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Spatial Resolution Enhancement using Image Fusion and Regression

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Abstract

Spatial resolution and temporal resolution both being high at wider swath is a problem being faced by space borne sensor. IRS Resourcesat-I satellite have AWiFS, LISS-III, and LISS-IV sensors onboard. LISS-III has spatial resolution of 23m at a swath of 140km. AWiFS has 56m spatial resolution at a swath of 740km. Ground processing techniques are used for prediction of high spatial resolution of 23m at a wider swath of 740km and temporal resolution of 5days. Images having high spatial resolution along wider swath can be achieved by using Fusion and Regression. Fusion and Regression are used for the spatial resolution enhancement. Proposed method spatially outperforms and retains rich multi spectral details.

Keywords: Spatial Resolution(SR), Swath, Temporal Resolution(TR), Regression, Image Fusion.

I. INTRODUCTION

Integration of information taken by data obtained with different spectral, spatial, temporal resolution and different swath width is known to be as remote sensing image fusion [5]. The purposes of fused image are Classification, Modelling, Feature Extraction, Photo–Analysis, etc [6]. Two sensors data namely AWiFS (Advanced Wide Field Sensor) and LISS-III (Linear Imaging Self Scanning Sensor) of Resourcesat–I mission are used for image fusion. Acquired data by these sensors is characterized by resolutions - temporal, radiometric, spectral and spatial.

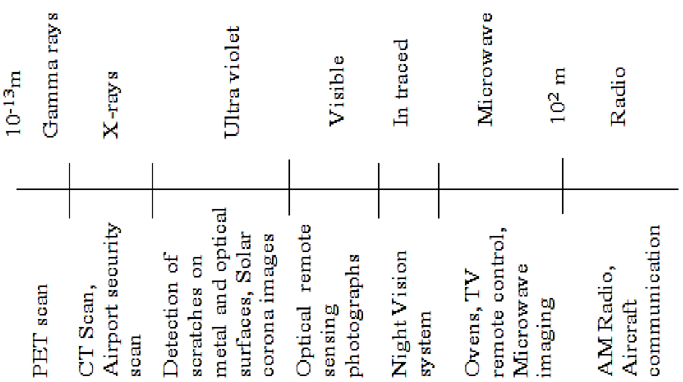

Fig 1. EM Spectrum with different intervals.

The ability to recognize different adjoining features for their well defined contrast, color, shape, distance, size characteristics is the resolving power of objects. Electromagnetic (EM) spectrum is shown in Figure 1. Different intervals of EM spectrum with different frequencies, wavelength and its applications are also specified in the figure [7].

Smallest discernable object by the remote sensing system on Earth's surface is called the Spatial Resolution. The SR of LISS-III is 23m, AWiFS is 56m. Swath means distance imaged by the satellite sensor on the Earth's surface. 140km is swath of LISS-III and 740km is swath of AWiFS images. For the pair of images used in this work, both sensors captures the same area on the Earth's surface on the same date. The Lat/Lon's of LISS-III matches at the centre Lat/Lon's of AWiFS. Therefore if a cross section of both sensor data is taken along the path and row, the LISS-III swath, 140 km is overlapped at the centre of 740 km swath of AWiFS as shown in Figure 2.

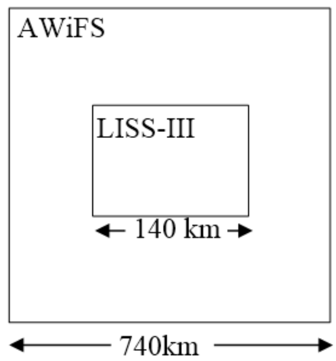

Fig 2. A cross section of pair of images.

II. BACKGROUND

The term "regression" literally means "stepping back towards average". This term was first used by British Biometrician Sir Francis Galton (1822-1911) in relation with the inheritance of stature. He investigated that abnormally short or tall parents tend to "regress" or "step back" to the average height of the population. But it is now used in statistics without having any reference to biometry as per convenience.

