



## Multi-spectral remote sensing digital image fusion algorithms for real world resources and regional development

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### Abstract

Multi-sensors remote sensing satellite imagery are merged to improve resolution of imagery by use of methods and algorithms for decision making for real world. Image Fusion techniques are band selection method, colour related techniques, statistical numerical methods, principal component analysis, high pass filtering, regression variable substitution, canonical variant substitution, component substitution and wavelets. Image fusion purpose is selection of appropriate techniques and algorithms for image merging and sharpening, accuracy in registration, feature enhancements, image classification, change detection, stereo modelling and so on. Image fusion major application areas are as topographic mapping and map updating, land use land cover mapping, agriculture and forestry, flood monitoring, ice sheet and snow monitoring as well as geology and geomorphic processes and exploration of earth's resources for regional development.

**Keywords:** multi-sensor, raw imagery, image fusion, algorithms, decision support system

### 1. Introduction

Earth Observation Systems (EOS), particularly deployed on remote sensing satellites, provides repetitively and consistently synoptic views of earth in form of digital imagery (Schowengerdt, 2007). More recently, due to development of new sensors, a need for data processing techniques has arisen which can use observations from a variety of different sensors. Multi-sensor data fusion is an evolving technology primarily concerned with the combination of data and information combination from the multiple sensors in order to achieve by the use of single sensor.

The earth observation satellite sensors produce data using different regions of the electromagnetic spectrum which resulted into the generation of different spatial, temporal and spectral resolutions. So, the data fusion covers a very wide variety of the fusion processes which is based upon so many wavelengths, acquisition means, platforms, applications and mathematical tools (Wald, 1999).

It is difficult to precisely define image fusion by a single definition. In general, "image fusion is the combination of two or more different images to form a new image by using a certain algorithm". In other words, the image fusion is the merging of multi sensors data (Pohl, 1996).

There is a confusion in using of the term data fusion and image fusion. Sometime these terms are used synonymously. Data fusion is "a process dealing with data and information from multiple sources to achieve refined/ improved information for decision-making" (Hall, 1992). Whereas, the image fusion is "the combination of two or more different

images to form a new image by using a certain algorithm (Gerndern and Pohl, 1994).

### 2. Objectives of Image Fusion

- 1) Image Sharpening
- 2) Improvement of Registration Accuracy
- 3) Creation of Stereo Data Sets
- 4) Feature Enhancements
- 5) Improved Classification
- 6) Temporal Aspects for Change Detection
- 7) Overcoming Gaps

### 3. Selection of Sensor

- 1) Orbit
- 2) Platform
- 3) Imaging Geometry - optical and radar
- 4) Resolution - spectral, spatial and temporal

### 4. Processing Levels of Image Fusion Approaches

- 1) Pixel Based Fusion
- 2) Feature-level Fusion
- 3) Decision Level Fusion

### 5. Suitable Fusion Levels

- 1) Pixel-based Image Fusion
  - a) Geometric Model (GM)
  - b) Ground control Point (GCP)
  - c) Digital Elevation Model (DEM)
  - d) Resampling Method (RM)

