Snapshot of Fused Image using Ehlers Fusion Method

In Figure 10, 11 & 12 shows the snapshot of image fusion using Mod-HIS, HPF & Ehlers. It is found that various features of the object even though they are distinct in reality it appears to be merged, here vegetation classification is not proper, water body has to be blue however it appears as black, even though railway track, national highway 104 is not distinct the same color appears for both in Principal component analysis, the dry area is indicated by green which is not so.

D. **Performance of Image Fusion Techniques**

1) Standard Deviation of Multispectral, Panchromatic and Fused images

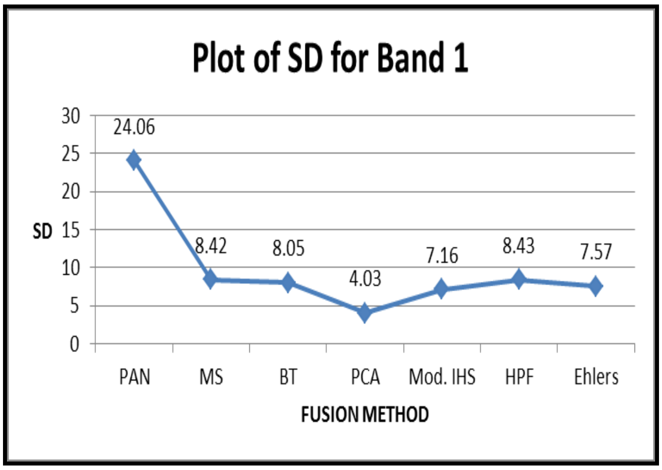


Figure 13: Plot of SD for Band 1

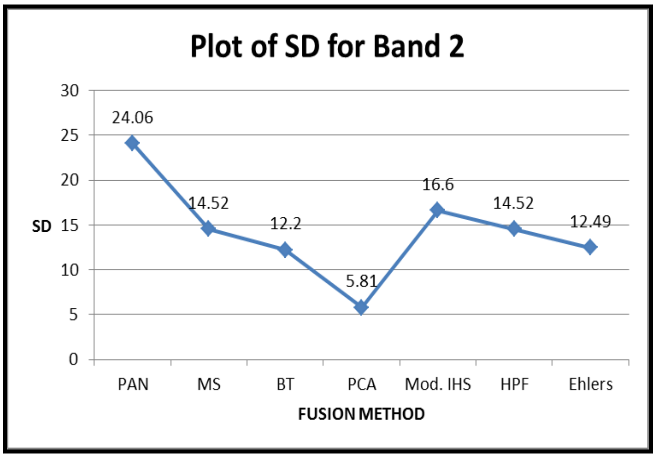


Figure 14: Plot of SD for Band 2

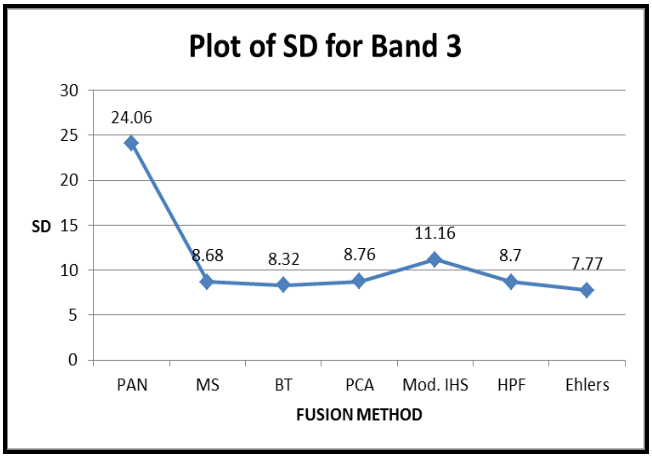


Figure 15: Plot of SD for Band 3

The Figures 13, 14 and 15 shows PCA fusion method is comparatively better than Mod-HIS and Ehlers fusion techniques. BT and HPF fusion techniques are failed to provide high quality fused image.

