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FUSION OF IRS-LISS III AND PAN IMAGES USING DIFFERENT RESOLUTION RATIOS

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ABSTRACT: Multisensor image fusion is a technology that is increasingly being used to obtain high resolution multispectral images from coarse resolution multispectral and fine resolution panchromatic images. Ideally, the methods used to fuse image data sets should preserve the spectral characteristics of the original multispectral input image. While many technologies exist and emphasize the preservation of spectral characteristics, they do not take into account the resolution ratio of the input images. This paper is an attempt to fuse high resolution PAN and low resolution multispectral Indian Remote Sensing satellite (IRS) LISS III at varying resolution ratios of the input images. Accordingly, three images of IRS-LISS III and PAN at different resolution ratios (LISS III=24m, PAN=6m), (LISS III=20m, PAN=5m), (LISS III=23.5m, PAM=5.8m) were used as input for image fusion. The fused images were compared and their utility was evaluated. In terms of image quality, it is observed that the fusion of the images with LISS III=23.5m and PAN=5.8m resolution, gives the best result, followed by the 24m-6m and 20m-5m combination. It is observed that fusion using the LISS III=20; PAN=5 ratio leads to distortion of shapes of smaller features, while the LISS III=24; PAN=6 ratio results in blurring due to down sampling. Thus, this study demonstrates the quality changes that occur due to multi-sensor image fusion at varying resolution ratios.

1. INTRODUCTION

Of the various enhancement techniques to improve image interpretability and resolution, multi-resolution image data fusion may be considered as a potential one. Image fusion is the combination of two or more different images to form a new image by using certain algorithms. Pohl *et al*(1998). Fusion of multi sensor image data is becoming a widely used procedure because of the complementary nature of the image data used. The digital images from the various sensors used for merging are geometrically registered to one another and a single, hybrid data set is created which contains the best of the input data sets. Cliché et al (1985) merged the 10m resolution SPOT panchromatic data with corresponding 20m resolution SPOT multispectral data of the Sherbrooke city area Quebec for image sharpness enhancement. The authors report that both, spatial and spectral resolution of the fused image approach that of the small scale high altitude colour infrared photographs. Lillesand and Kiefer (1987) illustrated the results of the fusion of LANDSAT TM colour composite and RADAR image data of the suburban Detroit area. Here, the higher (6m x 6m) spatial resolution and " side lighting" characteristics of the RADAR data was combined with the higher spectral resolution of the TM data to produce a composite that offered potentially greater interpretability than an image from either sensor alone. Chanussot *et al*.(1999) describes about the automatic detection of linear features in SAR satellite data with respect to road network extraction. Different images of the same scene, acquired at different dates (multi-temporal data) and the information provided by each of the available images were fused. The response of a pixel to the line detector was linearly mapped into [0,1] and was then considered as a confidence degree in its being part of a potential road. The degree obtained at different dates were merged. After the fusion, the result was linearly mapped back into [0,255] to result in an hybrid image.

In most examples of image data fusion including those cited above, the ratio of the spatial resolution of the data sets being considered has been a whole number perhaps for the sake of simplicity and computational convenience. This paper presents the results of fusing IRC 1C LISS III and PAN data with different resolution, and compares the results of such a fusion with original LISS III data.

2. IMAGE DATA AND METHODOLOGY

Since this study involved evaluation of the effect of the various resolution ratios for image fusion, an area that contains both manmade and natural features is essential to study these effects. Hence, the IRS 1C LISS III and PAN data of a part of Chennai (formerly Madras) city, containing roads, waterbodies, barenlands and vegetation was selected for this study. The study area lies between 12^o 15' 30" to 13^o 02' 30" north latitude and 80^o 12' 30" to 80^o 15' 00" east longitude. The ariel extent of the study area is about 17 Sq.m Table - 1 describes the details of the input image data used in this study.

Figure 1 shows the various steps involved in image fusion using different resolution ratios. The essential steps in this study includes image rectification, resampling, registration and fusion using PCA technique.

