Spatial Injection to Low Resolution Images using IIHS Transform

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Abstract
Image fusion, the process of combining multi-modal or multi-focus images to form a new informative image than input images. The fused image contains more information than their input images which helps remote sensing applications for image analysis efficiently. Many image fusion algorithms have been developed, but all of them introduced a term called as color distortion. The huge difference between the intensity of input images leads to the color distortion. The Intensity-Hue-Saturation fusion technique gives more access to the user to work on pixel by pixel. This method accessibility delivers the good fusion technique base to reduce the color distortion. We proposed an algorithm which solves the color distortion problem effectively and it can produce an output image as highly informative. The difference in intensity of input images reduced by injecting the intensity of the high resolution image. The proposed work performs better than existing algorithms and it is proved by statistical measures like a correlation coefficient, mean, standard deviation, ERGAS, UIQI and spectral angle mapper.

Keywords: Color Distortion, Enhancement, IIHS Transform, Image Fusion, Spatial Injection

1. Introduction
The image fusion is the process of combining two or more images into a single composite image with high resolution and make the final image more informative than input images1-6. Remote sensing sensors are monitoring the earth resources by providing the images in various resolutions and in various angles. The theme behind the satellite launched decides the spatial and spectral resolution of the image acquisition7-9. The two important resolutions are spatial and spectral resolutions. The spatial resolution is number of pixels per inch and the spectral resolution is providing the color information of the object which are presented in the captured image3,10. Both resolutions may vary depends upon its capability. The Panchromatic (PANC) image is the high spatial resolution grayscale image and multispectral (MSL) image the high spectral resolution color image with less spatial information7,8,11. The PANC and MSL gives less information to the researchers when they stand individually. The IKONOS, LANDSAT and Quickbird satellites are providing images in both format. As a single band image, the PANC image occupy less storage space and as the multiple band image, the MSL occupies more storage space8,11-14. The MSL sensors captures images in individual color during acquisition and makes them to the color image by pansharpening. The term image fusion is introduced to combine both resolution’s image to a single high resolution image with high spatial and spectral resolution2,5. The fused image provides more information to the researchers than the input images.

The different satellite sensor images are combined based on different image fusion algorithms like Intensity-Hue-Saturation method, Brovey method, Wavelet method, Principal Component Analysis (PCA), High-Pass filter and so many methods1-5,8. The
Intensity-Hue-Saturation method replaces the intensity of low resolution MSL image with high resolution PANC image intensity. The PCA method maximize the variance from the original image by translating and rotating the pixels. This method remaps the high intensity image with its principal component by substituting. PCA consumes heavy computational overhead and very slow method among other fusion methods. The Brovey transform is based on simple numerical methods to combine multiple sources of data by using the ratio algorithm. This method introduced to produce RGB images with respect to the assumption of PANC image spectral image. But this method is limited to three bands as the multispectral contains seven bands and the pixel values are smaller than the other methods with color distortion. The wavelet based methods are based on additive principle. The spatial information can be extracted from high resolution image to add with low resolution image by decomposition of both images to fix the wavelet approximation level. There are number of wavelet based fusion methods available, but they are producing the images with color distortion and loss of small objects and edges of the buildings. The high-pass filter method merging the PANC data with MSL data by resolution merge function. The pixel size of MSL data resampled with respect to the size of PANC data. The high-pass filtered high resolution image add with each band of the MSL image to produce the fused high resolution image by pansharpening all the bands. This method produces the output image with less sharpness leads to the low clarity of the objects. The Intensity-Hue Saturation method is the most useful method to fuse the different sensor images. This method consumes very less computational time due to the splitting and working on necessary pixels. The technique works well by calculating the spectral and spatial details of both images and replacing the intensity of MSL with respect to the PANC image.

In this paper, we proposed a technique based on Intensity-Hue-Saturation method to fuse the PANC image and 4-band MSL image. The proposed method produces the fused image by injecting the spatial information from PANC image to the MSL image. The resultant image visualizes the objects clearly as it contains high spatial and spectral resolutions. The proposed method works better than the other traditional methods and the performance of the method evaluated by the statistical parameters.

2. Methodology

The Intensity-Hue-Saturation (IHS) fusion method is the most widely used method for its speed and accuracy. This method is working based on the perceptual color model. The IHS method deals with intensity, hue and saturation in both linear and nonlinear transformations. The intensity of the image deals with linear transformation and remaining two properties deals with non-linear transformation. The equation (1), (2) and (3) presents the way of calculating the intensity, hue and saturation.

\[
\begin{cases}
I = \frac{1}{3} - \frac{\sqrt{2}}{6} & G = \frac{1}{3} - \frac{\sqrt{2}}{6} \\
v_1 = \frac{2\sqrt{2}}{6} & B = \frac{1}{3} - \frac{\sqrt{2}}{2} \\
v_2 = 1 - \frac{1}{\sqrt{2}} & v_2 = 1 - \frac{1}{\sqrt{2}}
\end{cases}
\]

\[H = \tan^{-1}\left(\frac{v_1}{v_2}\right)\]

\[S = \sqrt{v_1^2 + v_2^2}\]

The IHS fusion method require two or more images as an input for the fusion process. The PANC and MSL images are given as input for this method. The MSL image contains RGB values and then transformed to Intensity-Hue-Saturation color space. The intensity of the high resolution image replacing the intensity of the low resolution image and then inverse transform from Intensity-Hue-Saturation space to RGB produce the fused high resolution image. The following steps are the IHS fusion algorithm:

Step 1: Read Low Resolution color image and high resolution grayscale image.

Step 2: Up sample the low resolution image with respect to the size of high resolution image.