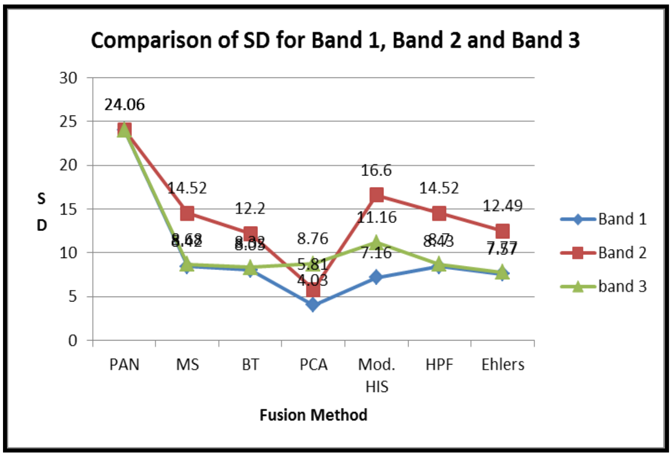


Figure 16: Comparison of Standard Deviation for Band 1, Band 2 and Band 3

TABLE III

STANDARD DEVIATION OF THE BANDS OF THE MULTISPECTRAL, PANCHROMATIC AND FUSED IMAGES

Band	PAN	MS	BT	PCA	Mod-IHS	HPF	Ehlers
B1	24.06	8.42	8.05	**4.03**	7.16	8.43	7.57
B2		14.52	12.20	**5.81**	16.60	14.52	12.49
B3		8.68	8.32	8.76	11.16	8.70	**7.77**

The Figure 16 and Table II shows PCA fusion method performs better in Band 1 and Band 2 compared to other image fusion techniques. But, Ehlers fusion method performs well in Band 3. BT, Mod-HIS, HPF fusion techniques fail to provide good quality image.

2) Mean of Multispectral, Panchromatic and Fused images

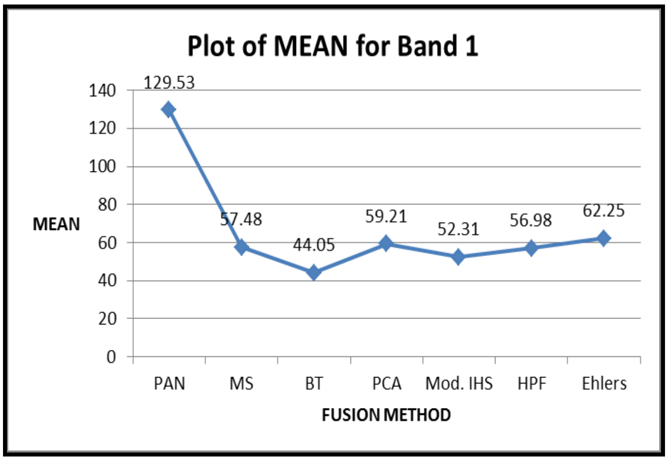


Figure 17: Plot of Mean for Band 1

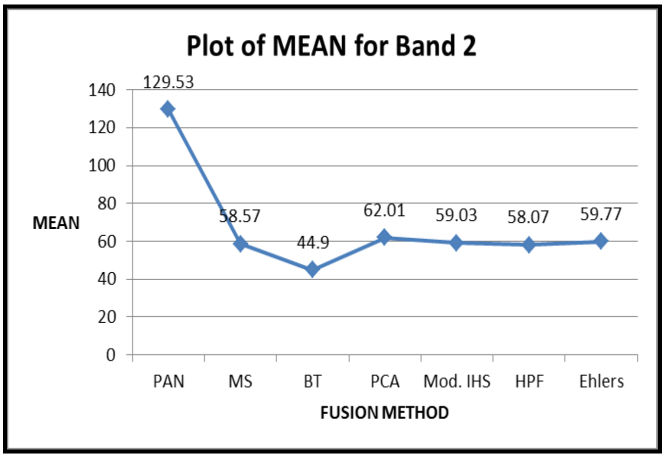


Figure 18: Plot of Mean for Band 2

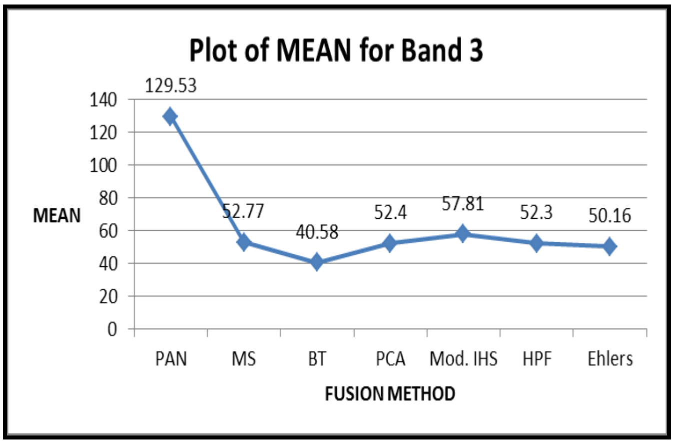


Figure 19: Plot of Mean for Band 3

The Figure 17, 18 and 19 shows PCA, Ehlers and Mod-IHS fusion methods are comparatively better than BT and HPF fusion techniques.