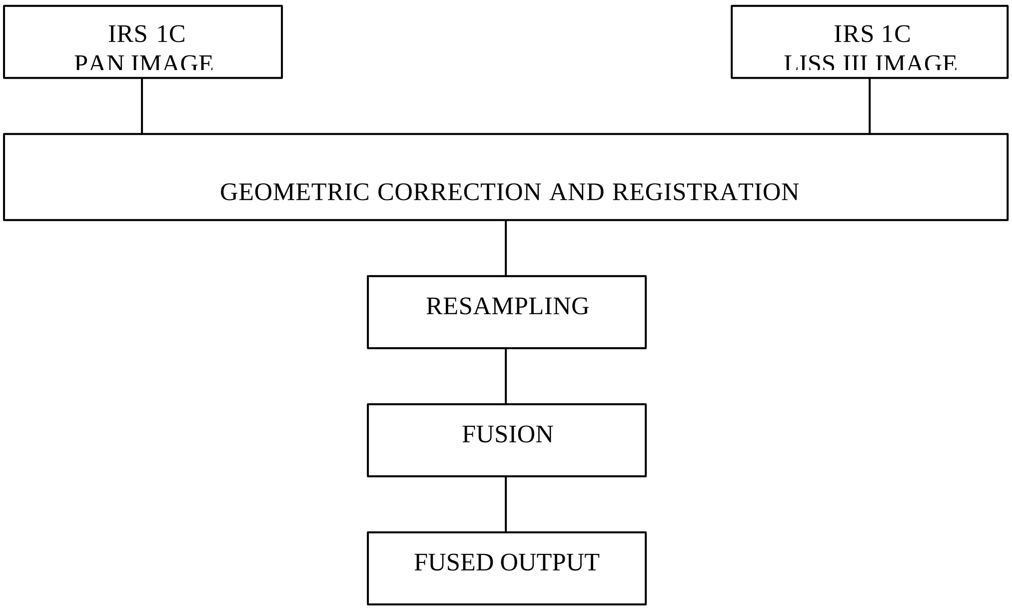

Figure 1. Flowchart depicts the methodology adopted for multi sensor image fusion.

Table.1. Details of the image data used in the present study

Sl.No.	Data Products	Path, Row
1	IRS 1C LISS III Digital data Date of Pass 7/6/98	102, 64
2	IRS 1C PAN Digital data Date of pass 7/6/98	102,64
3	IRS 1C Geocoded FCC Date of Pass 7/6/98	102,64

The PAN image data was first rectified using first order transformation with a topographic map. Fifteen GCPs were used and the corresponding image points were identified for rectification. The RMS error obtained was 0.6 of a pixel, which is an acceptable one. This was followed by co-registration of the PAN image with the LISS III without any mismatch. Resampling of the two images was done next at different resolutions to create various sets of images for fusion. The various resolutions obtained due to such a resampling technique are LISS III = 20, 23.5 and 24m, PAN = 5, 5.8 and 6m. Thus an effective set of input images was generated for fusion using the PCA technique. (See Table.2)

2.1 PCA Method of fusion

Though there exist various techniques for image fusion such as HPF (High Pass Filter), HIS(Intensity Hue Saturation), Brovey and Arithmetic transformation, various authors (Lakshmi 2000, Chevez 1991, Cliché 1985) have demonstrated their disadvantages and the efficiency and merits of PCA (Principal Component Analysis). Hence in this study, only PCA has been adopted as a fusion tool.

It is known that the Principal Component Analysis (PCA) is a statistical technique that transforms a multivariate data set of correlated variables into a data set of new uncorrelated linear combinations of the original variables. In contrast, an inverse PCA transforms the combined data back to the original image space. Further description about PCA may be found in Schowengerdt (1987) and Mather(1985). In the context of image fusion, the first principal component of the low resolution multispectral image is replaced by the high resolution image. This results in the transformation of a multi spectral data set into a image of higher spatial resolution (Pohl 1999).