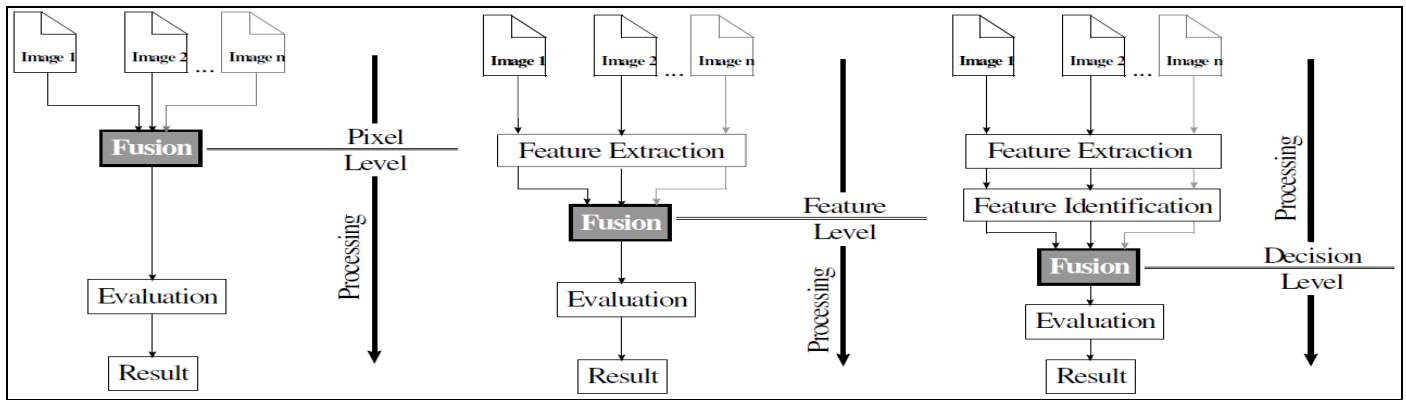


Fig 1: Schematic Processing levels of image fusion (Schowengerdt, 1998) [19].

**6. Application of Image Fusion** – to various types of data sets

- 1) Single Sensor – temporal – SAR multi-temporal for change detection
- 2) Multi-Sensor – temporal – VIR/ SAR image mapping
- 3) Single Sensor – spatial – High/ Low Resolution PAN/ multi-spectral SPOT

- 4) Multi-Sensor – spatial – High/ Low Resolution SPOT/ Landsat
- 5) Single Data – multi Sensor – ERS-1/ ERS-2

**7. Image Fusion Techniques**

In general, an overall processing flow for fusion of optical and radar satellite imagery is given below:

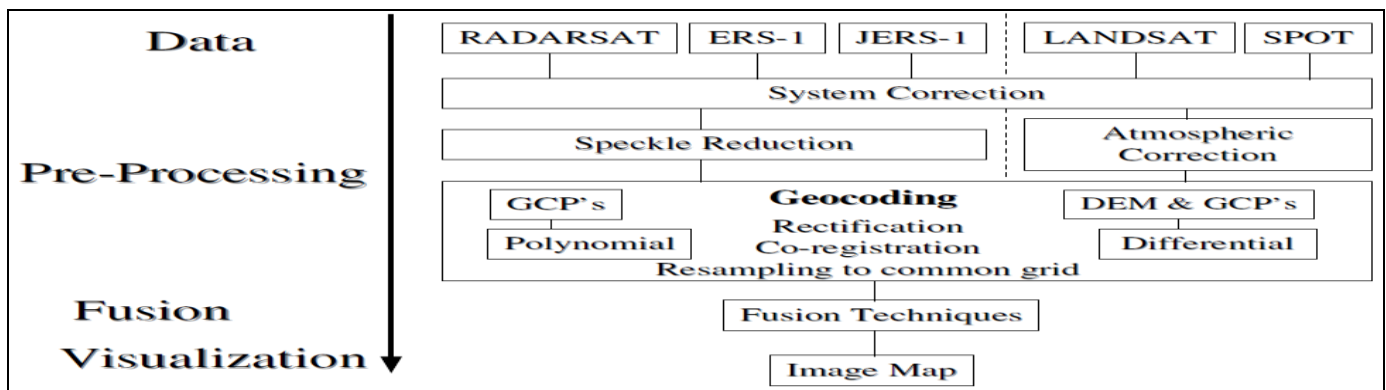


Fig 2: Schematic process of image fusion techniques for optical and radar satellites imagery (Schowengerdt, 1998) [19].

**i) Band Selection Method**

- 1) Optimum Index Factor (OIF)

$$OIF = \frac{\sum_{i=1}^3 \sigma_i}{\sum_{j=1}^3 |cc_j|}$$

Where:

$\sigma_i$  = standard deviation of digital number of bands;  
 $cc_j$  = correlation coefficient between any two of three bands.