In regression analysis there are two variables. One in used for prediction and this is called independent variable or regressor or predictor or explanatory variable, while the other is called dependent variable or regressed or explained variable.

If the two values of variables are plotted along the coordinate axes then the diagram of dots is known as scatter diagram . This diagram is useful whether the variables are correlated or not. If so, let it be

$$Y = a+bx \text{ ----- } (1)$$

where 'x' and 'y' are independent and dependent variables, arbitrary constants are 'a' and 'b'. These constants are determined by the Legender's principal i.e. in minimising the sum of the squares of deviations of the actual values of 'y' from their estimated values of 'y' obtained from the scatter diagram. Thus 'best fit' is obtained [4].

A. Linear Regression:

If the points (x,y) are concentrated around a straight line in the scatter diagram then there is Linear Regression, otherwise it is known as Curvilinear Regression [1].

Let P_i (x_i, y_i) be any point in the scatter diagram. Then the corresponding estimated point in the scatter diagram be H(x_i, a+bx_i) as shown in the diagram. Hence error of estimate or residual for y= y_i – (a + bx_i)

According to the principal of least squares, 'a' and 'b' are determined such that

$$E = \sum_{i=1}^{n} (y_i - a - bx_i)^2 \quad \text{is minimum i.e.,}$$

$$\frac{\partial E}{\partial a} = 0 = -2\sum_{i=1}^{n}(y_i - a - bx_i)$$

$$\Rightarrow \sum_{i=1}^{n} y_i = na + b\sum_{i=1}^{n} x_i \qquad \ldots..(2)$$

$$\frac{\partial E}{\partial b} = 0 = -2\sum_{i=1}^{n} x_i(y_i - a - bx_i)$$

$$\Rightarrow \sum_{i=1}^{n} x_i y_i = a\sum_{i=1}^{n} x_i + b\sum_{i=1}^{n} x_i^2 \quad \ldots..(3)$$

The equations (2) and (3) are called as the normal equations. Solving these two equations the unknown arbitrary constants can be found out, thereby the line of bestfit, (1) is obtained. This line is useful for prediction.

B. Regression coefficients and their properties:

It can be noted that there are always two lines of linear regression, one is to estimate or predict the value of 'y' in the equation y=a+bx, if the value of 'x' is given then 'b' is called the regression coefficient of 'y' on 'x'. Here 'b' is the slope of the line. It is denoted by b_{y_x}. Similarly we get the value of 'x', if 'y' is given. Thus there are two regression lines. These two pass through the point ($\bar{x}, \bar{y}$).

The properties of regression coefficients are as follows-

- If one of the regression coefficients in greater than unity, the other must be less than unity.
- Regression coefficients are independent of the change of origin but not of scale.
- The modulus value of the arithmetic mean of the regression coefficients is not less than the modulus value of the correlation coefficient.
- Correlation coefficient is the geometric mean between the regression coefficients.

C. Curvilinear Regression:

If the points in the scatter diagram are not along the straight line, then the regression is called Curvilinear Regression. It is of the type,

$$Y = a+b_1x + b_2 x^2$$

where 'x' is independent variable, 'y' is dependent variable, a, b_1, b_2 are arbitrary constants to be determined by the principle of least squares , so that

$$E = \sum_{i=1}^{n} [\,y_i - (a - b_1x_i + b_2x_i^2)]^2 \text{ is minimum.}$$

$$\therefore \frac{\partial E}{\partial a} = 0 = -2\sum_{i=1}^{n}(y_i - a - b_1x_i - b_2x_i^2)$$

$$\Rightarrow \sum_i y_i = na + b_1\sum_i x_i + b_1\sum_i x_i^2 \ldots\ldots\ldots\ldots.\ldots(A)$$

$$\text{Again, } \therefore \frac{\partial E}{\partial b_1} = 0 = -2\sum_i(y_i - a - b_1x_i - b_2x_i^2)$$

$$\Rightarrow \sum_{i=1} x_i\, y_i = a\sum_i x_i + b_1\sum_i x_i^2 + b_2\sum_i x_i^3 \ldots\ldots(B)$$

Similarly

$$\sum x_i^2\, y_i = a\sum_i x_i^2 + b_1\sum_i x_i^3 + b_2\sum_i x_i^4 \ldots\ldots.(C)$$

Solving the normal equations (A), (B), (C), constants a, b_1 and b_2 are found thereby the curvilinear regression, equation, y = a+b_1x + b_2x^2 can be obtained. This equation is a 2nd degree parabolic regression of best fit.