In the present context, PCA was applied to the LISS-III image and three principal components were obtained. Figure-2 explains the various steps involved in PCA fusion technique. The PAN data was stretched to have approximately the same variance and mean DN as the first PC. This stretched PAN image replaced the first PC and the resulting image was re-transformed to the original spatial domain. The logic behind replacing the first PC with the PAN data is that the PAN data is equivalent to the first PC image, i.e. the first PC contains the information which is common to all bands and it also accounts for maximum variance which can maximize the effect of the high resolution (PAN) data in the fused image. A similar logic was followed by Chevez (1989) and Shettigara (1992).

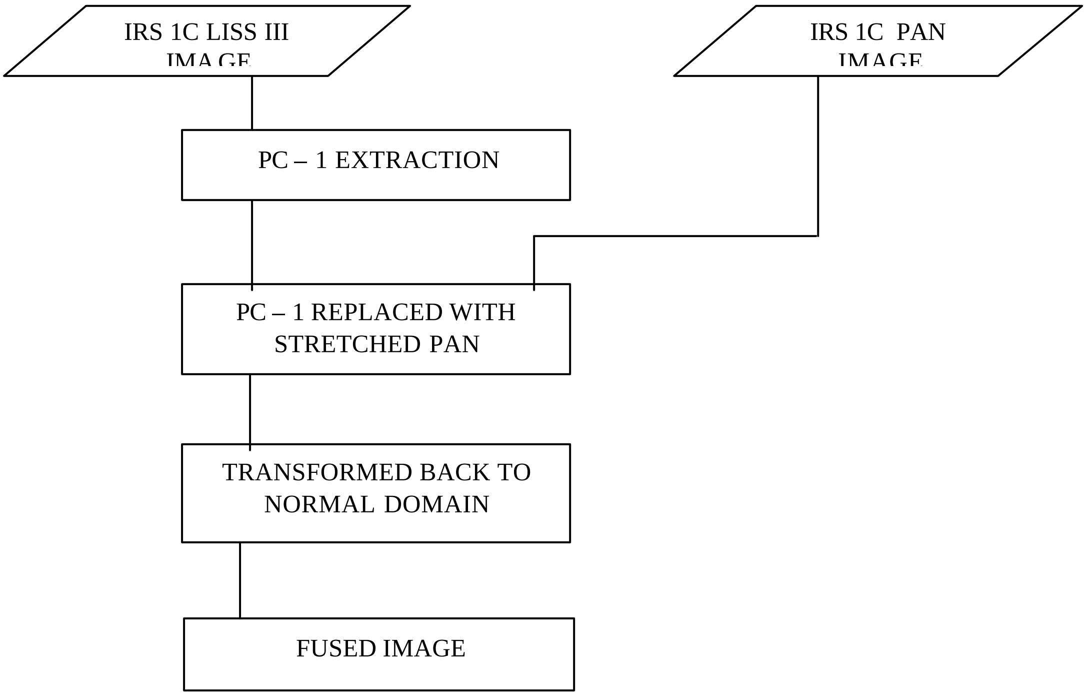

Figure 2 Procedure for fusion of LISS III & PAN images using PCA technique

Having described the PCA as a method of fusion, the following section describes the focal theme of this paper, namely fusion with different resolution ratios of the input images

2.2 Fusion with different resolution ratios

In section 2 it was mentioned that various resolutions of the input images were obtained by resampling technique. Thus, when the ratio of the resolution of LISS-III and PAN images are accounted for, we have several ratios such as (i) LISS III=20m; PAN=5m , (ii) LISS III=23.5m, PAN=5.8m and (iii) LISS III=24m, PAN=6m.

In terms of image dimensions, LISS-III image with 23.5m resolution contained 185 columns and 166 rows while the PAN image with 5.8m resolution contained 953 columns and 813 rows. Table-2 depicts the dimensions of the other input images obtained by resampling. With these data sets, fusion of the images (Table.2) with different resolution ratios was attempted using PCA technique (fig.2).

