Pan sharpening of Multispectral data using B-spline and Super curve

Sukanta Roy[1], Rahul Chauhan[2], and S N Omkar[3]

***Abstract*— Multisensor data fusion is an emerging technology of current research trends. Requirement of data fusion is increasing day by day in every field whether it's department of defense (DoD), medical diagnosis, smart buildings or subsurface analysis to determine the local pattern and many more application. Pan-sharpening is a special type of data fusion in which Multispectral image is sharpened with panchromatic image whereas it stands for "Panchromatic sharpening". In this sense, to "sharpen" means to increase the spatial resolution of a multispectral image. Regarding this type of fusion, the main concern is how much to sharpen so that the spectral information does not alter in practice. To address this issue, this paper proposes a new method of Pan Sharpening with help of super curve and B-spline. The coefficients of B-spline preserve the local information of spectral band during the interpolation. Similarly, the local information of Pan-chromatic image is founded out. In next, putting the weightage on sharpening, the super curve is formed during the fusion. This novelty of approach leads to better preservation of original spectral information. The experimental study also prove the improvement of sharpening in terms of quantitative assessments with respect to tradition weighted mean method of pan sharpening. The distinct improvement of correlation coefficient, structural similarity index (SSIM) and entropy justify the proposed method in study.**

***Index Terms*— Pan-sharpening, B-spline, super curve, weighted mean.**

I. Introduction

IN the application area of remote sensing, satellite sensors provide mainly two types of images for the scope of study: spatially high informative data and spectrally high informative data. To promote the accuracy in analysis, a lot of techniques catch the current trends of research vastly. In this regard, pan sharpening is one kind of data fusion become very wide spread method which populate the spectral band information with the influence of high spatial information. This data fusion is expressed in different way with different context of literature. In [1], the data fusion is defined as a ''inference process of multilevel, multifaceted several sources to get better representation of single source data.'' This type of perspective helps to integrate this technique in several problem formulation regarding generation of distinct features of analysis and their evaluation of performance [2]. In this context, the analysis of multispectral bands with panchromatic image, follow up the divertive methodology to enhance the performance of the study. Wherein the most of the concern is about preserving original information of multispectral image and increasing the spatial resolution of the multi-spectral image.

A lot of tradeoffs between spectral and spatial are experienced by researchers during IHS-based fusion [3], PCA-based image fusion [4], wavelet based image fusion [5]. The comparative studies show that there exists a tradeoff between the preservation of spatial details and quantitative improvement of spectral information [6]. Because of this reason, an Improved Additive-Wavelet technique is proposed to preserve the radiometric information in paper [7]. From similar aspects, Sheida Rahmani et. al., introduces the adaptability in terms of image itself and the presence of edges during the process of IHS method [8]. However, the fused images by IHS-based methods suffer from local artifacts which lead to new weighted least square filter-based pan sharpening technique. An Adaptive Pansharpening Method by Using Weighted Least Squares Filter]. This method can also be implemented for the purpose of measuring freedom surfaces on multi-sensors data [10]. Regarding this job, B-spline is introduced to fit linear surface model to each identified overlapping area of registered data sets. The result implies that method was capable of improving the fidelity of the reconstructed surface. It is observed that high-degree B-spline interpolation has superior Fourier properties, smallest Interpolation error, and reasonable computing times in both qualitative and quantitative analysis [11]. B-spline interpolating kernels enjoy fast, exponential decay [12]. In paper [18], Bi-cubic interpolation is used for up-sampling the multispectral image. It is carried out for the purpose of pan-sharpening. The most attractive properties of B-spline is local invertibility which helps to preserve the original composition in terms of one to one transformation locally. This property motivates us to use B-spline in pan sharpening. As because, after data fusion multispectral band should preserve its spectral information intact. In this paper B-spline is used for interpolation using mirror W- condition for panchromatic image and multispectral image, filtering of the spline-coefficients are calculated. Next, super curve is formed using the calculated coefficient of the images through B spline filtering. During this formation, weighted method is used for the fusion of multispectral and panchromatic image the discrete permutation-combination based search space.

The rest of the paper is organized as follows, section II is about the problem formulation. Section III gives insight to the

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B-Spline, Super curve and Weighted mean fusion. Section IV is focused on our proposed method of pan sharpening. In section V, experiments and results are discussed and the conclusion of this work is done in section VI.