Similarly the 3rd degree regression curve the exponential curves y = ab^x and y=ae^{bx} and the power curve y = ax^b can be fitted to a set of 'n' points.

The linear or curvilinear regression curves are tested for 'goodness of fit' by using χ^2 , t, F and Z distribution [2-3].

III. METHODOLOGY

In Figure 2 in the centre (i.e. inner box) on the same date, both LISS-III and AWiFS images are considered for image fusion. At swath of 140 km LISS-III is considered as high resolution image, where as out of 740 km swath of AWiFS is low resolution image. Only 140km in considered for image fusion. The outside box of AWiFS i.e. 600km around the inner box have only the low resolution image. Earth's surface features in the outer box area may have the same Earth's surface features as in the inner box area. Using this the high resolution image in the outer box area is predicted by performing image fusion of LISS-III and AWiFS in the inner box area. Figure 3 and 4 are the input images LISS-III and AWiFS of dataset I acquired on 27th November 2009. Similarly three more datasets are used as input image pairs. These datasets are downloaded from BHUWAN web site of National Remote Sensing Centre, Hyderabad [9]. The steps involved in predicting high resolution image, to prone the concept.

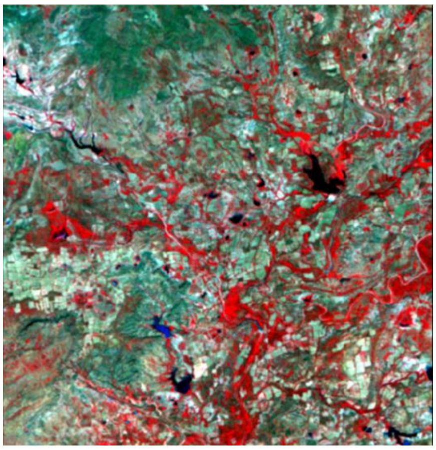

Fig 3. Input LISS-III

Fig 4. Input AWiFS

A. Registration of Images:

Since AWiFS and LISS-III are acquired on the same date and same Lat/Lon's, for these images there in no need of atmospheric correction. But for both the images, image-to-image registration has to be performed. Here the two images are of similar geographic area and same geometry. The registration is the scale, translation and rotation process of images. AWiFS is positioned coincident w.r.t. LISS-III. The LISS-III corresponds the features of Earth's surface in the same places. By performing this both LISS-III and AWiFS obtains pixel-to-pixel matching [8].

B. Normalization of Images:

Spatial resolution is AWiFS and LISS –III is 56m and 23m. Low resolution is same as high resolution being down sampled 2.4 times. The radiometric resolution of LISS-III and AWiFS is 8 bit and 10 bit data respectively. So comparison of digital numbers (DN) directly may not be suggested to the down sampled LISS-III is obtained using (1) and (2) [8].

$$L_{radiance} = DN(HR)/DN\_Max(HR) * SaturationRadiance\ (HR) \quad (1)$$

Using above $L_{radiance}$, the DN of HR image is obtained.

$$DN = L_{radiance} * (DN\_Max(LR) / SaturationRadiance(LR) \quad (2)$$

C. Matching for Regression:

In the overlapping area pixel to pixel mapping of low resolution and high resolution are considered for image fusion. One to one relationship is maintained for both the images. These are considered as 'x' and 'y' values. These input images are of size 512x512 pixels. The inner box coordinates top left and bottom right corners are (57,57) and (456,456).

