Image Fusion Technique: Algorithm to Application

Prakash Ghimire & Dr. Lei Deng
mail4prakash2017@gmail.com, denglei@cnu.edu.cn

KEYWORDS

Image Fusion, Resolution, AOI (Area of Interest), Supervised Classification, Accuracy Assessment

ABSTRACT

This paper highlights the image fusion technique with two images (one before flooding and another after flooding), thereby classifying the major land use categories in the flooding area. In July 2003, strong flooding occurred in Huai River, Anhui Province - China which caused serious harm to people's life and property. In order to reduce the loss, the detection of the flood inundated area and their land use categories need to be identified. Using multi-temporal images, during image fusion; the lacking information in one image is completed by another image. It substitutes missing information in one image with signals from another sensor image. The IHS sharpening technique is one of the most commonly used techniques for image sharpening. Different transformations have been developed to transfer a colour image from the RGB space to the IHS space. SAR image and TM multispectral image having different resolutions are fused giving higher resolution. The fused image is classified using unsupervised image classification technique with desired no of classes. The resulting classified image further divided into two categories only, namely disaster and non disaster area. Still, main task relies on how to categorize the disaster area into different land use classes and about their accuracies. The original image before flooding is classified using maximum likelihood classifier with desired number of classes. The maximum likelihood classifier performs its best due to the assumption of normal probability distribution of pixels, calculating probability density function for each pixel for each class and assigning them to the class where its occurrence is highest. So, when overall classification accuracy and KHAT statistic is good enough, final classification is made. The previously classified image with two categories and newly supervised classification are overlaid with proper transparency setting to get different land use categories.

1. INTRODUCTION

Image fusion is the process that combines information from multiple images of the same scene (Sreelekshmi, 2016). This approach of combining multi temporal images is concerned with increasing either spatial or radiometric details in resulting images. Image fusion enables us to integrate imagery of different spatial resolutions (Firouz et. al., 2011). Huai River in China is taken as study area where the SAR image and TM multispectral image having different resolutions (Table1) and taking in different time are analyzed using image fusion technique to highlight flooding information. SAR image is available in gray scale but TM multispectral in multiple bands. It is applied for remote sensing Image fusion/Resolution merge is the process of combining high resolution panchromatic image with low resolution multispectral image to get high resolution multispectral imagery (Sreelekshmi, 2016). To transform RGB space into IHS space to represent the information as Intensity, Hue and Saturation, IHS technique is one of the most commonly used image fusion techniques for image sharpening (Firouz et. al., 2011). It has become a standard procedure in image analysis for colour enhancement, feature enhancement, improvement of spatial resolution and fusion of disparate data sets (Pohl & Van, 1998). The fused image need to be classified using unsupervised classification. It is better to choose class number greater than the available band number which can give sufficient classification result based on the different spectral bands. Similarly, supervised image classification is performed for original TM multispectral image with major categories of River, Water, Plant, Farmland and Buildings. For accuracy assessment of the ML (Maximum Likelihood) classification was determined by means of a confusion matrix (sometimes called error matrix), which compares, on a class-by class basis, the relationship between reference data (ground truth) and the corresponding results of a classification (Lillesand et. al, 2004). The original TM multispectral image is overlaid into the unsupervised classified image having two classes namely disaster and non disaster. The land use categories in disaster area is determined.

1.1 Data/Image Used

Two images were taken for the analysis of disaster area near Huai River, China. One image is TM multispectral with combination of TM543 used as reference. It has pixel size (resolution) of 28.5*28.5 meter. A multispectral image consists of several bands of data. For visual display, each band of the image may be displayed one band at a time as a grey scale image, or in combination of three bands at a time as a colour composite image. It is the image taken before the flooding occurred.

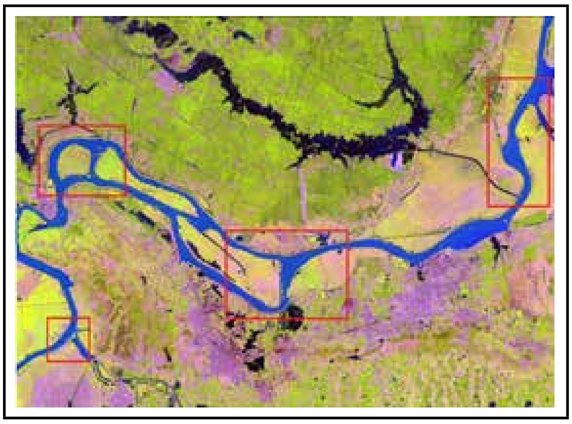

Figure1: TM543 (Multispectral) image

Similarly, there was another image which was taken after the flooding occurred. The SAR image is used here to show the flooding information having higher resolution than TM multispectral i.e. 20*20 meter. A panchromatic image consists of only one band. It is usually displayed as a grey scale image which is brightness of a particular pixel proportional to the pixel digital number which is related to intensity of solar radiation reflected by the targets in the pixel and detected by the detector. Thus, a panchromatic image may be similarly interpreted as a black-and-white aerial photograph of the area. The different red rectangles in two images indicates the major destroyed area before and after flooding.