II. PROBLEM STATEMENT

Images of outdoor scenes captured in bad weather suffer from poor contrast, atmosphere scattering. The resulting decay in contrast varies across the scene and is exponential in the depths of scene points. In order to restore the contrast of the scene captured, an improved pan sharpening must be introduced on multispectral data. A technique is to be implemented for the images in order to improve spectral and spatial information which is effective under a wide range of weather conditions including haze, mist, fog and other aerosols. So, a new approach toward pan-sharpening for images is implemented in this paper with the help of B-spline and super curve.

III. BASIC CONCEPT

A. B-Spline

B-spline, or basis spline, is a spline function which is used for the purpose of interpolation, having minimal support with respect to a given degree, smoothness, and domain partition. B-splines can be used for the purpose of curve-fitting and numerical differentiation of experimental data. In image processing, quality and resolution can be improved by using efficient filtering technique for processing images represented in terms of B-splines basis functions. B-spline function is a generalization of the Bezier curve. Let a vector known as the knot vector be defined:

$$T = \{t_0, t_1, t_2, \dots \dots . . t_m\}$$

where T is a non-decreasing sequence with $t_i \in [0,1]$,

$$P = m - n - 1.$$

The knots $t_{p+1}, \dots . . \ t_{m-p-1}$. are called internal knots.

Definition of the basis functions is as follows:

$$N_{i,0}(t) = \{ 1 \quad if \ t_i \le t < t_{i+1} \ and \ t_i < t_{i+1}\} \\ \{ 0 \quad otherwise$$

$$N_{i,j(t)=} \frac{t - t_i}{t_{i+j} - t_i} N_{i,j-1}(t) + \frac{t_{i+j+1} - t}{t_{i+j+1-t_{i+1}}} N_{i+1,j-1}(t)$$

where, $J = 1,2,3, \dots P$.

Then the curve defined by

$$C(t) = \sum_{i=0}^{n} P_i \ N_{i,p}(t)$$

Another fundamental result is the well known convolution property:

$$B^n(x) = B^{n-1} * B^0(x) = (n+1) times \ B^0(x)$$

which state that a B-spline of order n can be generated by convolving B^0 (n+1) times with itself; the function B^0(x) is a centered normalized rectangular pulse. Based on the above equation, it is rather straightforward to show that B-spline are positive and have an integral that is equal to one. For more detail discussion of the properties, refer to [15][16][17].

B. Super curve

In this paper we have used super curve for implementation of B-spline. Basically, super curve is a single curve which formed by two affine related curve registered and superimposed on each other. Super curve which is formed by superimposing two sets of points rather than superimposing the two curves formed by two data sets. For example, curve 1 is having 300 points and curve 2 having 200 points. Traditional B-spline representation would represent each curve using a separate B-spline .In this paper we are first superimposing the two related curve into a single frame and use a single B-spline to represent the combined super-curve. The combined super-curve would be having 500 sample points to form B-spline. Using a single B-spline also provides better efficiency and high accuracy. For detail discussion on super curve refer [17].

C. Weighted Mean

For data fusion, Weighted mean technique is a standard method in practice. This method of pan-sharpening, multispectral and panchromatic images takes as input for processing. In the process of weighted mean, mean of the corresponding pixels of images are calculated by giving preference according to our requirement. Each pixel of the images are provided with certain weight and then added in order to obtain final fused image. Generally 0.7 weight is provided for multispectral image and 0.3 for panchromatic image, but it can be adjusted according to requirement. Weighted value of 0.5 to each image, means simple average. In this paper, multispectral image consist of 4 bands, providing information about spectral resolution to greater extent as compared to the spatial resolution, and panchromatic image consists of single band and provides spatial information to a larger extent as compared to the spectral information. In this paper weight provided to multispectral image is 0.7, and 0.3 for panchromatic image. Same weight is used in B-spline and super curve. We are comparing results of this method to the result of B-spline and super curve. The flow of algorithm is given bellow.