The 'a' and 'b' values of each image are considered for prediction of high resolution image in the outside box i.e., 112 pixels width. By performing this methodology the proposed method is predicting high resolution image for the respective low resolution image. Therefore the predicted image is having a swath of 740 km, spatial resolution of 23 km and temporal resolution of 5 days.

D. Quality Assessment Parameters:

The obtained output image with high spatial resolution is compared with original high resolution LISS-III image data. In order to assess the quality of the predicted image certain parameters like Root Means Square Error (RMSE), Correlation Coefficient (CC), Spectral Angle Mapper (SAM), Structural Similarity Index Mapper (SSIM), etc are used [10-11].

IV. EXPERIMENTS AND RESULTS

In proposed work, pair of images namely LISS – III and AWiFS of Resoursesat-I satellite are considered for each dataset. In each dataset the overlapping area is comprising of 400 pixels. The predicted image is obtained by processing the four spectral bands separately. The multispectral images of the two sensors AWiFS and LISS-III are represented in False Colour Composite i.e. band combination of (4,3,2).

The datasets are downloaded from BHUWAN site of National Remote Sensing Centre, Hyderabad. In this work four different datasets are considered from different parts of India on different dates [9].

A. Dataset 1:

Figures 5,6,7,8 are the individual predicted bands B2, B3, B4, B5 of LISS-III for respective AWiFS bands 2,3,4,5 respectively. Figure 9 in the predicted image for the input image Figure 4.

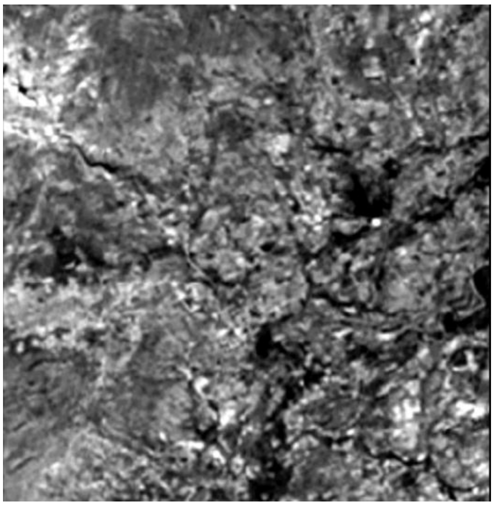

Fig 5. Band 2.

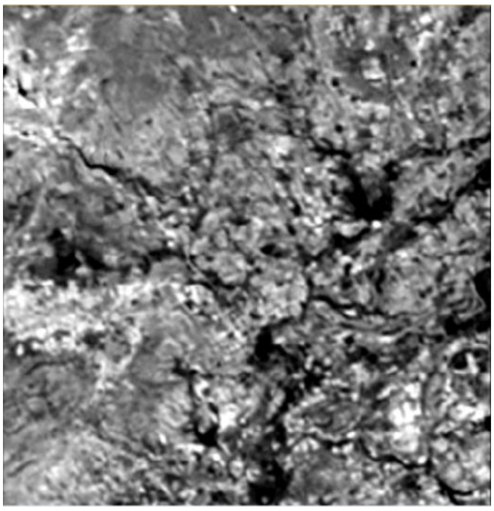

Fig 6. Band 3.

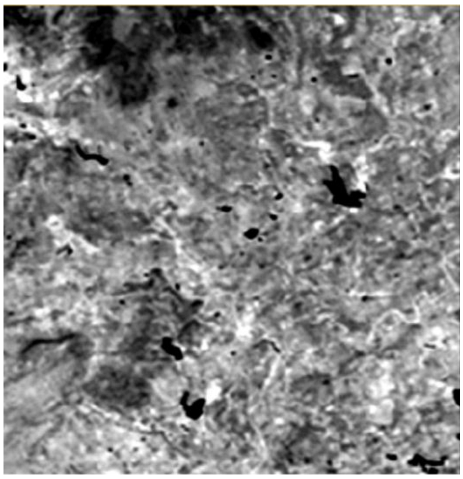

Fig 7. Band 4.