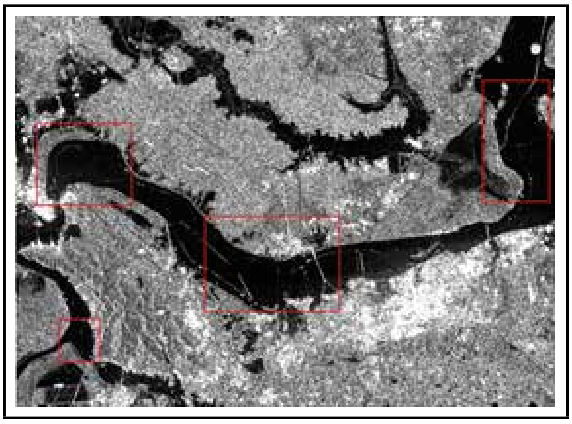

Figure2: Radarsat SAR image

1.2 Meta data

The detail information about the coordinate system and images is listed below:

Table1: Coordinate details of both image

XY Coordinate system	WGS_1984_UTM Zone_50N
Angular unit	(0.01745) Degree
Linear unit	(1.00) Meter
False Easting	500000 Meter
False Northing	0 Meter
Scale factor	0.9996
Central Meridian	117° E
Datum	D_WGS_1984

Table 2: Image details

Name	Format	Acquire Time, Resolution	Bands
SAR	TIFF	2003-07-14 (20*20m)	C
TM5 TM4 TM3	IMG	2002-09-22 (28.5*28.5m)	SW-IR Near-IR Red

1.3 Study Area

The image covers the range of 32° 34' 30"N to 32° 49' 30"N latitude and 116° 42' 00" E to117° 07' 00" E longitude as study area. The river is located in the southern east part of China, at the middle of Anhui province. The background map is the base map of China Online Street Warm access through Arc GIS 10.5 as shown in Figure3.

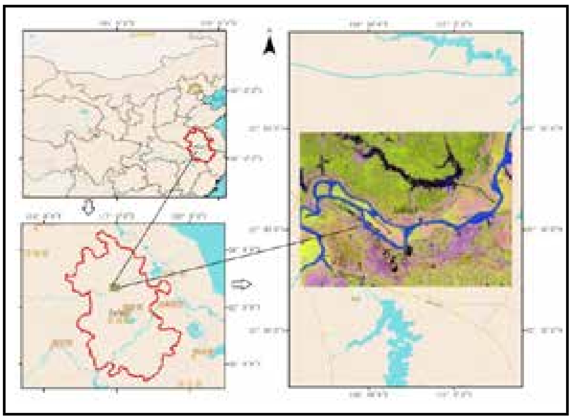

Figure3: Location of study area

1.4 Software used

During this research, the ERDAS Imagine 2014 software was used as image processing software and Arc GIS 10.5 was also used during final map composition and layout preparation.

2. METHODOLOGY

2.1 Visual Interpretation

Two image layers clearly show that after flooding more land is destroyed by course of river. There are many possible schemes of producing false colour composite images. However, some scheme may be more suitable for detecting certain objects in the image. Two different images can be viewed in parallel using swiping tool in Erdas Imagine 2014 software. That is useful for visual interpretation of images to check which part is destroyed more and which is less as shown in Figure4.

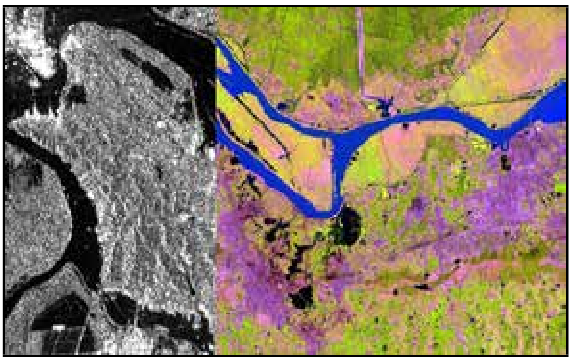

Figure4: Swiping of two images

A very common false colour composite scheme for displaying multispectral image is shown below:

R = (NIR band)
G = (Red band)
B = (Green band)

For the extraction of the destroyed area and to categorize them into land use classes, false colour composite was performed. In that performance, Red band was replaced by NIR band, Green band by Red band and Blue band by Green band respectively. After false colour composition, band of TM Multispectral image was assigned to SAR image and appeared yellow colour as the flood area (disaster area) as shown in Figure5 below.