Equation 1: Optimum Index Factor (OIF) for Digital Imagery.

**ii) Colour Related Techniques**

- A. Tristimulus Values
- B. Chromaticity
  - i. Colour composites (RGB)

The additive primary colours allow one to assign three different types of information to the three primary colours red, green and blue.

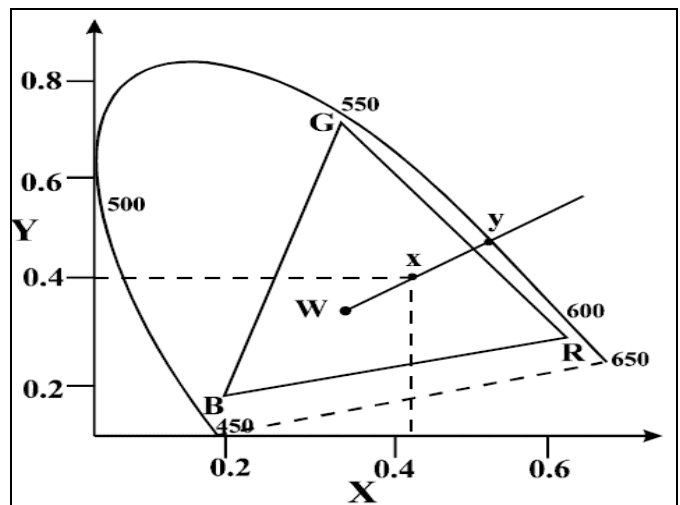


Fig 3: CIE Chromaticity Diagram (Hyden et al., 1982).

ii. Intensity-Hue-Saturation (IHS)

(a) HIS to RGB

The HIS colour transformation effectively separates spatial (*I*) and spectral (*H*, *S*) information from a standard RGB imagery.

$$\begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{pmatrix} * \begin{pmatrix} R \\ G \\ B \end{pmatrix} \quad (a)$$

$$H = \tan^{-1}\left(\frac{v_2}{v_1}\right) \quad (b) \quad S = \sqrt{v_1^2 + v_2^2} \quad (c)$$

Where:

- I* = intensity
- v*<sub>1</sub> & *v*<sub>2</sub> = intermediate variables
- H* & *S* = Hue & Saturation

Equation 2: Colours transformation of three imagery channels I, H & S into RGB. (Rast *et al.*, 1991).

(b) RGB to HIS

The RGB transforms three channels of the imagery representing RGB into the HIS colour space which separates the colour aspects in its average brightness intensity.

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & -\frac{2}{\sqrt{6}} & 0 \end{pmatrix} * \begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix}$$

Where:

- R = Red
- G = Green
- B = Blue

Equation 3: Colours transformation of three imagery channels R, G & B to IHS (Carper *et al.*, 1990).

iii. Liniment-Chrominance (YIQ)

A new colour encoding system is called YIQ which has a straight forward transformation from RGB with no loss of information.

$$\begin{pmatrix} Y \\ I \\ Q \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \quad (a)$$

$$\begin{pmatrix} R \\ G \\ B \end{pmatrix} = \begin{pmatrix} 1.000 & 0.956 & 0.621 \\ 1.000 & -0.272 & -0.647 \\ 1.000 & -1.106 & -1.703 \end{pmatrix} \begin{pmatrix} Y \\ I \\ Q \end{pmatrix} \quad (b)$$

Where:

- Y = luminance
- I = red minus cyan
- Q = magenta minus green

Equation 4: Relationship between YIQ and RGB is shown in the equations (a) and (b).

iii) Statistical Numerical Methods

A. Arithmetic combinations

i. Adding and Multiplications

$$DN_f = A(w_1 * DN_a + w_2 * DN_b) + B$$

$$DN_f = A * DN_a * DN_b + B$$

Where:

- A & B = scaling factor
- w<sub>1</sub> & w<sub>2</sub> = weighting parameters
- DN = digital number

Equation 5: Imagery fusion by multiplication (Yesou *et al.*, 1993).