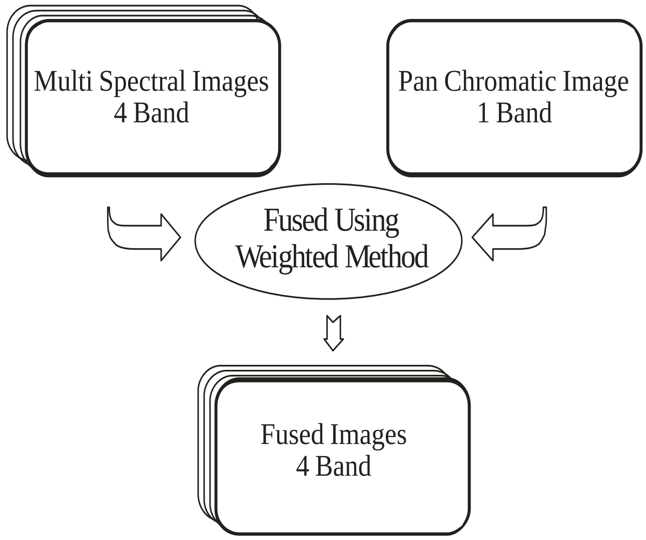

Fig.1 Weighted fusion

IV. PROPOSED METHODOLOGY

The applications of B-splines can go beyond interpolation technique. Their main advantage of it is to works as bridge between discrete and continuous signal domains. In this paper we have proposed the concept of B-spline filtering which is a process for applying a filtering operator on the B-spline signal which is continuous in nature. Before, performing interpolation, calculation of B-spline coefficients by means of B-spline filtration is important.

Steps involved in the methods are described below:

i. Requirements for pan-sharpening:
a) Multispectral image having 4 bands.
b) Panchromatic image (single band) .

ii. At first, both images are to be registered using suitable method (usually images are registered).

iii. Extraction of all 4 bands from multispectral image in an important step in this method of data fusion.

iv. Store the pixel value of single band panchromatic image in frame 1.

v. Store the pixel value of all bands (4) of multispectral image in frame 2.

vi. For an image processing we need to calculate coefficients in 2-Dimension. Due to separable kernel (2-D spline function is a tensor-product) 2-D filtration can be replaced by set of 1-D filtration along both rows and columns.

vii. Pixel value is taken from each frame and calculated B-spline coefficient on mirror boundary condition. For correct boundary processing the mirror-W boundary condition is applied in 2-D on the same principle as for single dimension.

viii. Value of B-spline is calculated at that point.

ix. Super curve is introduced taking both frame of images and then filtration technique is applied.

x. For the purpose of the superimposition of two curve weighted mean is introduced.

xi. New image is obtained from super curve.

Obtained new image is the fused image having both spectral and spatial information present in it. After the procedure of pansharpening, various comparison is being carried out between the obtained fused image and multispectral image via analysis of various parameter in the result section.

Outlines of method proposed in this paper:

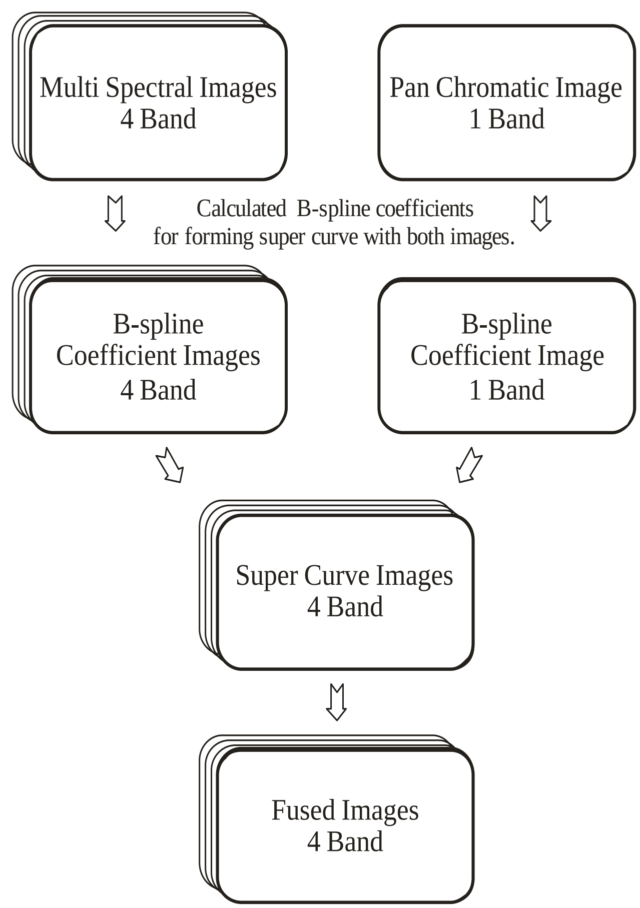

Fig.2 DatFusion Using B-spline and Super Curve

V. EXPERIMENTAL STUDY & RESULTS

A. Specification of data

Data used in this paper is taken from “QUICKBIRD-2” satellite. Quick bird imagery is a fine resolution remotely sensed product available to the public through Digital Globe.

sensor	Bands	Spectral range	Scene Size	Pixel Resolution
Multispectral	1=Blue 2=Green 3=Red 4=NIR	450-520μm 520-600 μm 630-690 μm 760-900 μm	1024X1024 Pixel	2.8 m
Panchromatic	Pan	760-850 μm	4096X4096 Pixel	0.7m

B. Quantitative Analysis

Analysis have been assessed on two data sets, one is fused image and second is multispectral image. Results have been calculated using statistical methods i.e. correlation coefficient and covariance. Entropy of images are also calculated for result analysis.

Correlation coefficient is a statistical measure of degree to predict the change between one values to another. It measures the strength and direction of a linear relationship between two variables. The mathematical formula for computation of correlation coefficient(r) is as follows:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{(n(\sum x^2) - (\sum x)^2)}\sqrt{((\sum y^2) - (\sum y)^2)}}$$