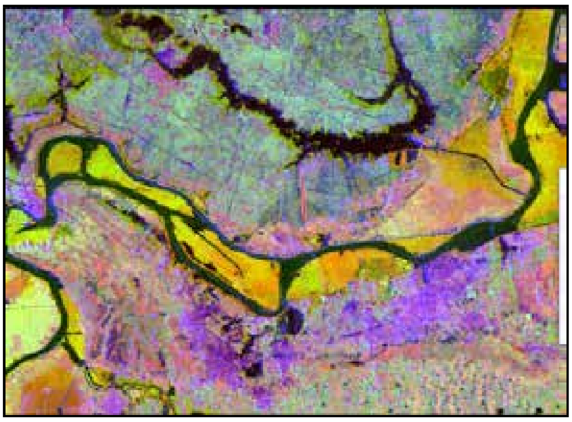

Figure5: Highlighted yellow colour as disaster area

2.2 Image Fusion

IHS method consists on transforming the R,G and B bands of the multispectral image into IHS components, replacing the intensity component by the panchromatic image, and performing the inverse transformation to obtain a high spatial resolution multispectral image (Bhaskarrajan, 2014). To obtain the land use categories in the flooding area, first need to the fuse the image. The following steps further explains about the Image fusion.

- Perform image registration (IR) to PAN (Panchromatic) and MS (Multispectral), and resample MS.
- Convert MS from RGB space into IHS space.
- Match the histogram of PAN to the histogram of the I component.
- Replace the I component with PAN.
- Convert the fused MS back to RGB space

The image fusion gives improved image in the sense that is combines both SAR and TM multispectral bands. The following figures shows after image fusion.

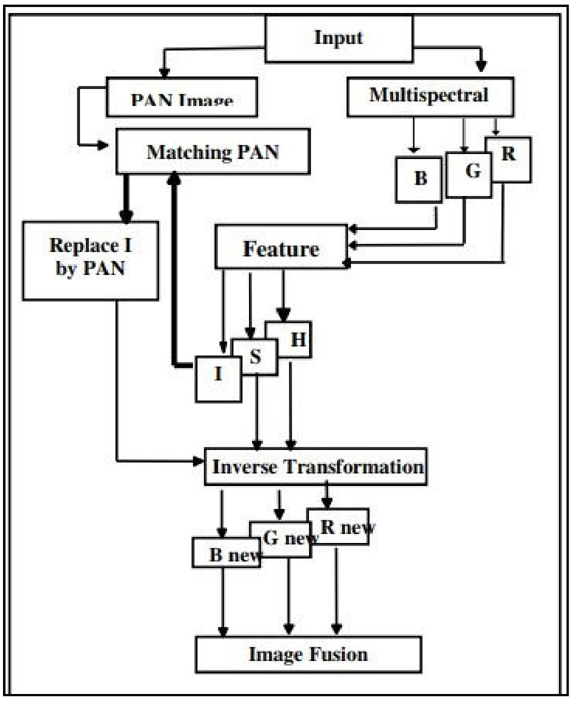

Figure6: Image Fusion Steps (Firouz et. al, 2011)

Literature proposes many IHS transformation algorithms have been developed for converting the RGB values. Some are also named HSV (hue, saturation, value) or HLS (hue, luminance, saturation). (Figure6) illustrates the geometric interpretation. While the complexity of the models varies, they produce similar values for hue and saturation. However, the algorithms differ in the method used in calculating the intensity component of the transformation. The most common intensity definitions are:

$$I = \frac{(R+G+B)}{3} \quad (1)$$

$$V = Max(R, G, B) \quad (2)$$

$$L = \frac{\max(R,G,B)+\min(R,G,B)}{2} \quad (3)$$

The first system (based on V), also known as the Smith's hexcone and the second system (based on L), known as Smith's triangle model (Nunez et.al., 1999). The hexcone transformation of IHS is referred to as HSV model which derives its name from the parameters, hue, saturation, and value, the term "value" instead of "intensity" in this system. (Sangwine&Horne,1989).

