QUALITATIVE AND QUANTITATIVE ASSESSMENT OF HIGH RESOLUTION MULTISPECTRAL IMAGE USING FUSION TECHNIQUE BY MEASURING ENTROPY– A CASE STUDY USING QUICKBIRD DATASET

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ABSTRACT:

This paper presents the qualitative as well as quantitative assessment of high resolution image generated by fusion technique. The information contained in fused image measured and compared with different methods. Current satellites produce high resolution panchromatic but low resolution multispectral images. As for example, QuickBird satellites provide panchromatic image with 0.6 m resolution but multispectral image with 2.44m resolution. However high resolution multispectral images can be generated using resolution merge technique, which takes care of spatial as well as spectral resolution of the image.

Information content in the high resolution panchromatic as well as low resolution multispectral image is preserved during the fusion of images. In this work image fusion is carried out by principal component analysis technique. Focal analysis technique is used to reduce the noise in input image before fusion. Fused image is generated by use of focal analysis technique and then compared using entropy with the fused image generated without removing noise of the input images.

1. INTRODUCTION

Fusion of remotely sensed imagery is useful technique for merging multispectral low-resolution remotely sensed images with a more high resolution panchromatic image. To enhance image information, the application is more useful because a high quality images are available for a reasonable price. Multi-sensor fusion can achieve the child image with more information than either parent image (Carper *et.al.,* 1990; Chavez *et. al.* 1991 and Munechika *et. al.* 1993). Most of the methods available explain the quality of the fused images. The quality of fused images checked with the parameters like shape, size, structure, location, relationship of and between objects available on the images, where for quantitative approach focused on the information content in the image.

Measure of information in terms of entropy is best way to assess the effects of information in fused images.

1.1 Information

Suppose there is a source (such as an image) which generates a discrete set of independent messages (such as grey levels) v_k, with probability P_k, k= 1…L.

Then the information associated with v_k is defined as,

$$I_k = - \log_2 P_k \quad \text{bits} \qquad (1)$$

Since

$$\sum_{k=1}^{L} P_k = 1 \qquad (2)$$

each $P_k = 1$ and I_k is non-negative. This definition implies that the information conveyed is large when an unlikely message is generated.

1.2 Entropy

Claude Shannon was the first person to introduce entropy in the quantification of information; Shanon (1948) employed the probabilistic concept in modeling message communication. He believed that a particular message is one element from a set of all possible messages. If the number of messages in this set is finite, this number or any monotonic function of this number can be regarded as a measure of the information when one message is chosen from the set, all choices being equally likely. Based upon this assumption, information can be modeled as a probabilistic process.

The entropy of a source is defined as the average information generated by the source i.e.,

$$\text{Entropy,} \quad H = - \sum_{k=1}^{n} P_k \log_2 P_k \quad \text{bits/message} \qquad (3)$$

for a digital image considered as source of independent pixels, its entropy can be estimated from independent its histogram.

In fact, to certain extent, Shannon's entropy (equation 3) is the same as thermodynamic entropy (see equation 4).

$$S = - k \sum_{i=1}^{n} P_i \ln P_i, \text{ where } k = 1.38 * 10 \ -23 \text{ J / K} \qquad (4)$$

To measure the information content, constant i.e., Boltzmann constant in thermodynamic entropy is set to unity. And the logarithm's base is determined by the choice of unit for the

information. For the digital manipulation of a base of 2 is appropriate, and yields the unit of bit.

Previous work Lau Wai Leung *et. al.,* 2001 proved that entropy can directly reflect the average information content of an image.

From a child image of multi-sensor fusion if its entropy is higher than the parent images it may be deduced that the child image contains more information than either of the parent images.

2. METHODOLOGY

2.1 Data used

Two types of QuickBird data were used. QuickBird satellite platform has high resolution visible sensor with two modes of operation (multispectral and panchromatic) each with different resolution. QuickBird panchromatic image are in the wavelength range of 0.450-0.90 µm with 0.6 m resolution and QuickBird multispectral images are in the range of 0.450 to 0.690 µm wavelength with 2.44 m resolution. Near IR band is not used in this study. The scenes covered the area of Jaipur city.

Before fusion the size of images and their coordinate system were checked. This process was necessary to maintain accurate spatial relationship in the fusion.

2.2 Fusion processing

Commonly used fusion method i.e., Principal Component Analysis was used to create the fused images.

Principal Component Analysis: This method calculates principal components, remaps the high resolution image into the data range of Principal Component (PC-1) and substitutes it for PC-1, then applies an inverse principal components transformation.

The Principal Component method is best used in applications that require the original scene radiometry (color balance) of the input multispectral image to be maintained as closely as possible in the output file. As this method scales the high resolution data set to the same data range as PC-1, before the inverse principal component calculation is applied, the band histograms of the output file closely resemble those of the input multispectral image.

Unfortunately, this radiometric accuracy comes at the price of a large computational overhead.

Another result of this methodology is that the output file tends to have the same data range as the input multispectral file. Consequently it is generally not necessary to use the stretch to Unsigned 8-bit option for the output file. Instead, simply set the output data type to be the same as the multispectral data type.

Nearest Neighbor technique used to resample the multispectral input to that of the high resolution image.

Focal Analysis: This model (Median Filter) is useful for reducing noise such as random spikes in data sets, dead sensor striping, and other impulse imperfections in any type of image.

Focal Analysis evaluates the region surrounding the pixel of interest (center pixel).

In this work the two data set i.e., Pan and multispectral are used for removal of noise using focal analysis technique.

Then fusion work carried out with the images generated using focal analysis technique. Also fusion work carried out without applying focal analysis technique on the input images, then the entropy of both the fused images calculated and compared to see the role of noise in the fusion technique.