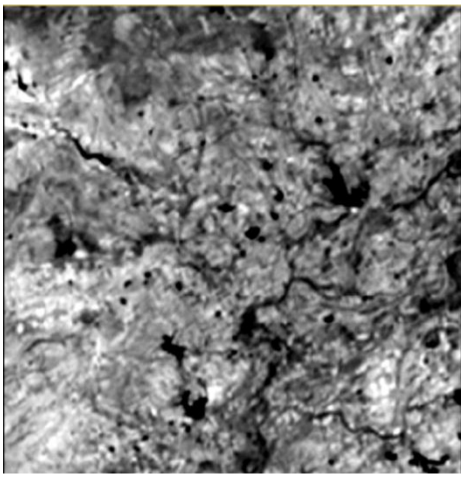

Fig 8. Band 5.

B. Other Datasets:

Three more datasets are also tested with the proposed method. Figures 10, 11, 12 are the predicted bands of LISS-III image for the respective AWiFS images of three datasets.

Fig 9. Dataset 31Oct09.

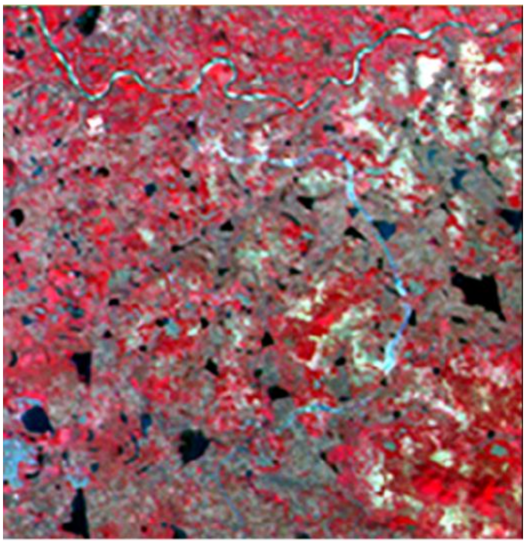

Fig 10. Dataset 27Nov09.

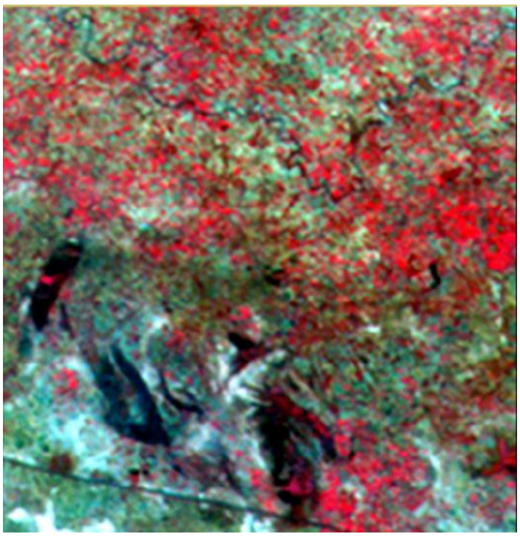

Fig 9. Dataset 07Nov08.

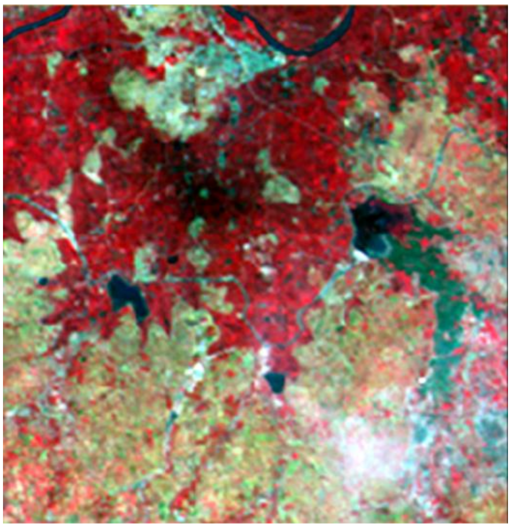

Fig 10. Dataset 02Nov09.