The Intensity Hue Saturation (IHS), Principle Component Analysis (PCA), Brovey Transformation (BT) and Wavelet transformation (WT) are contemporary image fusion techniques in remote sensing community. However, they often face colour distortion problem with fused image (Te-Ming et. al, 2001).

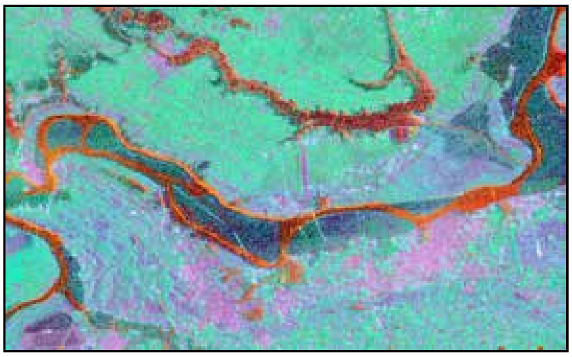

Figure7: IHS Fused Image

2.3 Fused Image Classification

For disaster area acquisition, unsupervised classification method is performed with 10 classes. These classes were divided into two categories "Disaster area" and "Non-disaster area". Making "Non- disaster area" of 9 classes as no colour and for "Disaster area" with red colour, the visualization seems like (Figure8) below. Similarly, the corresponding layer is added in the previous image which confirms the red area belongs to flooding area (Figure9).

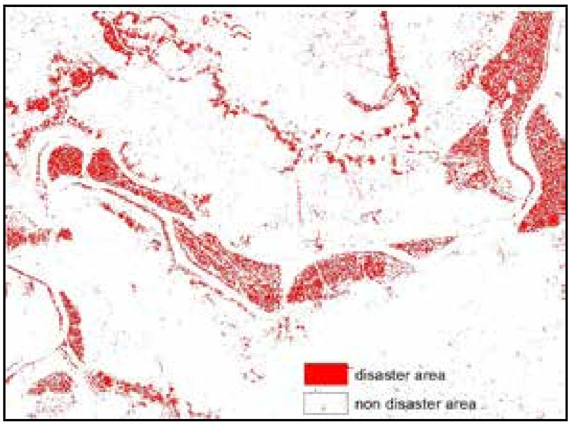

Figure8: Flooding(red), Non-Flooding(white) area

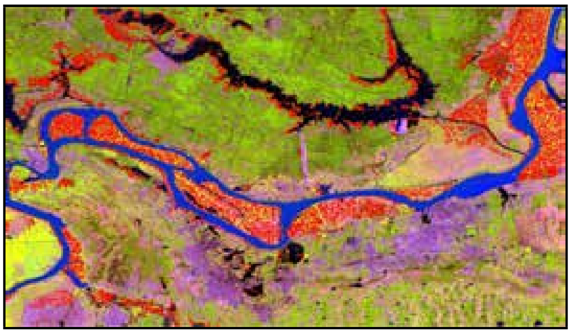

Figure9: Overlaid flooding area in original image

2.4 TM Image Classification and Accuracy

In the original TM multispectral image, five kinds of training samples were selected by artificial means: Huai River assigned as blue colour, water as black, buildings as red, farmland as yellow and plant as green colour.

The classification was carried out using maximum likelihood classifier. Selection and distribution of Area of Interest (AOI) is made in uniform way to represent them from all sides of the image so that the accuracy increases. Accuracy assessment of the ML (Maximum Likelihood) classification was determined by means of a confusion matrix (sometimes called error matrix), which compares, on a class-by class basis, the relationship between reference data (ground truth) and the corresponding results of a classification (Lillesand et. al., 2004).The training samples were evaluated using supervised classification and unsupervised classification. The results were verified through error matrix with overall accuracy, user accuracy and producer accuracy and the classification result with highest overall accuracy is adopted as good enough. At first, supervised classification accuracy was only 75 % and again classification was carried out and got 85% accuracy which is chosen as best.

$$KHAT = \frac{N\sum_{i=1}^{r} Xii - \sum_{i=1}^{r}(X_{i+} * X_{+i})}{N * N - \sum_{i=1}^{r}(X_{i+} * X_{+i})} \qquad (4)$$

Where,

r - number of rows in the error matrix

Xii- number of observation in row i and column i (the diagonal cells)

Xi+ Total observation of row i

X+i Total observation of column i

N - Total observation in the matrix

KHAT statistics (Equation 4) is a measure of the difference between the actual agreement between reference data and the results of classification, and the chance agreement between the reference data and a random classifier (Lillesand et.al, 2015). In this case the value of KHAT is found to be 0.79 which indicates that classification is 79% improvement from random assignment of pixels.