The assessment of qualitatively as well as quantitatively of high resolution image has been carried out. All operations were carried out on Hp workstation using Erdas Imagine.

3. RESULTS AND DISCUSSIONS

The output generated through fusion technique compared with the input images by parameters like shape, size, structure, location, relationship of and between objects available on the image. The fused image and input image are shown in Figure 1
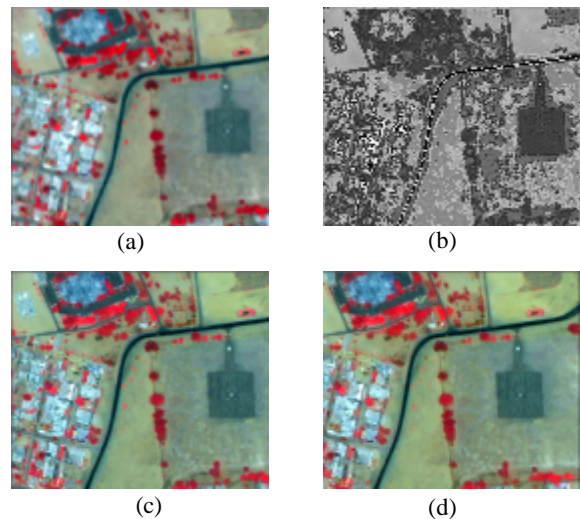

(a)   (b)

(c)   (d)

Figure 1: Comparison of output generated using QuickBird dataset with respective resolution:
(a) QuickBird multispectral image (2.4 m);
(b) QuickBird panchromatic image (0.6 m);
(c) Fused image generated without focal analysis (0.6m);
(d) Fused image generated with focal analysis (0.6 m).

Entropy of input PAN image with output fused images is also compared because both input and output images are of same resolution i.e., 0.6 m and are shown in Table 1.

PAN image	Fused image without focal analysis	Fused image with focal analysis
5.525192784	5.645508445	5.627080406

Table 1. Entropy of QuickBird panchromatic and fused images (bits / pixel)

It is clear from the Table 1 that the fusion process increases the information content in the image. The entropy of PAN image is less than that of fused image.

The entropy of fused images were found band wise and compared to observe the changes occurred during different method for fusion process are shown in Table 2.

Band	Fused without focal analysis	Fused with focal analysis	Difference
Blue	5.505696789	5.50508274	0.000614
Green	5.554927358	5.495540989	0.0593864
Red	5.875901189	5.880617488	-0.0047163

Table 2. Entropy of QuickBird fused images (bits / pixel)

The average entropy values of fused images without focal analysis and with focal analysis are 5.645508 and 5.62708 bits per pixel respectively. According to computation results, the decreased entropy indicates the loss in the information content through the focal analysis method. But it is not clear that whether the decreased entropy is a noise or information.

To solve this problem, the qualitative image comparison performed. The positive value for entropy from the PCA fusion without removal of noise indicates that this fusion is increasing the information content and enhanced the image.

This is supported by the visual inspection of Figure 2. It can be seen from the figure that feature information is clearer in the fused image than fused image generated by focal analysis technique.
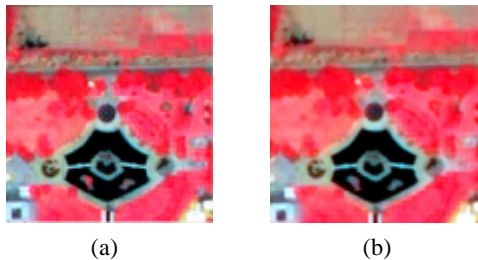

(a)   (b)

Figure 2: (a) Fused image without focal analysis;
(b) Fused image with focal analysis.

Entropy alone cannot provide the quality of assessment of fused images and information content in the image, unless the proposed approach of focal analysis technquie is used.

4. CONCLUSIONS

The PCA method has shown satisfactory results, demonstrating that fusion technique showed improvement in the image information. This approach is reliable for high resolution as well as low resolution dataset, however further investigation is needed for multispectral image where noise in the image play important role for data fusion technique. The output achieved by using focal analysis technique is very useful, because it has ability to assess the quality of fusion quantitatively.

The analysis performed on a limited data set and requires further testing using various data type. The fusion technique approach is more economic for generation of synthetic images with high spatial and high spectral resolution.

5. REFERENCES

References from Journals:
Shannon, C.E., 1948. A mathematical theory of communication. The Bell system Technical Journal, Vol. 27, July, pp. 379-423, 623-656.

References from Books:
Anil K. Jain, Fundamentals of digital image processing, 8th Indian edition, 2002.
Erdas field guide seventh edition

References from Other Literature:
Carper, W.J., Lillesand, T.M., Kiefer, R.W., 1990. The use of Intensity-Hue-Saturation transformation for merging SPOT panchromatic and multi-specteral image data. Photogrammetric Engineering and Remote Sensing, 56, 459-467.
Chavez, P.S., Sides, S.C., Anderson, J.A., 1991. Comparison of three different methods to merge multiresolution and multispectral data: Landsat TM and SPOT panchromatic. Photogrammetric Engineering and Remote Sensing, 57, 295-303.
Munechika, C. K., Warnick, J.S., Salvaggio, C., Scott, J.R., 1993. Resolution enhancement of multispectral image data. Paper to improve classification accuracy. Photogrammetric Engineering and Remote Sensing, 59, 67-72.

References from websites:
Lau Wai Leung, Bruce King, Vijay vohora, (2001). Comparison of image data fusion technique using entropy and INI. 22nd Asian conference on remote sensing, Singapore, 5-9 November 2001, vol. 1 pp. 152-157.