From Table-2 it may be observed that the image dimension increases with image resolution and accordingly the processing time taken for fusion is also higher. Having obtained 3 fused images from 3 pairs of input images, comparison and evaluation of the output was attempted.

3. RESULTS AND DISCUSSIONS

In order to evaluate the results of fusion using various resolution ratios, two approaches were adopted, namely visual comparison and statistical evaluation. In the visual comparison technique, the fused images were compared with the original LISS-III image and the degree of enhancement due to fusion was examined. Thus, it was observed that the fused image is exceptionally enhanced in the case of LISS-III=20m and PAN=5m, while it is good in the case of LISS-III 23.5m and PAN=5.8m. The fused image is least enhanced in the case of LISS-III=24m and PAN=6m (Fig.3). Since visual comparison alone is not a measure of performance of fusion, statistical evaluation was also attempted (Wald 1997, Arokiadas 1992). In the present context, image to image correlation is referred to as statistical evaluation. Thus each band of the original LISS-III image was compared with the corresponding band of the fused image and coefficient of correlation was computed. Table-2 shows the results of such a computation.

Table.2 Coefficient of correlation of original LISS-III image and Fused image

Band Name	**LISS III = 20m (220 x 200) PAN = 5m (1099 x 950)**	**LISS III = 23.5m (185 x 166) PAN = 5.8m (953 x 813)**	**LISS III = 24m (181 x 163) PAN=6m (921x786)**
NIR	0.93558	0.94088	0.93077
Green	0.92271	0.93199	0.92181
Blue	0.93139	0.93501	0.93840
Mean of Bands	0.92989	0.93596	0.93032

A cursory comparison of the correlation coefficients for various resolution ratios indicates that there is an overall high positive correlation between the fused and original images. This is perhaps due to the usage of the efficient fusion tool, namely the PCA technique. A closer look, however, reveals that the resolution ratio of the LISS-III=23.5m and PAN=5.8m results in the highest degree of correlation for individual bands and for mean of the bands. This is followed by the LISS-III=24m, PAN=6m and LISS-III=20m, PAN=5m . An explanation for such variations is as follows:

- In the fine resolution image (20,5), a few synthetic pixels are generated during resampling. These synthetic pixels do not represent any natural or man made object and are present in the peripheral regions of certain smaller landcover features. Such a presence leads to the distortion of the shape of certain features (a,b,c,d,e in fig 3 C). The least value of coefficient of correlation can also be explained due to the presence of synthetic pixels in the (20,5) fused image which are obviously not available in the original LISS III image. Apart from this explanation, it may also be inferred that this ratio is not favorable for use in image fusion.
- In the coarse resolution (24,6) input image, sharpness of the features (a,b,c,d,e in fig 3 E) is reduced due to the degradation of the resolution of the image during resampling. The coefficient of correlation between the original and fused images is also lower than that of 23.5m,5.8m fused image. This is because the number of pixels tend to get reduced while resampling to lower resolution is attempted.
- The fused output of the original / unaltered ratio (23.5, 5.8) has the highest coefficient of correlation. This is due to the fact that there are no synthetic pixels or dropping out of pixels due to resampling. Thus, an overall one-to-one match is maintained between the pixels of the original image and the fused image.

4. CONCLUSION

This study has demonstrated the need for the proper input for multisensor image fusion. Though fusion is possible with many types of multi resolution images, the need for appropriate and optimal resolution ratios has been indicated and emphasized this work. The merits of PCA technique as an efficient fusion tool have also been highlighted in this study. IRS 1C LISS III multispectral data, when fused with the corresponding low-resolution PAN data results in a high-resolution multispectral image. The quality of the image is, dependent on the resolution ratio of the input images. The quality was evaluated by using both, visual matching technique and statistical (image correlation) technique. It is observed that fusion using the LISS III=20m; PAN=5m ratio leads to distortion of shapes of certain smaller features