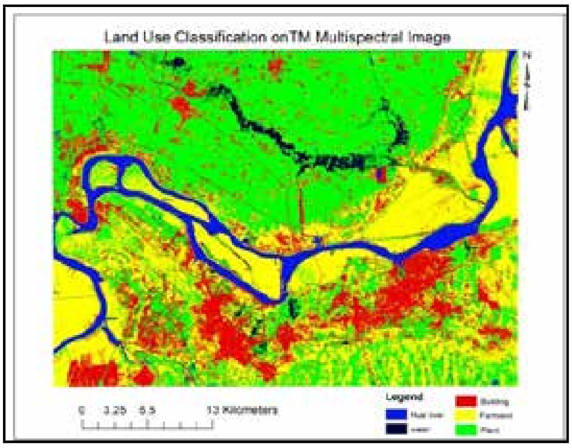

Figure10:Supervised Classification (Land Use)

Thus obtained classified image is overlaid with previous classification having two categories with proper transparency setting to get land use categories.

3. RESULT

Out of total study area (215.10 Square KM), 11.078 Square KM (5.15%) area lied into flooding/disaster/risky area. The black background colour is assigned for the "Non Flooding" area and different colour are assigned for different categories in the disaster area showing building to red, farmland to yellow, plant to green (Figure11).

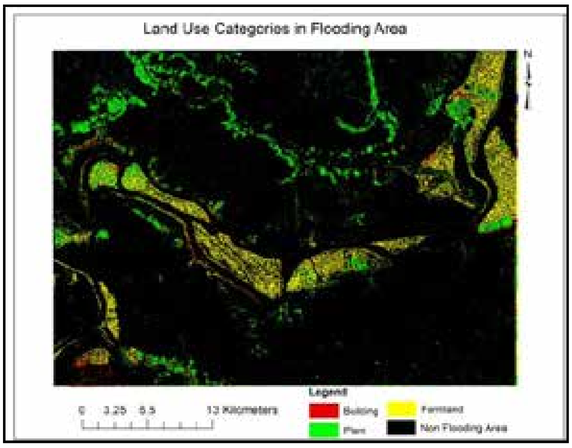

Figure11: Final land use map in flooding area

The final thematic map shows that in flooding area, most of the land use categories are farmland. Few of the buildings are in the risk area but most of them are in safe side. In the upper part of the study area, most of the plant are in the flooding area rather than farmland and build-up area.

4. CONCLUSION

From above discussion following conclusion is made with following subtopics.

4.1 Image fusion

Image Fusion techniques make it possible to emphasize and visualize certain features more clearly than they are in individual images. For example, highlighting change in certain area (like flooding), only SAR image and TM multispectral image is not possible and requires image fusion. It is fast, efficient and shows the information clearly. In this paper, the Modified HIS method is chosen because from different literatures, it is described as most widely used method. Because in this technique, the IHS (Intensity, Hue and Saturation) space are converted from the Red, Green and Blue (RGB) space of the Multispectral image. The intensity component I is replaced by the PAN. Then the reverse transform is applied to get RGB image as an output. So, although there were other methods like Principle Component Analysis (PCA), Brovey Transform (BT) and Wavelets Transform (WT) Modified IHS method can be used for image fusion, change detections and image enhancement in better way.

4.2 Classification and Accuracy

Both classifications (supervised and unsupervised) were performed but supervised classification with maximum likelihood method is better one. During classification, testing accuracies (overall, producer, user) and checking KHAT statistics value informs about the classification situation. When overall accuracy, producer accuracy and user accuracy approach to 100% and KHAT statistic tends to be 1 it shows excellent classification but here is 85% and 0.79 respectively which is satisfactory. Decision on making final classification depends on these accuracies and statistics. So for image classification maximum likelihood classification with supervised classification performs best.

5. RECOMMENDATION

This highlighted area in the map should be marked as risky area/vulnerable area by the government thereby making aware for people. Some safety measurement and early warning system is necessary near this area. As a new research approach, different image fusion techniques like PCA, BT and WT can also be used for same area and cheeking their different result. Some more research can be performed for making comparative analysis in different image fusion techniques for different sources and types of data.

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Author's Information

Name	:	Prakash Ghimire
Academic Qualification	:	M.Sc. in Cartography and GIS (Running...), MA(Economics), BE(Geomatics)
Organization	:	Survey Department, Government of Nepal
Current Designation	:	Survey Officer
Work Experience	:	4 Years