ii. Difference and Ratio Imagery

a. Normalisation

$$\frac{XS_3 - XS_2}{XS_3 + XS_2} - \frac{TM_4 - TM_3}{TM_4 + TM_3} + C$$

Where:

$$C = 128 \text{ for positive values}$$

Equation 6: Normalised TM and XS data for urban change detection (Griffiths, 1998).

b. Spatial Enhancement Ratio

$$DN_{HybridXS(j)} = DN_{PAN} \frac{DN_{XS(i)}}{DN_{SynPAN}}$$

Where:

- DN<sub>HybridXS(i)</sub> = *i*<sup>th</sup> band of the fused high resolution imagery;
- DN<sub>PAN</sub> = corresponding pixel in high resolution input PAN imagery;
- DN<sub>XS(i)</sub> = super pixel in *i*<sup>th</sup> band of input low resolution XS imagery;
- DN<sub>SynPAN</sub> = corresponding pixel in low resolution synthetic PAN imagery.

Equation 7: A spatial enhancement ratio is

presented in the above equation to maintain radiometric integrity while increasing spatial resolution. (Munehika *et al.*, 1993).

#### c. Brovey Transform

$$DN_{fused} = \frac{DN_{b1}}{DN_{b1} + DN_{b2} + DN_{bn}} * DN_{highres}$$

Where:

DN<sub>fused</sub> = fused imagery of *n* multispectral bands

DN<sub>highres</sub> = high resolution imagery

Equation 8: Brovey Transformation for Imagery.

#### B. Principal component Analysis

- 1) Covariance or correlation matrix
- 2) Eigen Values, Vectors
- 3) Principle Components

#### C. High Pass Filtering

#### D. Regression Variable Substitution

#### E. Canonical Variant Substitution

#### F. Component Substitution

Component Substitution (COS) Techniques:

- a. HIS Colour Transformation
- b. Regression Variable Substitution (RVS)
- c. Principle Component Substitution (PCS)
- d. Standard PC Substitution (SPS)

#### G. Wavelets

- 1) Multi-resolution Analysis(MRA)

#### 8. Combined Approaches

- 1) RGB/ other techniques
- 2) IHS/ other techniques
- 3) HPF/ Band Combination
- 4) Mosaic/ other techniques

#### 9. Application of Image Fusion

- 1) Topographic Mapping and Map updating
- 2) Land Use, Agriculture & Forestry
- 3) Flood Monitoring
- 4) Ice/ snow Monitoring
- 5) Geology

#### 10. Advantages and Limitations

1. Selection of Appropriate Data set and Techniques
  - 1) Pre-processing
  - 2) Techniques and Image Combinations
    - a) RGB
    - b) Band combinations
    - c) Brovey
    - d) PCA
    - e) HIS
    - f) Mosaic
2. Assessment criteria
3. Levels of Image Fusion
4. Operational Image Fusion
5. Future Improvements

#### 11. Conclusions

Earth Observation Systems, principally remote sensing satellites have proven valuable for monitoring earth's resources at local, regional and global levels. These satellites are providing spatio-temporal coverages of earth's resources as land, water, forests and so on in form of digital imagery. More recently, there have been easy availability of volumes of remote sensing imagery which continues to develop at a phenomenal rate due to technological advances in sensors as nano-sensor technology. So, spatio-temporal multi-resolution imagery are easily available of airborne aircraft or space-borne remote sensing satellites. However, more recently, due to increasing use of remote sensing technology, there have been enormous demand for digital image processing using image fusion algorithms. Such algorithms are used in processing of digital imagery to combine information received from different sensors into a single composite imagery especially for extraction of required geospatial information. So, image fusion is commonly described as a digital processing for enhancing resolution of satellite imagery by combining information captured by different satellite sensors. It has been widely used in many fields of remote sensing such as object identification, land use/land cover classification and change detection, natural hazards and risks monitoring, ice/snow cover monitoring and so on for real world's regional development for betterment of humanity on this planet earth.

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