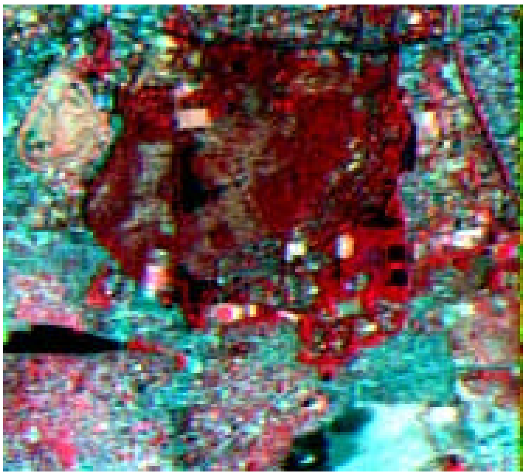

Figure 3.A LISS III Image

Figure 3.B PAN Image

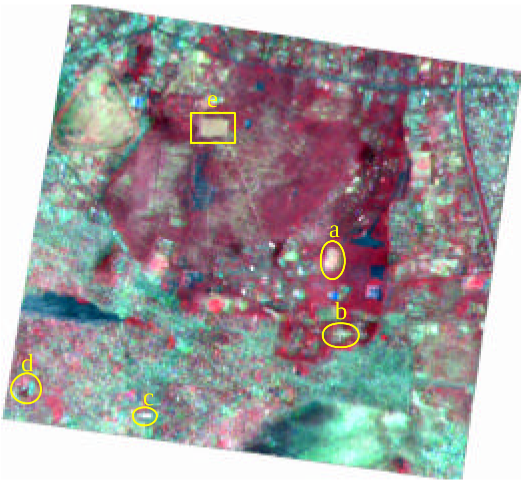

Figure 3.C Fused Image
(PAN 5m LISS III 20m)

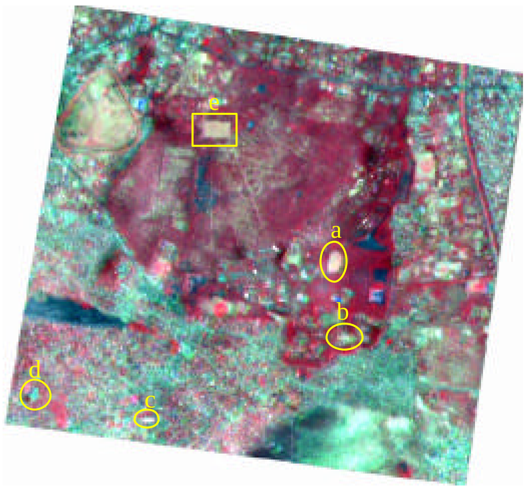

Figure 3.D Fused Image
(PAN 5.8m LISS III 23.5m)

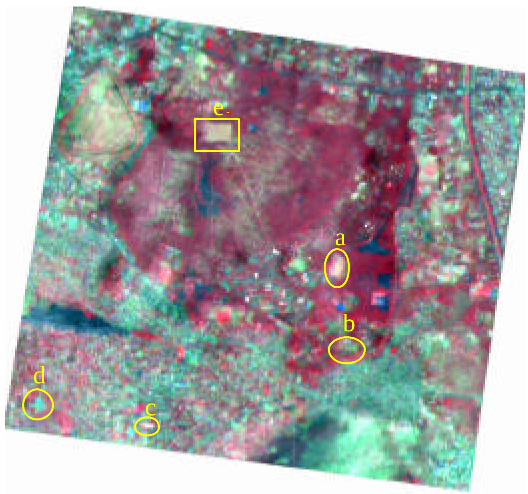

Figure 3.E Fused Image
(PAN 6m LISS III 24m)

due to the generation of synthetic pixels, while the LISS III=24m; PAN=6m ratio results in blurring due to down sampling. The fused output of the original / unaltered ratio LISS III=23.5m;PAN=5.8m results in a fused image with best qualities, since no synthetic pixels are generated and no blurring/ down sampling occurs. Thus, this study demonstrates the quality changes that occur due to multi-sensor image fusion at varying resolution ratios. This study also prompts the authors to suggest that no alteration of resolution of the input images be attempted before image fusion.

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