TABLE III

MEAN OF THE BANDS OF THE MULTISPECTRAL, PANCHROMATIC AND FUSED IMAGES

Band	PAN	MS	BT	PCA	Mod-IHS	HPF	Ehlers
B1	129.5	57.48	44.05	59.21	52.31	56.98	**62.25**
B2		58.57	44.90	**62.01**	59.03	58.07	59.77
B3		52.77	40.58	52.40	**57.81**	52.30	50.16

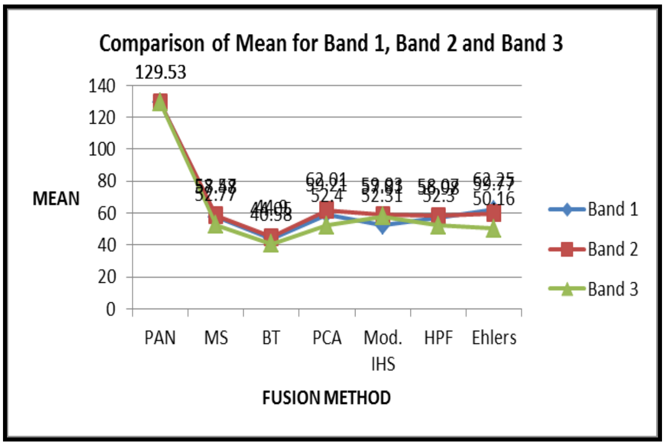


Figure 20: Comparison of Mean for Band 1, Band 2 and Band 3

The Figure 20 and Table III shows Ehlers fusion method performs better in Band 1, PCA fusion method performs better in Band 2 and Mod-HIS fusion method performs better in Band 3. BT and HPF fusion techniques fail to provide good quality fused image.

VI. CONCLUSION

The image fusion evaluation process consist of Visual Interpretation and Statistical Analysis. In this work, we have considered five different image fusion techniques to evaluate the performance. The size of the image considered is 580*596 pixels and resolution is 5.0 m for multispectral data and 2.5 m for panchromatic data. The fused image is obtained for all the five fusion techniques and it is observed that fused image characteristics were varying in nature.

A. Visual Interpretation

The resulting images obtained from different conventional techniques had erosion scars and some of the deposition areas enhanced related to the other targets in the images. PCA looks much closer to Multispectral band in colour hence look more vivid in PCA than BT. Further, PCA is brighter than BT, HPF and Ehlers looks dull and smoky. Next to PCA it is the Modified-IHS which is closer to Multispectral data. In brightness retaining quality too the fusion technique is found to be bright and better preserving the original Multispectral details. When all the visual evaluation put together, the PCA is found to be bright and better in preserving the original Multispectral details. However for these approaches one can verify that it was not possible to obtain a good detail. For example, grass, natural fields and vegetation cover in the early growing stage were not well discriminated. It was also possible to notice a defocusing in the images, which made the erosion scars look like stains instead of linear feature. Among the conventional techniques, it was observed that PCA seems to give the best result of image fusion.

As already mentioned, due to limitation of human vision in terms of distinguishing the number of grey levels, comparison and appreciation by visual method doesn't reveal the exact potentials of the fusion methods. Hence comparison of image statistics was attempted to evaluate the results of fusion using PCA, BT, MT, Mod-HIS and Ehlers methods. It is believed that such a comparison would accurately quantify the loss of information after fusion.

B. Statistical Interpretation

The Mean and Standard Deviation are used to calculate the spectral changes of all the regions. The experimental result was analyzed based on Mean & SD as in Table II and Table III. The SD and Mean values between the fused images with their corresponding MS image indicate that the pixel values are less distorted in the, PCA for Band 1 and Band 2 compared to the Brovey Transform, Mod-IHS, HPF and Ehlers methods. Similarly, the SD and Mean values between the fused images with their corresponding MS image indicate that the pixel values are less distorted in the, Ehlers for Band 3 compared to the PCA, Brovey Transform, Mod-HIS and HPF methods.

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