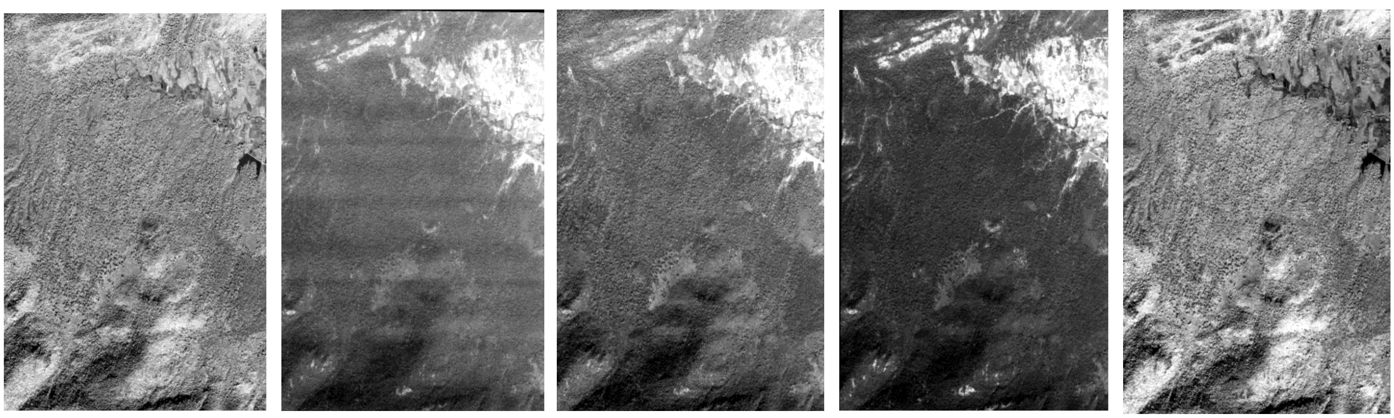

Fig. 3 PAN, MS1, MS2, MS3, MS4 images

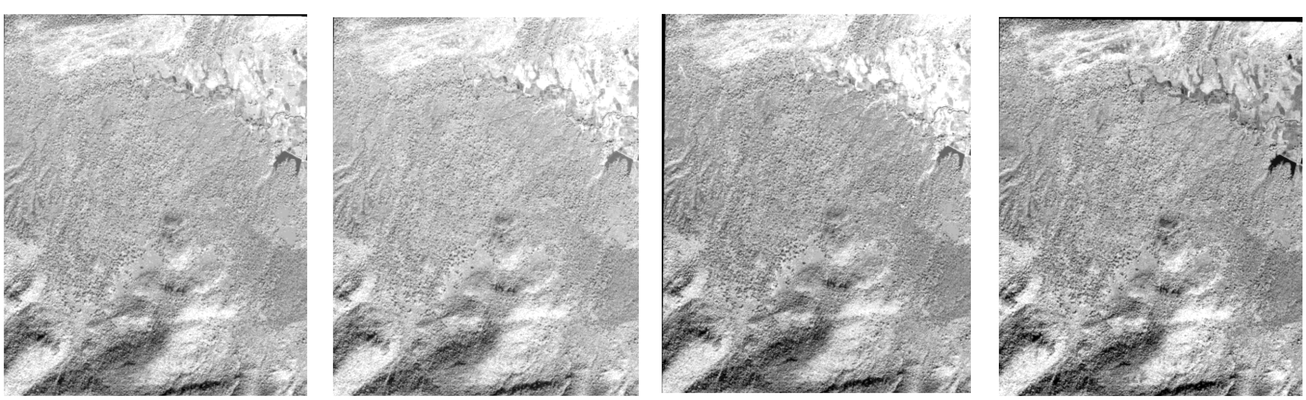

Fig. 4 Fused images by weighted mean method.

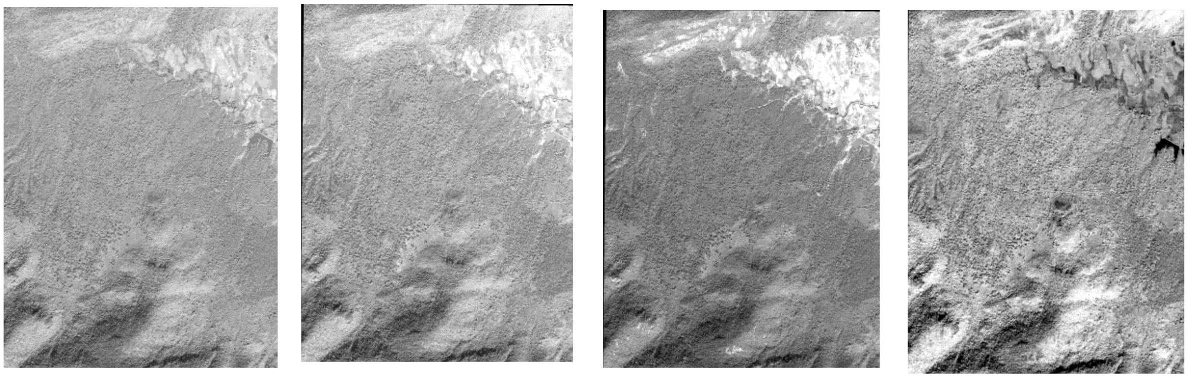

Fig. 5 Fused images by B-spline and super Curve method

where n is the numbers of pairs of data, X and Y are the pixel value of fused image and multispectral image respectively.
The value of r is such that $-1 \le r \le +1$.The +ve signs and –ve signs are used for positive and negative linear correlation coefficient, respectively. If ‘r’ is close to +1, it indicates a perfect positive fit. A correlation greater than 0.8 is generally considered as strong, whereas a correlation lesser than 0.5 is described weak. These values can vary on the basis of data that need to be examined. A study utilizing scientific data requires a very strong correlation than usual data.

Method proposed	Modified weighted mean	B-spline and super curve
Band 1	0.6549	0.8027
Band 2	0.7774	0.9123
Band 3	0.4372	0.9395
Band 4	0.2864	0.9308

Table 1 correlation coefficient of fused images

Covariance provides a measure of the strength of the correlation between two or more sets of random variables. The covariance for two random variables X and Y, each with sample size N, can be written out explicitly as

$$COV(X,Y) = \sum_{i=1}^{N} \frac{(x_i - \bar{x})(y_i - \bar{y})}{N}.$$

For uncorrelated variables COV(X, Y) =0. If the variables are correlated in some way, then their covariance will be non-zero. In fact, if COV(X,Y)>0, then Y tends to increase as X increases.