V. QUALITY ASSESSMENT

The predicted LISS-III images are compared with the original LISS-III images. Different parameters are used for Quality Assessment namely SSIM, SAM, RMSE, CC, R^2, etc. Table 2 shows the quality assessment parameters for different datasets. The values shown in the table are the average of all the four bands values of that particular assessment parameter.

Table 2. Different Quality Assessment Parameters.

	SSIM	**SAM**	**RMSE**	**CC**	**R^2**	**ERGAS**
Dataset 31Oct09	0.9561	1.5926	2.6580	0.9252	0.8561	1.9652
Dataset 27Nov09	0.9275	3.1040	4.0851	0.8823	0.7784	3.8754
Dataset 07Nov08	0.8356	2.6754	5.8682	0.8299	0.6902	3.1307
Dataset 02Nov09	0.9208	2.6228	4.3362	0.9430	0.8894	3.5870

VI. CONCLUSION

The proposed method predicted LISS-III image for the spatial resolution enhancement, is achieved with image fusion and regression. The quality assessment parameters are checked for the predicted images and the original image. These parameters are found to be satisfactory . The quality of the predicted image is found to be satisfactory. Thus predicted imaged is with spatial resolution of 23m, temporal resolution of 5 days and swath of 740 km.

REFERENCE

[1] John H. Mathews 2005, “Numerical Methods for Mathematics, Science and Engineering”, 2nd Ed. New Delhi, Prentice Hall of India.

[2] V.K. Kapoor, S.C. Gupta, “Fundamantals of Mathematical Statistics,” Educational Publisher S. Chand & Co. Company 23, Darya Gang, New Delhi- 110023.

[3] Richand A Johnson, 2007, “Miller 80 “Frecind’s Probability” and Statistics for Engineers”, 7th Ed. Prentice Hall of India (P) Ltd.

[4] Udney Yule and Kendald, M.G., 1953 “An introduction to Statistical Theory”, 4th Ed. London, Charles Griffin & Co. Ltd.

[5] Li, S., B. Yang, and J. Hu. 2011. “Performance Comparison of Different Multi-Resolution Transforms for Image Fusion.” Information Fusion 12 (2): 74–84. doi:10.1016/j.inffus. 2010.03.002.

[6] Hu, J., and S. Li. 2012. “The Multiscale Directional Bilateral Filter and Its Application to Multisensor Image Fusion.” Information Fusion 13: 196–206. doi:10.1016/j.inffus. 2011.01.002.

[7] C. V. Rao, J. Malleswara Rao, A. Senthil Kumar, B.Lakshmi, V.K.Dadhwal. "Information Retrieval through the Fusion of Multi-Sensors Data over Multi-Resolutions”, IEEE International Conference on Contemporary Computing and Informatics, pp. 1262-1267, Nov 2014.

[8] C. V. Rao, J. MalleswaraRao, A. Senthil Kumar, A. S. Manjunath,“ Restoration of High Frequency Details while Constructing the High Resolution Image”, Annual IEEE India conference on Engineering sustainable solutions (INDICON), 2011.

[9] National Remote Sensing Centre, https://bhuvan.nrsc.gov.in.

[10] Ch. Venkateswara Rao, P.Shasidhar Reddy, D. S. Jain, K. M. M. Rao. 2007. “Quantitative Value Addition Analysis of Multisensor Data Fusion”. The Icfai Journal of Earth Sciences, Vol. 1, No. 1.

[11] Zhuo Wang, Alan Conrad Bovik, Hamid Rahim Sheikh, Eero P. Simoncelli. 2004. “Image Quality Assessment: From Error Visibility to Structural Similarity”. IEEE Transactions on Remote Sensing, 600-612, Vol. 13, No. 4 doi 10.1109/TIP.2003.819861.