Step 3: Transform the low resolution color image into Intensity-Hue-Saturation color model.

Step 4: Replace the intensity of the high resolution grayscale image with low resolution color image.

Step 5: Inverse transform the Intensity-Hue-Saturation space to RGB image.

The IHS transform method replaces the intensity of low resolution image by high resolution image and makes the final mage more informative than the input.
images. This traditional method produces good results but introducing color distortion problem in fused image. The color distortion occurs due to the large difference between the intensity of MSL and PANC images and spatial distortion occurs due to the upsampled low resolution image. In this paper we introduced a method will solve the color distortion problem by effective spatial injection scheme and producing better results than traditional methods.

3. Proposed Method

This paper presents a fusion method namely Improved Intensity-Hue-Saturation transform for effective fusion of satellite images. The PANC and three band MSL images given as an input to test this algorithm. The proposed method derived from its traditional IHS method and overcome the spectral distortion by injecting spatial information to the MSL image effectively. The intensity of the both image compared and measured the absent intensity of MSL image to fix the spatial injection range. This spatial injection helps to reduce the spectral distortion which occurs due to the large difference between both input images during intensity replacement. The procedure of the proposed algorithm given as:

Step 1: PANC and MSL images as an inputs.
Step 2: Resize the MSL image with respect to the size of PANC image.
Step 3: Transform the MSL image to I, H and S space.

$$\begin{bmatrix} I_0 \\ v1 \\ v2 \end{bmatrix} = \begin{bmatrix} \frac{1}{6} & \frac{1}{6} & \frac{1}{6} \\ -\frac{\sqrt{2}}{6} & -\frac{\sqrt{2}}{6} & \frac{2\sqrt{2}}{6} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} Ro \\ Go \\ Bo \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} \quad (2)$$

Where $I_0$ represents the original intensity and R, G and B represents the Red, Green and Blue Bands. Ro, Go and Bo represents the original RGB values.

Step 4: Measure the intensity of the MSL image.

$$MSL_1 = \frac{Ro + Go + Bo}{3} \quad (3)$$

Where $MSL_1$ is the intensity of the MSL image.

Step 5: Measure the variation range of intensity between two images.

$$Int_{diff} = Pan_t - MSL_1 \quad (4)$$

$Int_{diff}$ is the variable to store the difference between the intensity of PANC and MSL images and $Pan_t$ is the intensity of PANC image.

Step 6: Inject the spatial information to MSL with respect to the value obtained from step 5.

$$\begin{bmatrix} R_{new} \\ G_{new} \\ B_{new} \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 1 & \frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} Int_{diff} \\ v1 \\ v2 \end{bmatrix} \quad (5)$$

$R_{new}$, $G_{new}$ and $B_{new}$ are the newly generated RGB values.

Step 7: Inverse transform of new I, H and S to RGB space.

$$\begin{bmatrix} R_{new} \\ G_{new} \\ B_{new} \end{bmatrix} = \begin{bmatrix} 1 & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 1 & \frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} I_0 + (Int_{diff} - MSL_1) \\ v1 \\ v2 \end{bmatrix} \quad (6)$$

Step 8: Visualization of fused image.

The proposed algorithm measuring the intensity difference between the images by comparing their intensity value by comparing their pixels. This value fixes the range of spatial details to be inject in the MSL image. The presenting spatial information in MSL remains same and the extra spatial details from the PANC image increasing the quality of the fused image. This proposed method reducing the intensity variation in huge amount. So the spectral distortion problem avoided and the objects in the fused image representing with their original color information. The proposed algorithm performs well in fusing any multispectral images with respect to their Panchromatic images to produce an high resolution multispectral image. As the remote sensing applications required the images with good spatial and spectral resolution for analysis purpose. The proposed method output eases the function of the segmentation, classification and feature extraction processes. This proposed method works faster than the many other fusion methods.
The time complexity and computational complexity of the proposed method are better than traditional methods. The quality of the fusion measured by using statistical parameters like mean, correlation coefficient, standard deviation, UIQI and ERGAS. The proposed algorithm performances visualized in the following section.

4. Results and Analysis

The proposed method works fine with MSL and PANC images in various resolutions. This method applicable for many multi-sensor data fusion in remote sensing. The proposed method producing good images and the results are compared with existing method. The PANC image intensity replaces the absent intensity of MSL image identified and injected to the MSL image. The Figure 1 (a) and (b) used as inputs for the proposed algorithm. The proposed algorithm works fine with the given multi-sensor data and producing the good amount of improvement in the output image. Figure 2 shows the output of the proposed method. The deep visualization of improved spatial details displayed in the Figure 3 along with its comparison output of existing method.

![Figure 1](image1.png)
(a) (b) PANC and MSL images of the same location.

![Figure 2](image2.png)
Proposed method Output.

![Figure 3](image3.png)
Deep visual analysis of Proposed and existing method. Top upper images are from existing method output and lower images are proposed method output showing the spatial enhancement.
5. Conclusion

The traditional Intensity-Hue-Saturation method simply replacing the intensity of the PANC image with MSL image without any modification which leads to the spectral distortion. The spectral distortion reduced in the proposed due to the proposed spatial injection scheme. This IIHS scheme identifies the absent intensity level in MSL image by comparing both image intensity. The identified difference intensity level injected to the MSL image to enhance the spatial properties of MSL image. The proposed IIHS method works very well with less time complexity as it reduced the intensity replacement time by spatial injection method. The proposed algorithm performs better than many other fusion algorithms and the results displayed graphically. The visual analysis is the best way to measure the quality of the fusion and visuals are proving the quality of the IIHS method as well as better algorithm for multi-sensor remote sensing fusion method.

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