Method proposed	Weighted mean	B-spline and Super curve
Band 1	10.2217	10.2580
Band 2	20.2445	20.5124
Band 3	30.2347	30.9030
Band 4	40.2195	40.8183

Table 2 covariance of fused images

Entropy and SSIM (structural similarity index) are calculated for all fused images. Results shoes that the proposed method B-spline and super curve method is better than the weighted mean method. Observation of results are shownbelow in form of tables.

Method proposed	Weighted mean	B-spline and Super curve
Band 1	0.2899	0.3559
Band 2	0.3234	0.8492
Band 3	0.3085	1.2428
Band 4	0.2776	1.1105

Table 3 entropy of fused images

Method proposed	Weighted mean	B-spline and Super curve
Band 1	0.860782	0.980719
Band 2	0.397363	0.512086
Band 3	0.139203	0.278426
Band 4	0.114265	0.275456

Table 4 SSIM of fused images

After the process of pan-sharpening, the image obtained are observed using statistical methods. From the above result, we can observe that the correlation coefficient and covariance of the B-spline and super curve method is greater than weighted mean. Correlation coefficient establishes the relationship between fused image and multispectral bands in the way of similarity. Value of Correlation coefficient ranges from 0 to 1. Greater the value of correlation coefficient greater is the similarity. If value of covariance is zero, it indicates no correlation and increasing value greater than zero establishes linear relationship between the fused and multi spectral image. B-spline and super curve methods provides better information in terms of spectral and spatial resolution and increases smoothness in the fused image.

C. Qualitative Analysis

Proposed method of pan-sharpening is applied for the purpose of color enhancement and observation is shown below. Observation shows that, fused images obtained after pan-sharpening of panchromatic and multispectral image shows color enhancement. A sample image was processed to verify color enhancement using both methods. B-spline and super curve method shows better results than the weighted mean method. Observations of images processed is shown below in form of figures.

Fig. 6 MS image and panchromatic image

Fig. 7 Fused image using B-spline and super curve, fused image using weighted mean respectively.

We would like to magnify an image obtained after pan-sharpening through proposed method, by a factor M. Let us reason on a one-dimensional image, the extension of a two-dimensional image straightforward as a result of the separability. A demonstration of pan-sharpening for zooming ability is shown below.

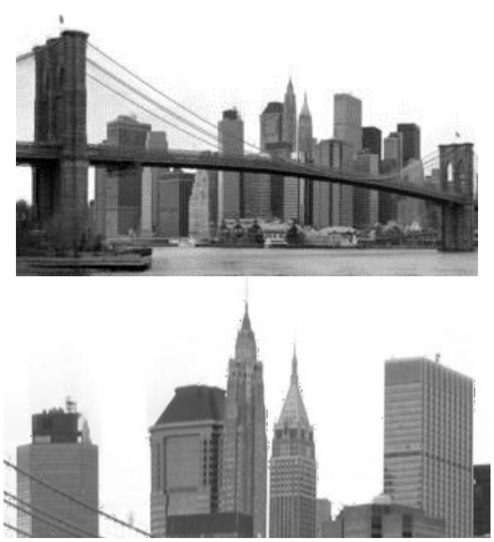

Fig. 8 part of original image

As a result of the sampling of the image, the position of the edge is known to within a pixel. The approximation which imposes that the functions pass by the points of the image gives rise to overshoots on the approximated image as it appears in fig 9,10.

Fig. 9 Original image

Fig. 10 Rate factor 1

Fig. 11 Rate factor 3

In the field of image processing edge detection of an image plays an important part in obtaining more information. With the help of the proposed method of pansharpening in this paper, edge detection of an image has improved to large extent which provides us detailed information. It is possible due to B-spline interpolation.

VI. Conclusion

Multispectral and panchromatic images were taken as input for the processing of data fusion through pan-sharpening. These images were taken by “Quickbird-2” satellite. Images were processed through a new method proposed in this paper. In this process of pansharpening filtering, interpolation, coefficient calculation and super curve formation are carried out with the help of B-spline. The finally obtained image (fused image) provides more information both spectrally and spatially as compared to any of the single image. The proposed method in this paper improves the smoothness of image, enhance the natural color visualization and increases resolution, all of it can be noticed visually. B-spline and super curve are easy to implement, unlike others it does not need any form of transformation, and provides better with more information.

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